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ELECTRICAL HOROLOGY

LANGMAN

Electrical Horology

A PRACTICAL MANUAL ON THE APPLICATION OF THE PRINCIPLES AND PRACTICE OF ELECTRICITY TO HOROLOGICAL INSTRUMENTS AND MACHINES FOR THE MEASUREMENT AND TRANSMISSION OF TIME

WITH AN ACCOUNT OF THE EARLIEST ELECTRICALLY-DRIVEN CLOCK MECHANISM

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AND

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THIRD EDITION REVISED AND ENLARGED

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PREFACE

In preparing this edition no substantial change has been made in the subject-matter of the earlier chapters, since these have apparently proved of value to students of electrical horology. A few of the manufacturers' blocks have, however, been exchanged with the idea of depicting the latest mechanisms.

Chapter IX. has been expanded by the inclusion of both new matter and illustrations.

Advantage has been taken in the new edition to introduce two chapters covering as far as possible latest advances in this fast expanding science.

I desire especially to acknowledge the generous aid I have had from Messrs Gent, of Leicester, and Messrs Everett Edgcumbe, of Hendon; both firms have also freely supplied blocks to illustrate their mechanisms.

To Messrs Smith, of Acton, my thanks are also due for particulars of their synchronous clocks.

HENRY R. LANGMAN.

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ELECTRICAL HOROLOGY

CHAPTER I

HISTORICAL

THE ancients, in an attempt to record the flight of time, devised the earliest forms of time-keeping mechanism.

The oldest of all was no doubt the Clepsydra or water clock, its origin being generally attributed to the Chinese, and later it was reinvented by the Babylonians, from whence it was passed on to the Greeks and Romans in about the fifth century B.C.

The water clock was set up in several forms and the design became more complicated as the centuries passed.

The ancient "sundial," originally from Asia and freely used by the Babylonians, was the second form of time recorder. This instrument may still be seen set in the walls of many a noble mansion, but it is now regarded more as a curiosity and a link with the past than one of general utility.

The old-fashioned domestic "sand glass" is yet another example of an ancient time-keeping device to which it is impossible to assign any date of inception, but little progress was made, however, in the subject until the year 1370.

A mechanism of more serious design and construction was not attempted until the year 1370, when one Henry de Vick constructed a weight-driven clock for Charles V. of France. The clocks of that period possessed but one hand, which marked the hours on a dial plate and later announced the hours by striking a corresponding number of blows upon a bell or gong.

Since the introduction of public and domestic timepieces in the year 1370, numerous improvements have been made in the mechanism, and by degrees the community have been provided with clocks possessing a time rate that can be tolerated.

One of the branches of science into the service of which electricity has been impressed is that of horology, and the aid it has given dates from about the year 1839. Stenheil, in 1839, appears to have been the first horologist to attempt the transmission of "time" by electrical means. During the year Alexander Bain was successful in an attempt to drive a clock entirely by the agency of the electric current, and 1840 may be accepted as the starting point of "electrical horology."

The fundamental principle of all clocks operated by the agency of electricity is based upon the mysterious force of magnetism which becomes revealed whenever an electric current passes along a wire.

It was Professor Oersted, of Copenhagen, in the year 1820, who discovered that the electric current had the property of deflecting a magnetic needle, such as a compass needle. A far more startling and useful discovery was made by the French electrician Ampère; he observed that a coil of wire bearing an electric current exhibited all the properties of a magnet.

Practically in all the electric clock mechanisms, past and present, the controlling force has really been "electro-magnetic," and the discoveries of these two great scientists have been directly applied to the measurement of "time."

In all the electric clock systems introduced or suggested the principle of action is not always identical, each possessing its peculiar characteristics, and it is most desirable to classify the systems under five headings. It will therefore be convenient to classify the various systems in the following order:—

1. Clocks in which the entire motive power is electricity, the current supplying impulses to the pendulums by electro-magnetic induction.

2. Clocks having an ordinary clockwork mechanism, the vibration of the pendulums being controlled by an electric impulse transmitted from a standard clock.

3. Any variety of clock may be wound at regular intervals by devices electrically operated.

4. The usual ratchet or "step by step" movement, which consists of a system of wheelwork, and which is operated at regular intervals by electrical impulses transmitted from a form of standard or master clock.

5. Any form of clock having a fairly accurate going rate may be synchronised electrically from a standard clock at certain intervals, and by this means the hands brought to time.

In this chapter it is the intention to describe rather the principle on which each system operates, than to attempt a minute description of the mechanism introduced for the functioning of the system concerned. Each system will be treated under its class in the chapters that follow, and the mechanical arrangements made lucid by the aid of specially drawn diagrams.

The long series of experiments conducted by Alexander Bain from 1840-52 resulted in the production of many ingenious forms of electrically controlled and even driven clocks. The pendulums of these clocks were actuated by the force of magnetic attraction and repulsion, and caused by this means to vibrate from side to side. By the introduction of a crutch lever the oscillatory movement of the upper portion of the pendulum rod was found suitable for the propulsion of the wheelwork actuating the hands of the clock. In the early electric clocks the pendulum was really the medium by which the wheelwork was driven. This is permissible in all types of clocks provided with the common "recoil escapement."

Bain's first clock was exhibited at the Polytechnic Institute in the year 1841, but it was not electrically driven, and consisted merely of an ordinary pendulum clock fitted up so as to complete an electrical contact at every alternate swing of the pendulum; transmitting in this way an electrical impulse to a specially constructed clock movement, now termed "secondary clock" or "dial," comprising only a few wheels and a pair of hands rotating in front of an hour dial. To briefly describe the secondary clock used in conjunction with Bain's transmitting or master clock, an electro-magnet receiving the electrical impulse transmitted attracts an armature and allows a pawl attached to its lower end to pass over one tooth of a ratchet wheel, and on the circuit becoming broken at the master clock through the pendulum commencing its return swing, the armature, now being released from the electro-magnet, returns to its original position. In returning to its normal position the armature, through the intervention of the pawl, pulls the ratchet wheel one tooth forward, and by suitable wheelwork the hands of the clock are driven. The number of teeth on the ratchet wheel will, however, be decided by the length of the pendulum; for instance, if the pendulum of the transmitter beats seconds, then the impulse will be sent out less often than if the pendulum were a three-quarter seconds beat. Evidently the number of teeth contained in the ratchet wheel will be greater for a short pendulum than for a long one, since the vibration varies as the length becomes increased.

Bain, experimenting further, dispensed with the weight and spring which had previously supplied the motive power, retaining only the wheelwork required for the propulsion of the hands. To make this possible he then devised an electrically driven pendulum; there are two varieties, but the principle of either when in action is identical. These pendulums are sometimes called "Bain's pendulums" to distinguish them from those of contemporary inventors.

In one form the "bob" had two permanent magnets; these were attracted and repelled by two coils of wire through which an electric current was allowed to pass, the coils being situated on either side of the vertical line of the pendulum's swing. The pendulum controlled the current for exciting the coils by actuating a curious but ingenious form of "break," which will be described later. In the other form of "electric pendulum" the state of affairs was reversed. The "bob" of the pendulum was actually a coil of wire through which the current was permitted to flow, the latter being conducted down the rod from the suspension bracket of the pendulum. Permanent magnets of cylindrical form were placed on either side of the "bob" so that as the pendulum vibrated, the coil was carried a short distance over the permanent magnet. A moment's thought will, however, satisfy us that the magnetic effect remains unchanged.

Dr Hipp, following in the footsteps of Bain, introduced another form of "electric pendulum," the vibrations of which were maintained by the reaction set up between a soft iron armature attached to the lower extremity of the pendulum rod and an electro-magnet over which the armature vibrated. An ingenious type of "contact maker" or "break" permitted the electro-magnet to become excited or demagnetised at the correct instant so as to exert the maximum pull upon the armature. This device was introduced for the first time by Hipp, although it has been suggested that the arrangement had been proposed by Foucault. The pendulum carries on its upper portion a small trailer which is pivoted and free to move from side to side. Beneath the trailer is a springy strip of metal, one end being held rigidly. Mounted near the unfastened end of the strip is a small inclined plane of steel, in which is cut a notch. Beneath the free end of the strip is placed a contact screw tipped with platinum, the strip being likewise equipped with a suitable contact. When the arc of vibration of the pendulum becomes greatly reduced so that it is below a given point, the trailer dips into the notch of the inclined plane and on the return swing of the pendulum the strip becomes depressed, and contact is made with the contact screw, to which allusion has previously been made. The circuit being now closed, the electro-magnet, becoming energised, attracts the armature, and a fresh impulse is imparted to the pendulum. This process continues until the arc of vibration has become again restored, when the trailer merely passes idly over the inclined plane, only engaging into the notch when the pendulum seeks a fresh impulse. This form of "break" may be constructed in numerous ways, but the principle of operation remains unchanged.

Even to-day in some systems either the original form of Hipp "break" or a modification of the same is relied on for the accurate time-keeping qualities of the pendulum of a master clock or transmitter.

Yet another form of electro-magnetic clock was devised by Lemoine, and consisted of an electro-magnet attracting an armature attached to the base of the "bob" as in the Hipp clock, but the "break" was of rather different design. Lemoine pivoted to his pendulum rod a long but light wire or "trailer," the lower end having mounted upon it a light vane taking the form of a butterfly; the fact has sometimes been responsible for it being designated the "butterfly clock."

To return to the Lemoine "break." A strip of metal suitably shaped is rigidly fastened at one end, the other carrying a contact point. When the strip becomes depressed by the "trailer" through the arc of vibration of the pendulum falling below a fixed point, the contact is completed with a fellow contact situated beneath the strip. The electro-magnet forms part of the circuit and, on becoming excited, attracts the "bob," restoring once more the desired arc of vibration. When this has taken place the "trailer" idly slides over the contact strip in precisely the same manner as the "trailer" of the Hipp system.

In many of the early church and turret electric clocks a "commutator" was employed to reverse the direction of the exciting current instead of cutting off the current entirely at the end of the pendulum's excursion from side to side. By this method the pendulum was attracted and repelled consecutively.

In the electrical arrangements of Bain, Hipp, and Lemoine, the vibrations of the pendulums are maintained by electro-magnetic attraction set up between the "bob" and an electro-magnet or solenoid and permanent magnet. The great objection to this method of imparting impulses to a pendulum is that the strength of the impulse will become reduced as the battery deteriorates. A diminishing current will fail to energise fully the electro-magnet, and consequently, the impulses becoming weaker, the arc of vibration of the pendulum will be permanently reduced, and indirectly the time-keeping qualities of the clock will be affected.

It has been proposed that an auxiliary battery might be employed and automatically placed in circuit with the clock electro-magnet should the main battery fail or suddenly become weak. Hipp and Webber are two of the many inventors who have produced suitable arrangements to overcome, if possible, this evil.

Wheatstone experimented along different lines. He transmitted an impulse from a standard clock to a specially constructed "secondary clock" or "dial." On the seconds arbor of the standard clock was mounted a small commutator taking the form of a metal disc. The disc was divided in sixty equal divisions, every alternate division being cut away and the space filled in with some insulating material. Contact with the disc was assured by means of a very light spring, the latter being carefully insulated from the framework. The rotating disc permitted the spring contact to rest alternately on metal and insulation. When the spring made contact with the metal, an electrical impulse was sent out to the secondary clock. The duration of the impulse will be exactly one second.

The mechanism of the secondary clocks consisted of an electro-magnet reacting on the teeth of an escapement wheel. The teeth were of peculiar shape and were propelled one-sixtieth part of a revolution at each impulse. Only a few wheels were contained in the movement of the secondary clock to communicate the movement to the hands.

Wheatstone also attempted to drive a clock movement by the aid of magneto-electric currents, but his experiments did not yield such good results as he anticipated.

M. Brequet constructed a special form of clock for turret and lantern use, driven by means of electrical impulses transmitted from a standard clock. The transmitter consisted of a small drum of ivory fitted with metal discs at either end, and mounted on an arbor capable of being rotated by a pinion from the standard clock mechanism. Projecting across the face of the drum from the metal plates are a number of pins which make contact alternately with two spring fingers. One of the discs is insulated from the arbor, the second disc being directly attached to the arbor. The circuit is such that it is only complete when the spring fingers rest on any of the pins. The rotation of the drum causes the pins to come into contact alternately with the spring fingers, which has the effect of reversing the direction of flow of the current each time a contact is made.

The construction of the Brequet secondary clock movement demands the reversal of the current at each impulse to enable it to operate, and the foregoing is a simple means by which the desired object is attained.

Two sets of electro-magnets are connected in series, and arranged in such a manner that their opposite poles face each other when an impulse is received from the standard clock. Placed between the four poles of the electro-magnets are two permanent magnets mounted on a horizontal spindle, so that they may oscillate freely between the poles of the electro-magnets. The spindle also has a rod extending downwards, the end of which by suitable catches and pawls engages a ratchet wheel. The oscillatory movement of the rod affords a means of propelling the ratchet wheel, and then through other wheels the hands of the clock.

Charles Shepherd, in the year 1849, patented and introduced an entirely new method of maintaining the vibration of a pendulum. An electro-magnet, acting through a series of lever, raises a "gravity" or "weighted arm," which is then held by a catch or detent. The pendulum during its swing lifts the catch, thereby releasing the gravity arm, and the latter in falling imparts an impulse to the pendulum. The pendulum controls the current for resetting the gravity arm as well as the current for transmission to the secondary clocks, the current required for the latter purpose usually being supplied by an independent battery.

Shepherd's secondary clock depends upon the attraction and repulsion set up between electro-magnets and bar magnets for its time-keeping qualities. The bar magnets are set free to move in a horizontal plane, and normally are caused to oscillate whenever the electro-magnets are energised. This movement, by means of a crutch lever actuating a pair of pallets, was found convenient to drive an escapement wheel and through a system of wheelwork, the hands of the clock.

It was proposed to keep the time at the great Exhibition of 1851 by the Shepherd system, but unfortunately it broke down at the critical moment. The world-famous twenty-four hour clock at the Royal Observatory of Greenwich was constructed by Shepherd about the middle of the last century, and is electrically driven, operating on the principle just described.

R. L. Jones introduced a system of electric clocks in 1869, in which a standard clock controls any number of ordinary pendulum clocks, and is in reality an elaboration of the "Bain electric pendulum." Each pendulum "bob" had a coil of wire wound around it, and as the pendulum vibrated the current was picked up from a series of contacts. A permanent magnet situated on either side of the pendulum set up a magnetic reaction whenever an impulse was received by the coil from the standard clock.

Now, should the pendulum be vibrating too slowly, the magnetic reaction will quicken the former; if, on the other hand, it reaches the end of its swing a little too soon, the pendulum will be held back slightly. In this system the clocks are only controlled, and the pendulums made to beat the same as that of the standard clock, assuming of course that the lengths of the pendulums are equal. There is one thing in favour of this system: should the electric current fail at any time, the clocks continue to go and keep their own time.

Jones's controlling system was in use for some years at Chester railway station, also his clocks were exhibited at the International Exhibition of 1862.

Ritchie, of Edinburgh, introduced a system of electric clocks somewhat on the same lines as that of Jones; the former, however, found it possible to dispense with the winding of the "primary clocks." An escapement wheel received its motion from curiously shaped pallets, some of which served to lock the wheel, and others to propel it. The pendulum during its excursion from side to side engaged the lower ends of these pallets, which were pivoted at the top, and resembled very closely the pallets of a gravity escapement.

The normal or standard clock sent out impulses to the secondary clocks which were equipped with short pendulums. To describe these briefly: the pendulum, instead of being suspended in the usual manner, was pivoted or suspended at its centre, and the two ends provided with coils that embraced permanent magnets during each swing. The current passing through the coils by means of a suitable arrangement was reversed twice during a complete vibration of the pendulum.

Ritchie's system was installed at both the Liverpool and Edinburgh Observatories, and in 1873 Mr Ritchie read a paper before the Royal Scottish Society of Arts.

Mr Henry Campiche introduced an electric clock in which he dispensed with the clockwork train.

It is scarcely possible to enumerate all the different methods by which an ordinary spring-driven clock movement may be wound periodically by means of the electric current.

One successful method of doing so is to connect a ratchet wheel through the medium of a coiled spring to one of the wheels nearest to the escapement wheel, usually the third wheel of the clockwork train, a weighted lever pivoted at one end and having a pawl which engages into the teeth of the ratchet wheel. The lever, during its gradual descent, exerts sufficient energy through the coiled spring to drive the escapement wheel, and maintains the swing of the pendulum which controls the going rate of the clock. When the lever has descended to a fixed point it automatically completes an electric circuit, and an electro-magnet returns the lever to its normal position. The potential energy now stored in the lever continues to drive the hands of the clocks until the cycle of resetting is repeated.

We now come to a class of electric clocks which differ from any previously described. A new lease was given to the science of electrical horology by the introduction of a system patented in 1895 by Messrs Hope-Jones and Bowell. Since then many inventors have given their attention to the science, and many improvements have been made on the earlier mechanisms. Especially may be mentioned W. E. Palmer, who patented his system in 1902; and later in the same year R. M. Lowne patented his well-known system. Other inventors include Parsons and Ball, T. Murday, The Silent Electric Clock Co., The Standard Time Co., The Magneta Time Co., and others too numerous to mention.

It would be impossible to enumerate all the inventions that have been made for the improvement of the electric clock. Much ingenuity has been displayed in its construction, and it now seems to have arrived at a state bordering on perfection. Many of the improvements have been patented, and thus the manufacture of the mechanism has been in a great measure restricted to the patentees of that particular system. Any novel or worthy invention appertaining to the subject will be described, if it is thought to be of sufficient interest and likely to serve a useful purpose.

The principles involved in many of the systems already mentioned are identical, and may be summed up briefly in the following manner: generally speaking, a heavy gravity or weighted arm, or even a spring, is reset by the assistance of an electro-magnet, and then retained in that position by a detent or catch. It is so arranged that the said gravity arm can only be released at an opportune moment when the pendulum is in the path of the falling arm. The gravity arm, on coming into contact with the pendulum, imparts an impulse to the latter.

The arm is now reset by being raised to its normal position by the aid of an electro-magnet. The circuit supplying the current for the resetting of the arm is automatically closed by the gravity arm when it reaches the extent of its travel. In some systems the current that excites the electro-magnet also operates the mechanism of the secondary clocks.

Usually the rotation of a count wheel or ratchet wheel, either pulled or pushed forward one tooth at a time by a hook or detent directly attached to the pendulum, is found a convenient method for releasing the gravity arm when about to impart an impulse to the pendulum. In practice it is desirable that the count wheel be pulled by the pendulum rather than pushed forward.

The principle on which the "Magneta" system operates is, however, different from all the preceding systems, since the generation of magneto-electric currents are necessary for the successful working of the secondary clocks. These peculiar currents are generated within the master clock. No outside source of current is needed, consequently there are no contact points; in other words, the circuit is a closed one.

Of recent years clocks having an independent motive power may have their time-keeping qualities greatly improved by being electrically synchronised at regular intervals from a standard clock. Turret clocks are especially suitable for regulation in this manner. There is one method of driving large turret clocks entirely by electricity by the employment of a large pendulum operating on the "Hipp" principle. Sometimes these pendulums are called "motor pendulums." The pendulum is sufficiently powerful to drive the wheelwork and hands of the clock, only seeking impulses when the arc of vibration falls below a fixed point; this, of course, largely depends on the resistance that the clock has to overcome. For instance, wind pressure would cause the "motor pendulum" to seek impulses more frequently than in calm weather. The "motor pendulum" is so adjusted that it has always a gaining rate, and when it has propelled the minute hand to within twenty-seven seconds of the half-minute, the pendulum becomes automatically detached from the wheelwork, the pendulum continuing to swing idly. A standard or master clock exactly at the half-minute transmits an impulse to an electro-magnet, which releases the catch that previously disconnected the pendulum from the clock movement. The "motor pendulum" now continues to drive the wheelwork, and immediately brings the hands of the clock to time. This procedure is again repeated at about three seconds to the minute. By this means the turret clock is controlled, and the time rate kept accurate. The "motor pendulum" merely performs the work of driving the hands of the clock. Not only may turret clocks be synchronised, but any number of smaller dials may be controlled from a master clock.

There are also numerous other ways by which time may be transmitted. For instance, "time balls" are allowed to drop at stated hours by being released electro-magnetically by an impulse transmitted from Greenwich.

The wireless transmission of daily time signals was undertaken in the early days of "broadcasting" by the French authorities from the Eiffel Tower at Paris.

Thanks to wireless, we now receive time signals during the day from "Big Ben" and Greenwich.

It would appear, however, that we are now entering on an era where the escapement and pendulum controlled clocks of yesterday will be superseded by an electric clock incorporating a new principle, advantage being taken of the time-controlled frequency of the alternating current of the lighting mains to operate specially designed "synchronous" electric motors, which drive the hands of the clock indirectly through gearing. The system was evolved by H. E. Warren, of America, and in that country 60 per cent. of the clocks sold in 1931 were of the synchronous type.

Many British firms are engaged in the production of this type of clock, and already we have "Electromatic," "Smith's," "Ferranti," "Synchronomains," and the "Synclock" being manufactured in this country, all of which are operated from the lighting mains when the frequency is time-controlled.

CHAPTER II

ELECTRO-MAGNETICALLY DRIVEN CLOCKS

Bain's "Electric Pendulum"—Hipp Clock—Electric Church Clock—Lemoine's Clock—Clocks by Féry, Swift, Parker, and Warren—Wengelin "Electric Pendulum"—Webber's "Auxiliary Battery Appliance."

IN this chapter it is proposed to treat in fuller detail many of the earlier systems, of which mention has been made in the preceding chapter; also will be added a description of the mechanical arrangements, old and modern, wherein the vibrations of the pendulum are maintained by electro-magnetic impulses. No special attempt has been made to deal with the mechanisms either in their historical or mechanical order, but are placed on record here to show along what lines progress has been made in clocks operating on this principle.

It may be as well, first of all, to examine the mechanical arrangement of the Bain "electric pendulum," which may be accepted as the pioneer of all electrically driven pendulums.

Bain's "Electric Pendulum."

Bain dispensed with the weight often employed for supplying the motive power in an ordinary clock, and introduced instead an electrically driven pendulum, which by the intervention of a crutch lever oscillated the pallets of an escapement wheel, causing the latter to rotate and communicate its movement through a train of wheels to the hands of the clocks. Bain's "electric pendulum," as it was then termed, was constructed in two forms, but the principle of the two when in action is identical.

In the one form the "bob" had two permanent magnets. These were attracted and repelled by two coils of wire through which an electric current was allowed to pass, the coils being situated on either side of the vertical line of the pendulum's

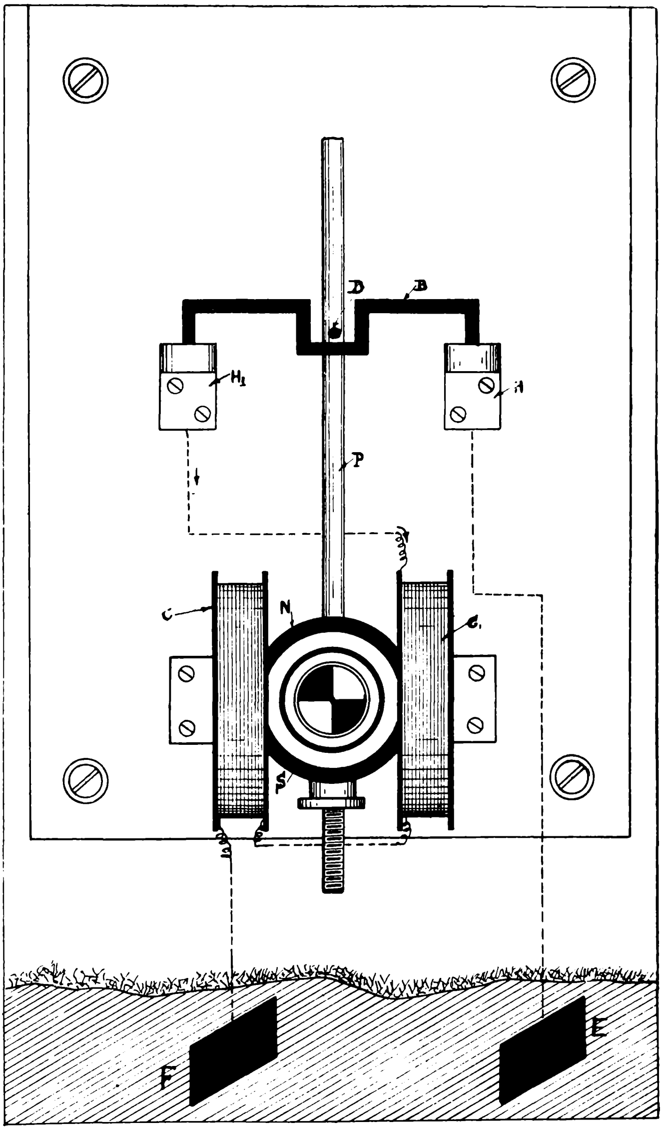


Fig. 1.—Bain's "Electric Pendulum."

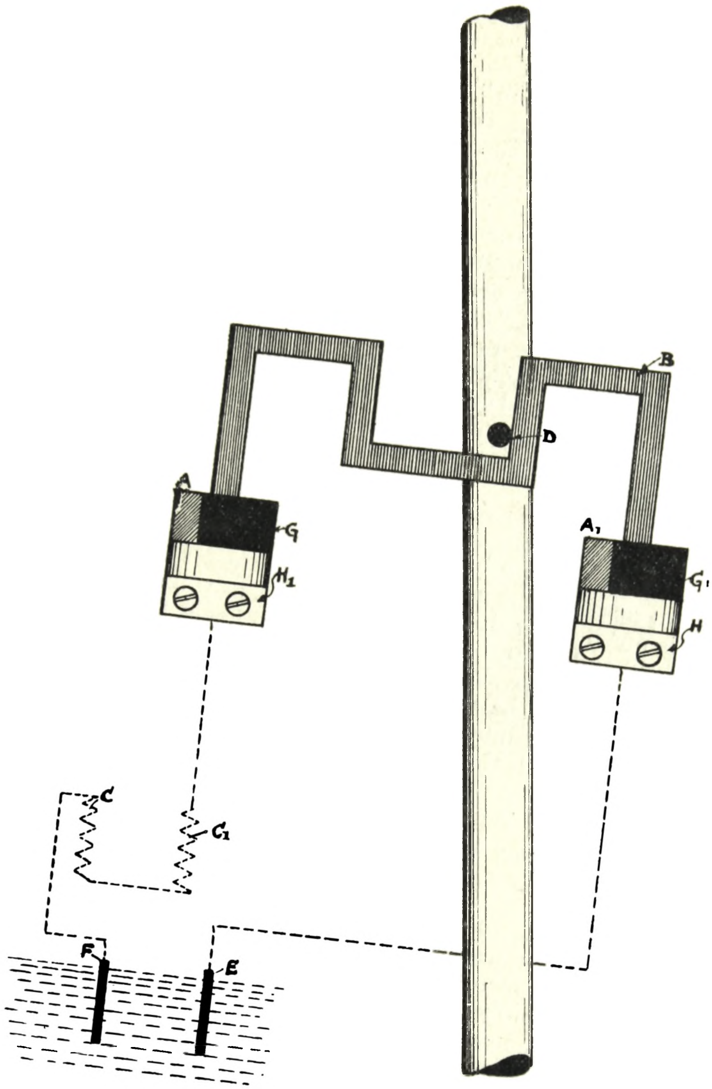


FIG. 2.—Bain's Electric "Break."

swing. The pendulum controlled the current for exciting the coils by operating a curious form of "break."

In the other form of electric pendulum the state of affairs was reversed. The "bob" of the pendulum was in reality a coil of wire carrying the current, the latter being conducted down the rod from the suspension. The permanent magnets were of cylindrical form, and placed on either side of the "bob," so that as the pendulum vibrated, the coil was carried a short distance over the permanent magnet. But a moment's thought will satisfy us that the magnetic effect remains unchanged.

Fig. 1 shows the former kind of pendulum with the two coils CC_1 and the pendulum "bob" with the two permanent magnets NS arranged with like poles pointing in the same direction. Bain employed an "earth battery" as a suitable source of current. The zinc and copper plates F and E are buried a short distance apart in the moist earth, the moisture being sufficient to set up the chemical action to produce the current for exciting the coils.

The "break" needs describing, and is shown in Fig. 2. Two semicircular pieces of gold and agate are held in contact by means of a metal band, and form part of the pillars HH_1. Let GG_1 represent the gold, and AA_1 the agate. The size of the gold is much larger than that of the agate, as will be observed. The gold and agate have a groove cut through their centres, and in this groove slides the metal bridge B. Now, suppose the pendulum to be moved to the extreme right, so that the pin D of the pendulum engages the bridge B and moves the latter also towards the right. The points of the bridge B now resting on the gold pieces GG_1, place the two pillars in electrical connection, and the current accordingly flows from G_1 to G by way of the bridge B. The coils now becoming excited, the attraction on the one side and repulsion on the other tends to send the pendulum towards the left. The pendulum continues to do so until the pin D again engages the bridge B and carries it towards the left also; but this time the points of the bridge merely move on to the agate AA_1, and instantly the circuit is broken. The pendulum, no longer influenced by the coils CC_1, now returns by its own weight. During the return swing, however, the pin D pushes the bridge towards the right until the points of the latter rest again on the gold pieces GG_1. The cycle is repeated, and in this manner the pendulum is kept vibrating.

The current for operating the secondary clocks is let on and off by one of the points of the bridge sliding over a metal contact, but this does not take place until the pendulum is almost at the end of its swing. This contact is not shown in the diagrams, but the principle is easily understood. It will be noted, however, that the current when not exciting the coils is operating the secondary clocks.

Hipp Electric Clock.

Dr Hipp's arrangement of electric clock is represented in Fig. 3, its novel feature being the contact maker for controlling the current needed for the excitation of the electro-magnet. The mode of propelling the wheelwork of the clock is similar to that adopted by Bain, but the method of controlling the current is very different and more economical, and in many respects the Hipp system is superior to the Bain system.

The pendulum rod has pivoted to it a "finger" F (Fig. 3). Beneath and in the path of F is a notched block of steel S mounted on the light spring T, one end of which is rigidly fastened to a bracket B, the free end being equipped with a contact C engaging beneath it the contact screw Y. If the pendulum is caused to vibrate slightly, the "finger-piece" F does not leave the block S, but merely drops into the notch. On the return swing of the pendulum, the spring is depressed and the contact completed between C and Y. The circuit now being closed, current passes from the battery D through the electro-magnet E and the circuit shown.

The contact between C and Y is completed at every alternate swing of the pendulum until the arc of vibration has become restored, when the "finger" F slides idly over the notched block S. Failing to depress the latter, the pendulum continues to vibrate until the arc becomes reduced, when the "finger" again engages into the notch, and the electro-magnet again imparts a fresh impulse to the "bob." Unlike the Bain "break," the circuit is only completed when the pendulum seeks a fresh impulse; a great saving in current is thereby effected.

The "Hipp" contact maker has reappeared in some of the inventions of recent years for the controlling of motor pendulums in connection with the driving of turret clocks.

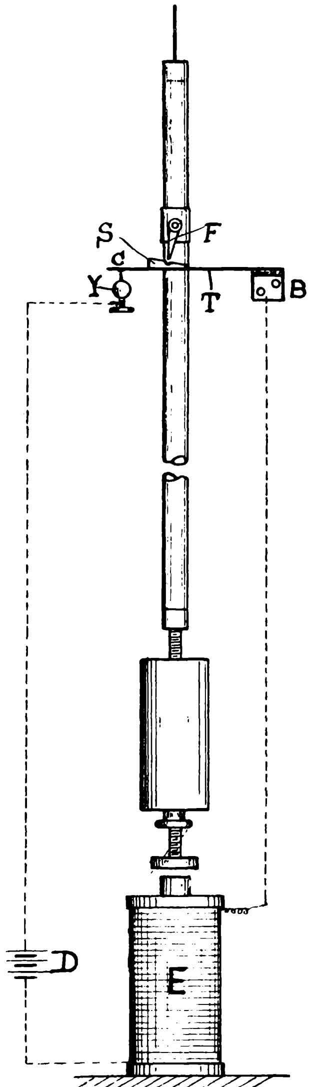


FIG. 3.
Hipp's "Electric Pendulum."

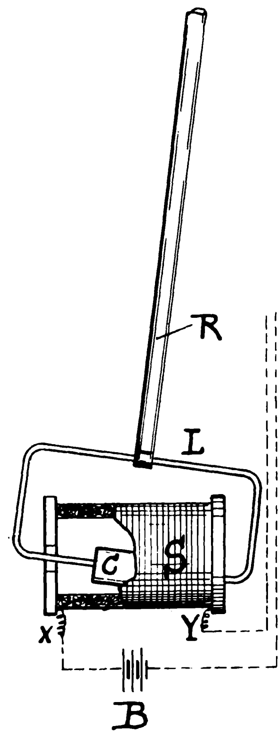


FIG. 3A.
Wengelin's "Electric Pendulum."

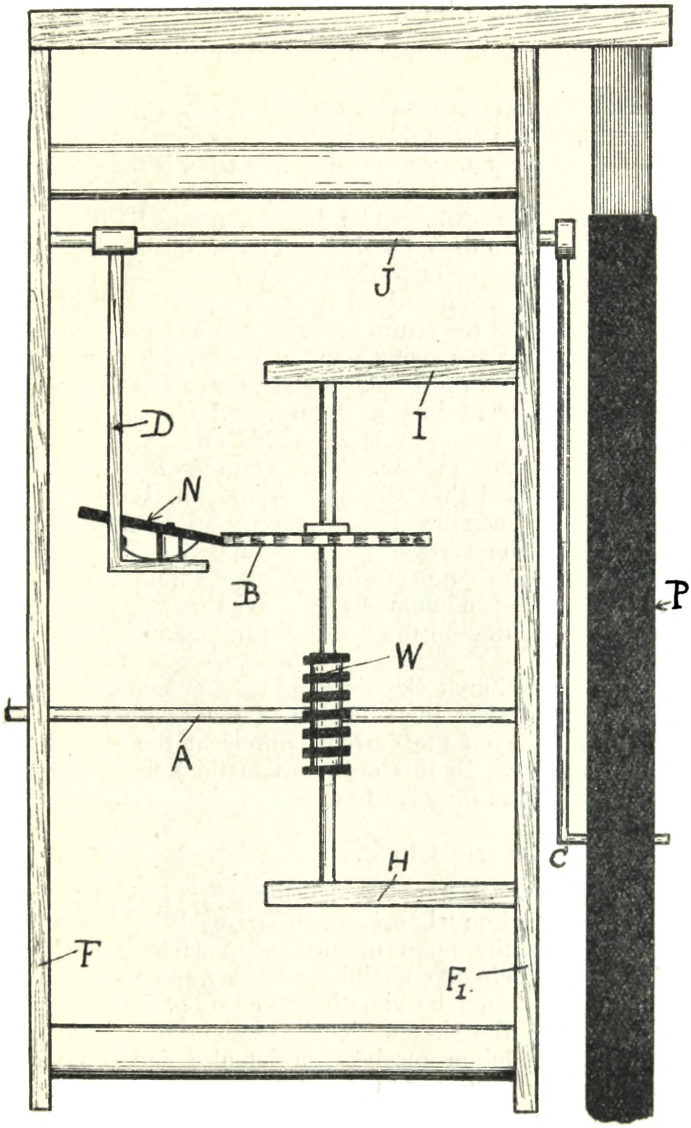


FIG. 4.—Early Form of Electric Turret Clock.

Electric Church Clock.

An early form of electric turret or church clock is shown in Fig. 4.

The massive wooden pendulum rod P, during its excursion to the right, pushes aside the crutch rod C, which is attached to the horizontal arbor J. Fastened to this arbor is the bracket D carrying a click N, which is kept in position on the wheel by a light spring as shown. The bracket D will have a small rotary movement to the right similar to that of the pendulum, and during its movement to the right the click will jump over one tooth of the ratchet wheel B, the latter being fixed to a vertical arbor. On the return swing, which will be completed by the weight of the moving parts, the click will now propel the wheel B one tooth forward. The vertical arbor also carries a worm W engaging into a worm wheel mounted on the horizontal arbor A, and it is from this arbor that the dial wheels obtain their motion. The worm and worm wheel are so proportioned that all intermediate wheelwork can be dispensed with, and the dial wheels are attached direct to the arbor A. The vertical arbor is supported in the projections H and I, the whole being mounted within the frames F and F_1. The pendulum P receives its impulse from an electro-magnet acting on the "bob" in the manner previously described.

In the early church electric clocks a "commutator" was introduced to change the direction of the exciting current, instead of cutting off the current entirely at the end of the pendulum's swing. By this ingenious method the pendulum received an impulse from left to right and vice versa.

Lemoine's Electric Clock.

Lemoine devised a clock, of which the pendulum was provided with an iron "bob," and so arranged that it was free to vibrate over the poles of an electro-magnet, the latter forming part of a circuit containing a battery and a spring key. Should the pendulum be vibrating too slowly, the key automatically closed the circuit. The electro-magnet becoming excited, the pendulum received an impulse and was again restored to its normal amplitude.

Attached to the pendulum is a rod A (Fig. 5), provided with a piece of mica B; this rod merely slides over the raised

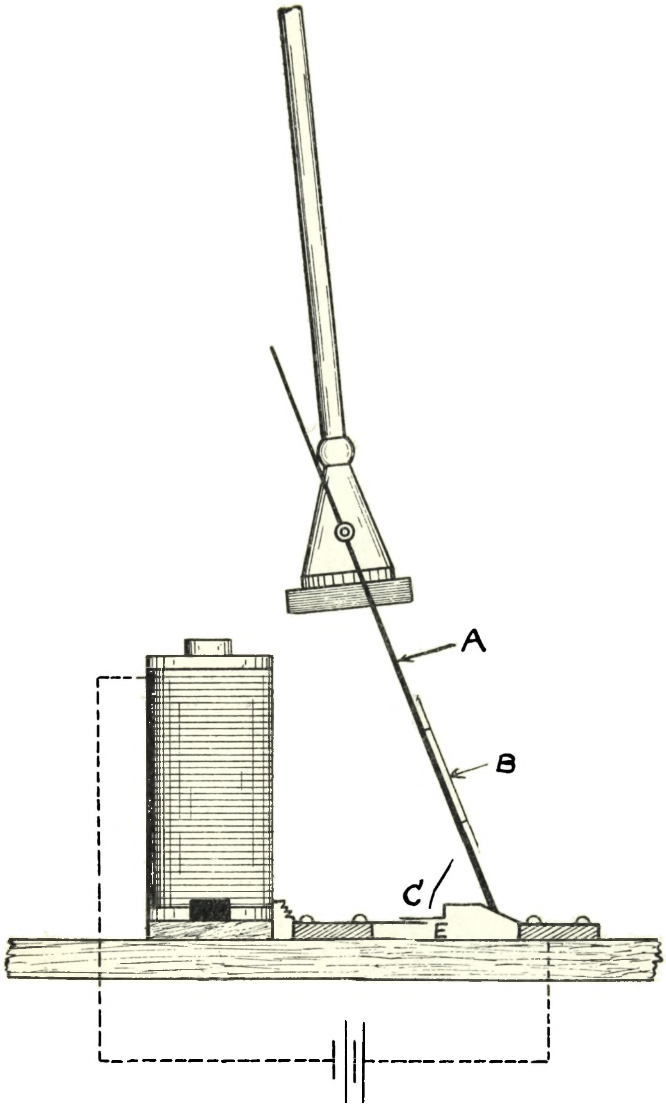


FIG. 5.—Lemoine's Electric Clock.

part of the spring key C when the pendulum is vibrating normally. Should the rate of the pendulum, however, be slow, the rod A pushes the light spring C down, making contact with a fellow spring E, and thereby closing the circuit. The electro-magnet now becoming energised attracts the pendulum "bob," which increases the arc of vibration. This continues until the pendulum has gained sufficient momentum to allow the rod A to again slide over C without depressing it and closing the circuit.

This clock was certainly a great improvement on the earlier ones, and doubtless the "time rate" of Lemoine's clock was superior to that of Bain.

The Féry Electric Clock.

The pendulum P (Fig. 6) carries at its lower extremity, in place of the customary "bob," a permanent horse-shoe magnet M, the lowest pole of which is encircled by a coil C. A second but smaller pendulum S is caused to vibrate in sympathy with the larger pendulum by being attached to the magnet M. On either side of the small pendulum S are situated the contact screws A and B. The circuits are separate, and two sets of batteries, O and X are required. The contact B on the pendulum swinging to the right, completes the circuit through the small pendulum, and an impulse is transmitted to the secondary clock. On the other hand, when the pendulums P and S vibrate to the left, the contact is completed between A and S, and the battery O energises the coil C, which imparts an impulse to the pendulum through the magnetic reaction set up between the coil C and the pole of the magnet M. With this arrangement the pendulum S acts as a pendulum switch, and alternately completes the contact at A and B, the former controlling the power circuit, while the latter allows the battery X to operate the mechanism of the secondary clock.

Swift's Electric Clock.

This system is shown in Fig. 7, and consists of an electro-magnetically driven pendulum propelling a ratchet wheel, which by suitable contacts, ingeniously transmits electric impulses at regular periods to a system of secondary clocks.

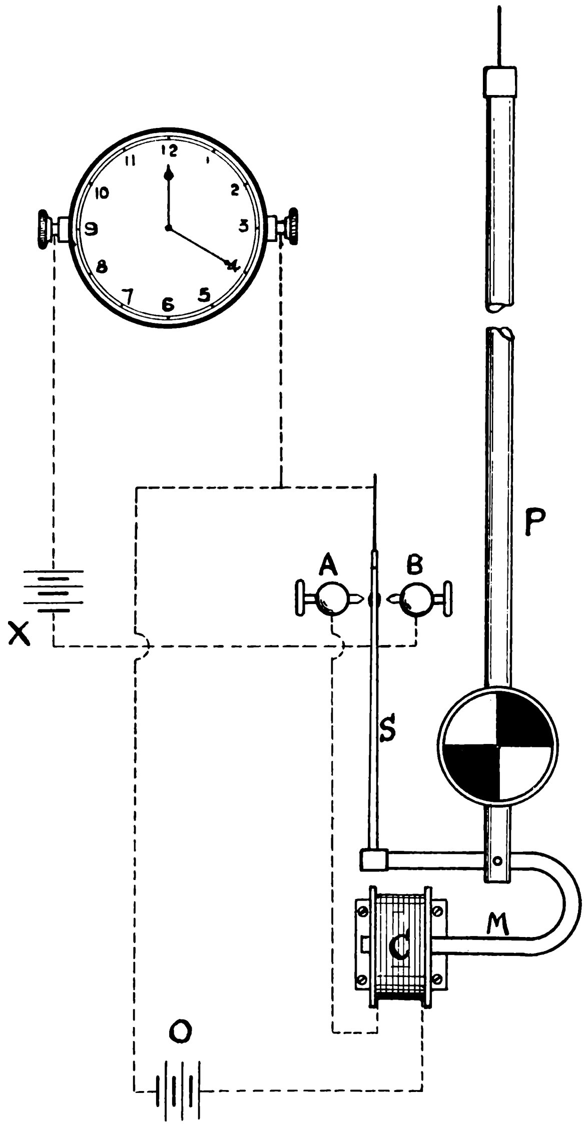


FIG. 6.—Féry's Electric Clock.

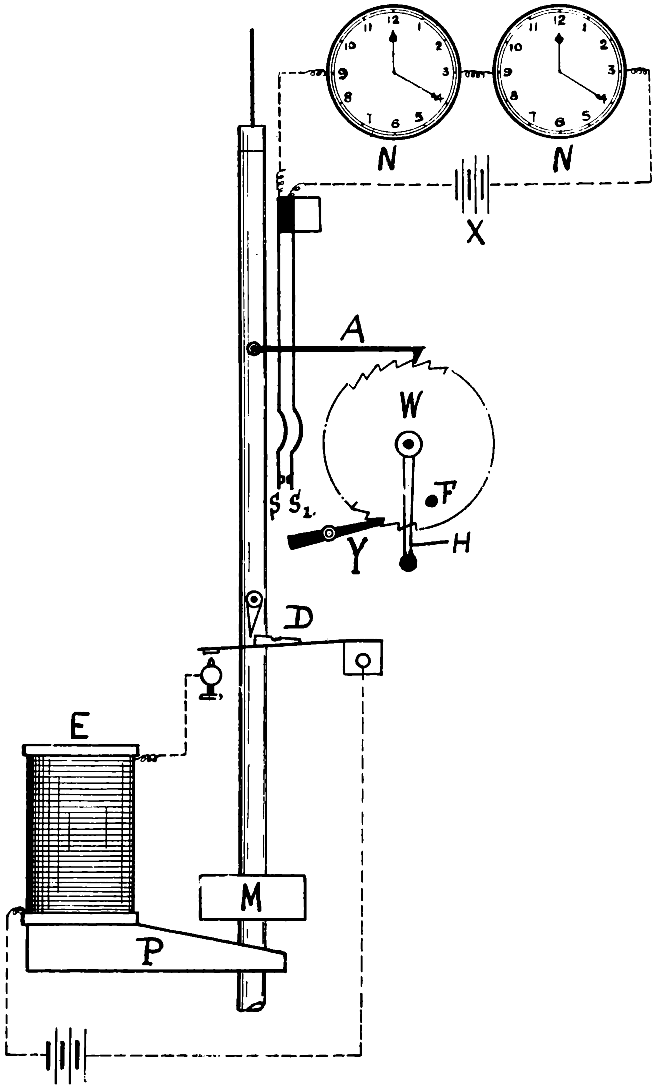


FIG. 7.—The Swift Electric Clock.

The "Hipp" contact device D regulates the current for exciting the electro-magnet E, which has one pole-piece P tapered and extending towards the pendulum rod.

As the "Hipp" contact maker has been fully described at the commencement of this chapter, there is no need to dwell any longer on the construction or principles involved in this device when in operation.

Vibrating with the pendulum is an armature M, it being so situated on the pendulum rod that it comes within the field of the pole piece P. A hook A, pivoted to the pendulum rod, at every alternate swing of the latter propels a ratchet wheel W one tooth forward. As the ratchet wheel W rotates, the pin F comes into contact with a loose arm H which it raises to the vertical, when it immediately falls by gravity; but in doing so it momentarily causes the two springs SS_1 to make contact and allows the battery X to supply an impulse to operate the secondary clocks N. The detent Y prevents the ratchet wheel from turning in the reverse direction.

It will be perceived by a glance at Fig. 7 that the magnetic impulses are not delivered directly to the "bob," as in the other forms previously alluded to, but are delivered above the "bob" at the point M.

Generally the impulses are delivered below the "bob," but this is immaterial so long as the pendulum is in a favourable position for the reception of the impulse.

Warren Electric Clock.

Messrs Warren, in an ingenious arrangement shown in Fig. 8, adopt a pendulum equipped with a peculiar "bob" B resembling the greater portion of a ring. As the "bob" vibrates it allows a coil C to enter its gap, the coil having an iron core which presents its opposite poles to the two faces of the ring "bob" B. The current for the excitation of the coil C is controlled by a novel device D, which essentially consists of a glass tube of the shape shown. One end has fused into it the wires WW_1, which are in turn connected to the terminal X and the pendulum respectively. Within the tube D is a large globule of mercury M, which runs from end to end of the tube as the pendulum vibrates. When the "bob" approaches the coil C, the globule M will have a natural tendency to flow towards the ends of the wires WW_1, and will eventually form a

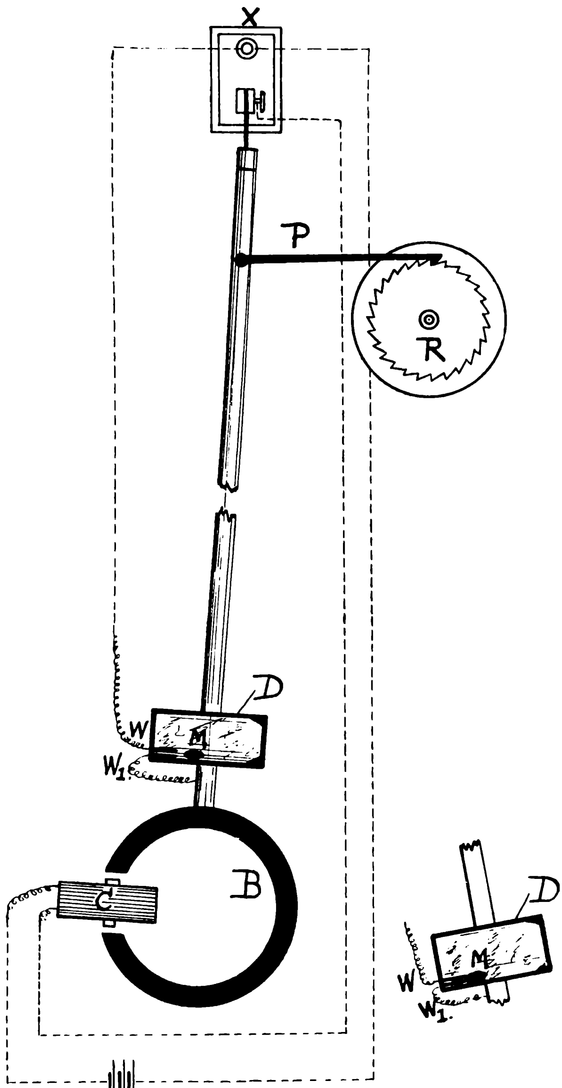


FIG. 8.—The Warren Electric Clock.

conducting path for the current between the two wires. The inside of the tube is specially prepared and presents a rough surface to the mercury, reducing somewhat the adhesion between the glass and mercury. Advantage is taken of the oscillatory movement of the pendulum rod to drive the ratchet wheel R through the intervention of the pawl P. The ratchet wheel being mounted on the second's arbor of the clockwork train, drives the hands in the usual manner.

Wengelin's Electric Pendulum.

Another "electric pendulum" arrangement was suggested by Wengelin and patented in 1908.

In Fig. 3A the familiar "bob" has been replaced by a metal loop L attached to the pendulum R. The lower part of the loop is surrounded by an iron core or cylinder C. Encircling that portion of the loop bearing the iron core is a solenoid S, its internal diameter being sufficiently great to permit of the core C vibrating freely within its interior. The ends XY of the coil S are connected in series with a battery B. A simple form of contact maker operating on the upper portion of the pendulum rod R regulates the current for exciting the solenoid. The magnetic reaction set up between the iron core and the solenoid causes the pendulum to oscillate.

Webber's Auxiliary Battery Appliance.

It may not be uninteresting to complete this section of our work with a description of an appliance whereby, to a great extent, the chances of failure in electro-magnetically maintained pendulum clocks through the diminishing in strength of the current supplied by the battery, are reduced to a minimum by the automatic introduction of an auxiliary battery in the circuit. This may be carried out in the following manner, for which we are indebted to A. B. Webber who patented this arrangement in 1905.

On examining Fig. 9 it will be noted that it is an arrangement operating on the "Hipp principle," and is in some respects a modification of the original. The central idea of this mechanism is that the pendulum, through a system

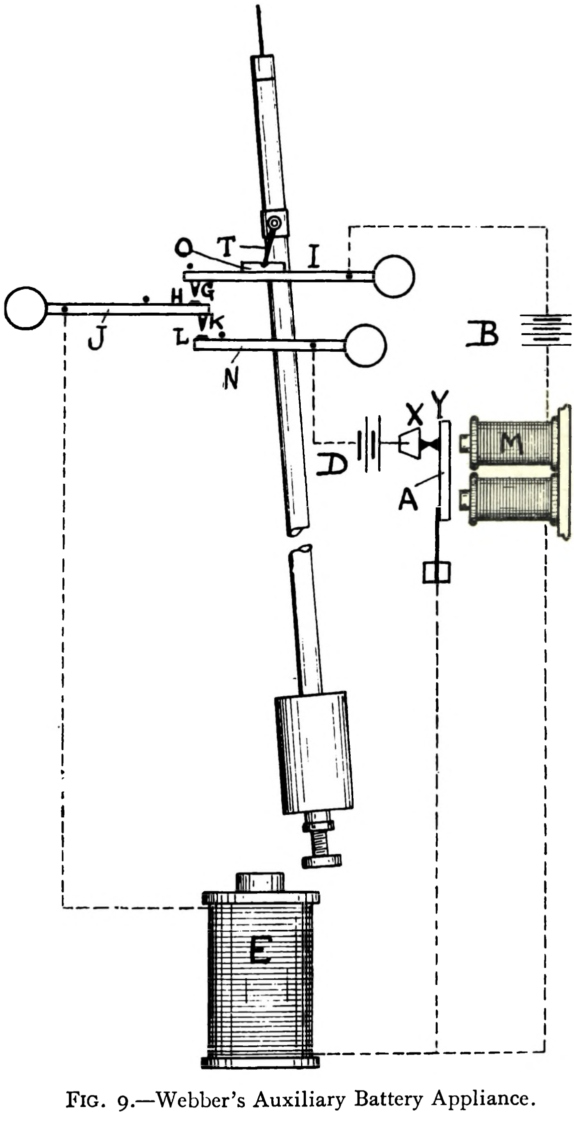


FIG. 9.—Webber's Auxiliary Battery Appliance.

of pivoted arms and contacts, brings into action an auxiliary battery should the main battery supplying the energy to maintain the vibration of the pendulum fail at any time.

An arm I, which is pivoted, has at its outer end a contact G, and on being depressed it engages the contact H on a second but inverted arm J. The latter is provided with a second contact K engaging the contact L on a third arm N.

When the amplitude of the pendulum becomes greatly reduced the "finger-piece" T engages into a notch of the block O, which results in the arm I being depressed and uniting the contacts G and H. The depressed arm J now completes the contact between K and L, so that the circuits are now closed. The main battery B, being connected up in series with the arms I and J, has inserted in the same circuit an electro-magnet E and the electro-magnetic switch M.

Now, on the completion of the contact between G and H, current flows from the battery B through the arms I to J, hence through the electro-magnet E, returning by way of the electro-magnetic switch M. When the coils of M are energised, the armature A is attracted and the circuit of the auxiliary battery B is opened by the contacts X and Y being held apart, the energy required by the electro-magnet E now being derived from the main battery B.

Supposing, now, that the main battery B is weak and is unable to supply the requisite current; then when the arms I and J are depressed in the usual manner by the "finger-piece" T, the contacts H and L engage one another. The electro-magnetic switch M is now unable to operate, and consequently the contacts X and Y remain in the closed position, which allows current to flow from the auxiliary battery D through the circuits shown, and energising the electro-magnet E, the vibration of the pendulum is assured.

CHAPTER III

ELECTRICALLY CONTROLLED CLOCKS

THE electrically controlled clock was regarded for many years as a promising system, and perhaps would still have been in extensive use had not the systems described in the next chapter been found to be more efficient and serviceable. Before entering into a description of the working of the various systems of electrically controlled clocks, it may help in the right comprehension of our subject if reference is first made to the early mechanisms of Bain.

Bain's Electric Transmitter.

Alexander Bain exhibited his first clock at the Polytechnic Institute in 1841, and took the form shown in Fig 10.

The pendulum of an ordinary clock beating seconds makes contact through A with a light spring S, the latter being insulated from the base B by being mounted on a block of insulating material. The framework B and pendulum rod being metallic, forms part of the circuit in which is inserted a battery C and a secondary timepiece T. Each time the contact A attached to the pendulum rod P engages the spring S, the circuit thereby becomes closed and allows the current from the battery C to flow momentarily through the circuit to the clock T.

The mechanism of the latter is of the simplest nature, and will be described in a succeeding chapter; suffice it to say that a ratchet wheel is propelled one tooth forward, or one-sixtieth of a revolution, the hands denoting the correct time.

Other details are: E represents the crutch lever, which is caused to oscillate by the escapement wheel within the frames of the clock acting on the surface of the pallets. The lower and forked end of the crutch lever E embraces the pendulum rod P and imparts the impulse to the latter, so that it is enabled to make its excursions from side to side.

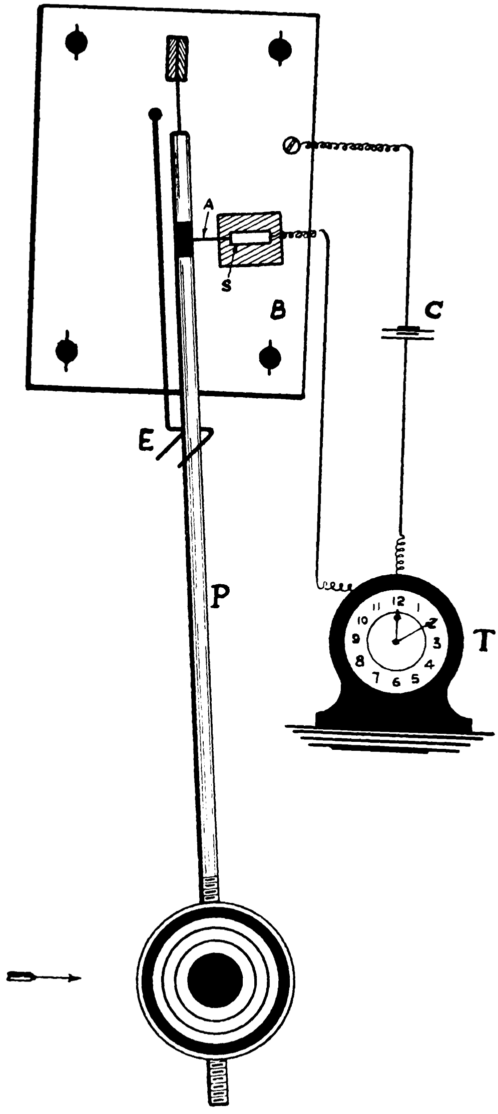


FIG. 10.—Bain's Electric Transmitter.

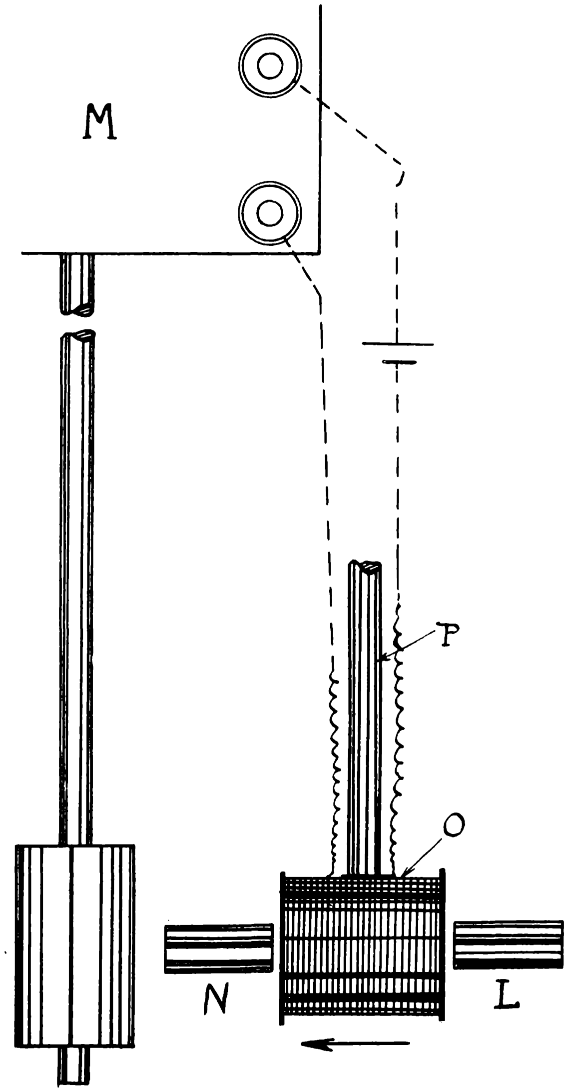


FIG. 11.—Jones's System.

R. L. Jones's System.

The clock M (Fig. 11), shown on the left, is the standard, master, or transmitting clock, and is one whose time-keeping qualities are beyond reproach, the pendulum preferably beating seconds. The standard clock is independently driven by either falling weights or a spring wound up at intervals, a simple contact device operating on the seconds arbor of the clockwork, or mounted on the clockcase in such a way that as the pendulum swings it completes the contact, and allows an impulse to be transmitted to the pendulum P of the secondary or controlled clock.

The "bob" of the controlled clock is in reality a coil of wire O through which the impulse transmitted passes, and the former becoming endowed with magnetic properties, a reaction is immediately set up between the energised coil and the permanent magnets L and N situated on either side of the vertical.

A system of contacts was provided in the original Jones system, so as to enable the pendulum P of the controlled clock to pick up the current as it made its excursion from side to side.

A moment's thought will suggest that the Jones system is but a modification of the Bain "electric pendulum" pressed into service, the impulse received, however, only correcting the swing of the pendulum rather than supplying it with motive power. Again, the hands of the subordinate clocks are propelled by any other means than by the electric current. The electric impulse passing through the pendulum coil, performs the office of controlling or correcting the subordinate pendulum in the following ingenious manner: Imagine the pendulum to be moving in the direction denoted by the arrow, and arriving at the end of its vibration a little too soon, it will then be held back slightly by the magnet N. On the other hand, if the pendulum is vibrating too slowly, the magnet N will quicken the vibration of the pendulum. The coil O when it comes within the vicinity of the second magnet L experiences the same phenomena as it did when nearing the magnet N.

In this arrangement it will be perceived that the pendulum of the subordinate clock or clocks must be of the same length as that of the standard clock, otherwise it would be impossible to control them.

The chance of failure with this system is that the pendulums of the subordinate clocks may get out of beat with that of the standard clock, through the electricity failing to supply the requisite impulse. Provided, however, that the impulses do not fail for more than a few minutes, and that the pendulums of the subordinate clocks do not become a beat wrong, the "time rate" is not affected. Should the current fail entirely at any time, the system has the redeeming feature that the clocks continue to go under their own motive power, and consequently keep their own time.

Ritchie's System.

The Jones electrical system of controlling clocks was further improved upon by Ritchie, of Edinburgh, who by displaying great ingenuity in the construction of his clocks, was successful in driving his clocks entirely by electrical means; and was thus able to dispense with the springs and weights which supplied the motive power in the Jones system.

The essential features of Ritchie's clock are represented in Fig. 12, in which the pendulum raises peculiar shaped pallets, which have the power when raised of exerting sufficient force to drive the escapement wheel. During the forward motion of the escapement wheel, the pallets return to their lowest or normal position, and then securely lock the teeth of the escapement wheel to prevent any false movement that may be caused by external forces, such as wind pressure on the hands of the clock.

Unlike the preceding system, should the electric current fail for more than a minute, the result would be serious as the pendulum would only have sufficient momentum to complete a few swings, the arc of vibration becoming so greatly reduced that even in the event of the current becoming again restored, the coil upon the pendulum would be beyond the influence of the permanent magnet, and this may result in the system being brought to a standstill. Nevertheless, under ordinary conditions the Ritchie system has found great favour and has given good results; indeed, it was highly spoken of by the Astronomer Royal of Scotland.

Referring to the figure, which shows the general mechanical arrangement of a subordinate clock—at least the method of propelling and locking the escapement wheel w by means of

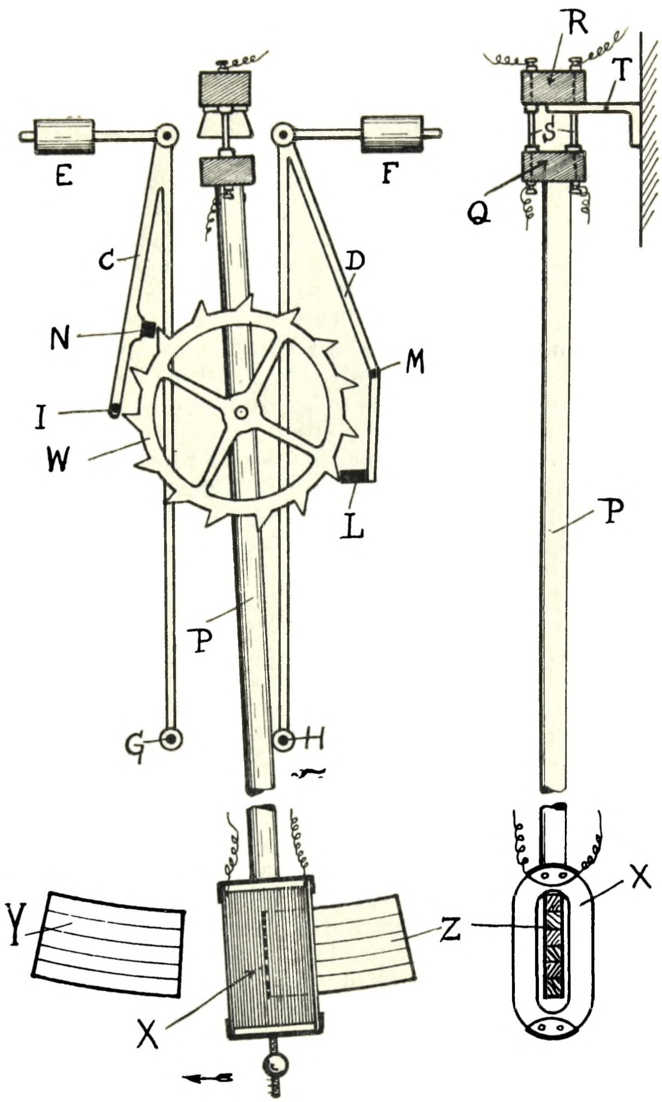


FIG. 12.—Ritchie's Electric Clock.

pallets or gravity arms CD—each pallet has a balance weight EF, and rods extending downwards terminating in the banking pins GH. P represents the pendulum rod.

For convenience we will assume that the pendulum P has swung to the right and raised the pallet D to the position shown, and that the pendulum is now returning to the extreme left as denoted by the arrow; but in doing so the pendulum rod will engage the banking pin G. The former, continuing its excursion, will push the rod likewise to the left, and since the pallet C is attached thereto, the projection I unlocks the tooth of the wheel W. Immediately this has been effected, the lower portion of the pallet D at L engages a tooth and pressing on it, drives the wheel ahead a short distance until the pallet has fallen sufficiently for a tooth to abut against the stop M, thereby arresting the progression of the wheel W.

The pendulum having by this time swung to the extreme left and having raised the pallet C so that the stop N is now pressing against one of the teeth of the escapement wheel, continues its swing to the right. Engaging the banking pin H of the pallet D, it pushes it aside until the stop M has been withdrawn by the movement of the pallet. The wheel W now being unlocked and free to turn, the weight of the pallet C pressing on the tooth at N causes the wheel to turn until the pin I in the falling pallet arrests the wheel, and at the same time locks it in this position. The cycle is repeated, and the hands of the clock receive their motion from the escapement wheel through a train of clockwork, the motive power being virtually the pallets C and D.

It now remains to describe how the pendulum receives the requisite impulse to maintain the arc of vibration.

The pendulum rod terminates with a coil of wire X, the coil being of an oval shape, and as it vibrates from side to side the groups of permanent magnets YZ are embraced by the coil. To create as strong a magnetic field as possible the opposite poles of the permanent magnets face each other. The ends of the wire of the coil X are extended upwards and are in electrical connection with the two suspension springs S, which are set in a block of insulating material Q. The other ends of the springs are attached to a second block of insulating material R, the latter being bolted to a substantial bracket T, which is in turn rigidly fastened to a wall or other firm support. Two terminals mounted on the block R, and in electrical connection with the springs S, form a convenient means of conducting the current into and out of the coil X.

The standard clock, of course, will have to be equipped with a current reverser, so that the direction of the lines of force produced by the coil X may become changed in direction when the pendulum arrives at the end of its swing. The magnetic reaction arising between the coil and the magnets imparts an impulse to the pendulum, and assists the latter to commence its return swing.

Another ingenious form of "electric pendulum" was devised by Ritchie, wherein the pendulum was suspended at its centre, and each end of the pendulum was provided with a coil of wire embracing two sets of magnets as it vibrated from side to side. The mode of picking up the current for the excitation of the two coils was precisely the same as that adopted in the preceding clock. By connecting the coil up in such a manner that the current passes first through one and then the other of the coils, makes it possible to double the force of repulsion and attraction set up between the coils and the permanent magnets.

Brequet's Lantern Electric Clock.

The illustrious Brequet constructed a novel form of commutator or current reverser, which was driven from the wheelwork of a standard clock, and so arranged that at a predetermined moment two spring contacts, by engaging two metallic conductors on the commutator, completed the circuit supplying the current to control the secondary clock.

On the commutator moving through another fraction of a revolution, the spring contacts engaged two fresh conductors, but situated in the reverse order. This had the effect of reversing the current in the external clock circuit.

In Fig. 13 a small ivory cylinder is mounted on an arbor and by a wheel having ten teeth. It is driven from one of the upper wheels of the clockwork train, moving through a fraction of a revolution each minute. The ends of the cylinder are fitted with two metal discs MN, one of which is attached to the arbor, whilst the other disc is insulated from it.

Across the face of the ivory cylinder are a series of pins P projecting alternately from the discs MN, and arranged so as to make contact with the pins P are two light strips of metal BC

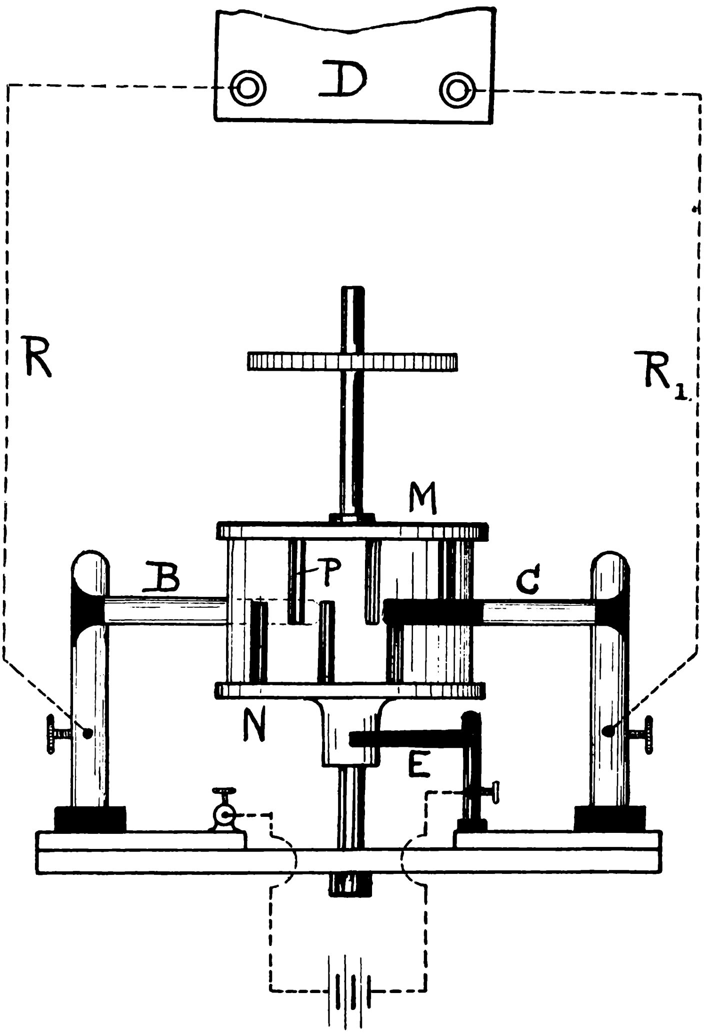


FIG. 13.—Brequet's Lantern Electric Clock.

attached to standards as shown. The standards also serve as a means of conducting away the currents as they are reversed

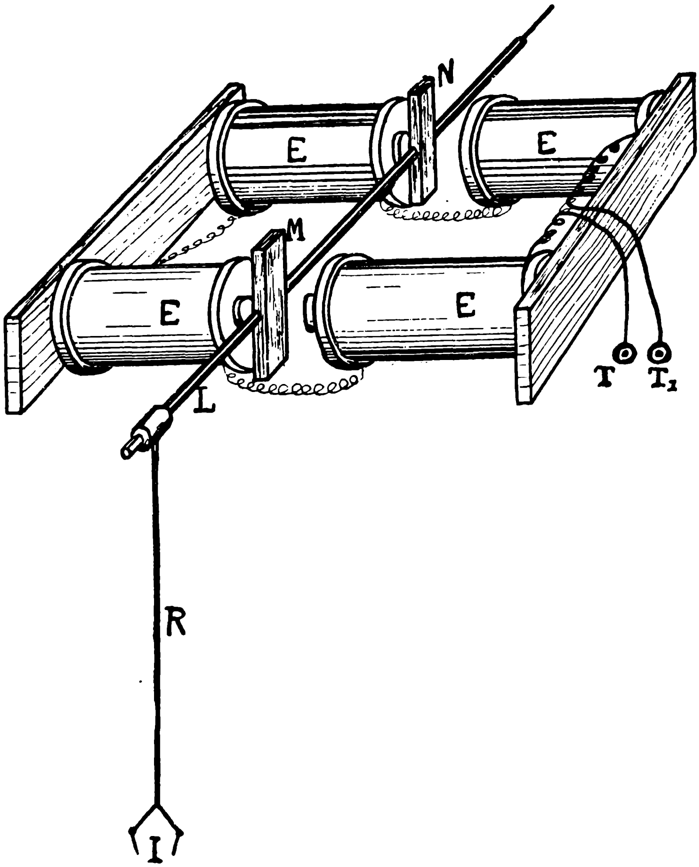


FIG. 14.—Electro-Mechanism of the Brequet Electric Clock.

to the clock D. The spring contact E conveys the current to the insulated disc M, the former being insulated as well as the other standards from the base-plate.

The method of utilising the electrical impulse transmitted by the commutator will be made clear by referring to Fig. 14, in which will be observed four electro-magnets E, arranged with their poles facing one another. The windings of the electro-magnets are connected up in such a manner that, when a current is passing through their respective windings, the magnetic condition of the facing poles will be opposite in nature; that is "north and south." A spindle pivoted at either end carries two permanent magnets MN, a sufficient space being allowed between the facing poles of the electro-magnets to permit of the magnets MN oscillating slightly.

Now, when an impulse is transmitted by the commutator in Fig. 13, the electro-magnets E become excited, and the polarity produced at their poles attracts or repels the permanent magnets MN. If, on this occasion, the magnets MN oscillate to the left of the figure, then on the reception of the next impulse the current being now reversed, the magnetic reaction will be opposite and the magnets MN will immediately swing to the right.

Mounted on the outer end of the spindle L is a light rod R extending downwards, and provided at its end with two pallets or catches I which engage the teeth of a ratchet wheel, causing the latter to rotate and propelling the hands of the clock through a system of wheelwork. With impulses transmitted each minute from the standard clock, the rod R will then make one complete oscillation in two minutes.

The circuit needed for conveying the current from the standard clock to the secondary clock is shown in diagram 13. The wires RR_1 from the commutator are connected to the terminals TT_1 of the secondary clock. The source of current, such as a battery, is shown by dotted lines.

Wheatstone's "Electric Transmitter."

Mention has been made in Chapter I. of the method adopted by Professor Wheatstone for the transmission of impulses from a standard clock to operate a secondary clock or dial. Wheatstone's secondary clock was of the simplest construction and consisted of only a few wheels and a pair of hands to show the time.

A metal disc, divided into sixty equal parts,* has every

* In the figure only twelve divisions are shown for sake of convenience in drawing.

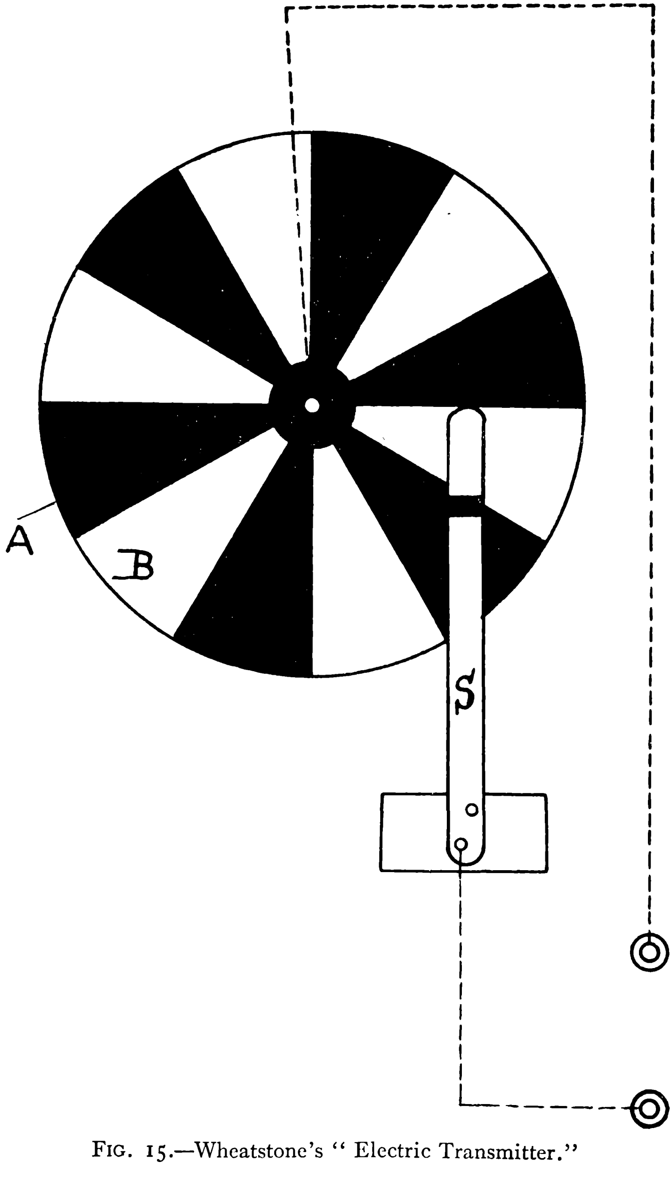


FIG. 15.—Wheatstone's " Electric Transmitter."

alternate part cut away and filled in with insulating material as illustrated in Fig. 15, A being the metal section and B one of the filled-in section. The disc is mounted on the seconds arbor of the clock, and therefore turns once in a minute. Pressing lightly on the face of the disc is a light spring S, the latter being insulated from the clock-frame. As the seconds arbor rotates, the spring S makes contact alternately with the metal and insulating material, with the result that the circuit will be made and broken every second. An electro-magnet in the secondary clock actuates an escapement wheel, which drives the hands of the clock each time that an impulse is sent out from the commutator disc.

Of recent years, however, the controlling of clocks by electrical means on the principles attempted by Brequet, Jones, and Ritchie have to a great extent been supplanted by more efficient mechanical systems to be described in the next chapter.

The ambition of the present-day inventor of electric clocks is to secure a uniform impulse to maintain the arc of vibration of a pendulum, and more often than not the pendulum is in reality a form of switch, sending out impulses with the greatest accuracy at regular intervals to operate a system of sympathetic clocks or dials.

For the various ways in which development has been effected it will be necessary to pass on to that class of clock which is electrically wound at regular intervals.

CHAPTER IV

ELECTRICALLY WOUND CLOCKS

CLOCKS coming under this heading rely on either a spring or weighted lever for their motive power. If a spring is adopted it must be endowed with potential energy at regular intervals by being wound electrically. If a weighted arm is chosen as the means of propulsion, then the arm is raised by electrical means, and since it is free to fall gradually, provision has to be made that it shall be temporarily connected to the mechanism of the clock to act as the driving force of the latter.

Strictly speaking, it is convenient to divide electrically wound clocks into three classes:—

1. Clocks in which a spring supplying the motive power is periodically wound by an electrical arrangement.

2. Clocks in which a weighted arm or lever is raised into an effective position by electrical agency and then allowed to fall, the lever being temporarily connected to the wheelwork of the clock. On the lever falling to a predetermined position it automatically completes an electric circuit, and the lever is replaced to its original position by the aid of an electro-magnet.

3. In recent practice it is customary to raise, electro-magnetically, a weighted arm or lever which is then held by a catch or detent.

At a predetermined moment the pendulum releases the arm which during its descent imparts an impulse to the pendulum.

The pendulum receiving the impulse enables it to maintain the normal arc of vibration, until, when a given interval has elapsed the arm is again released. When the arm falls to its lowest position it completes an electric circuit, and the arm is reset by an electro-magnet ready for the next impulse.

Wengelin's Winding Gear.

Dealing with the systems in their respective order, it may not be uninteresting to study first the electrical winding gear suggested by Wengelin (Fig. 16).

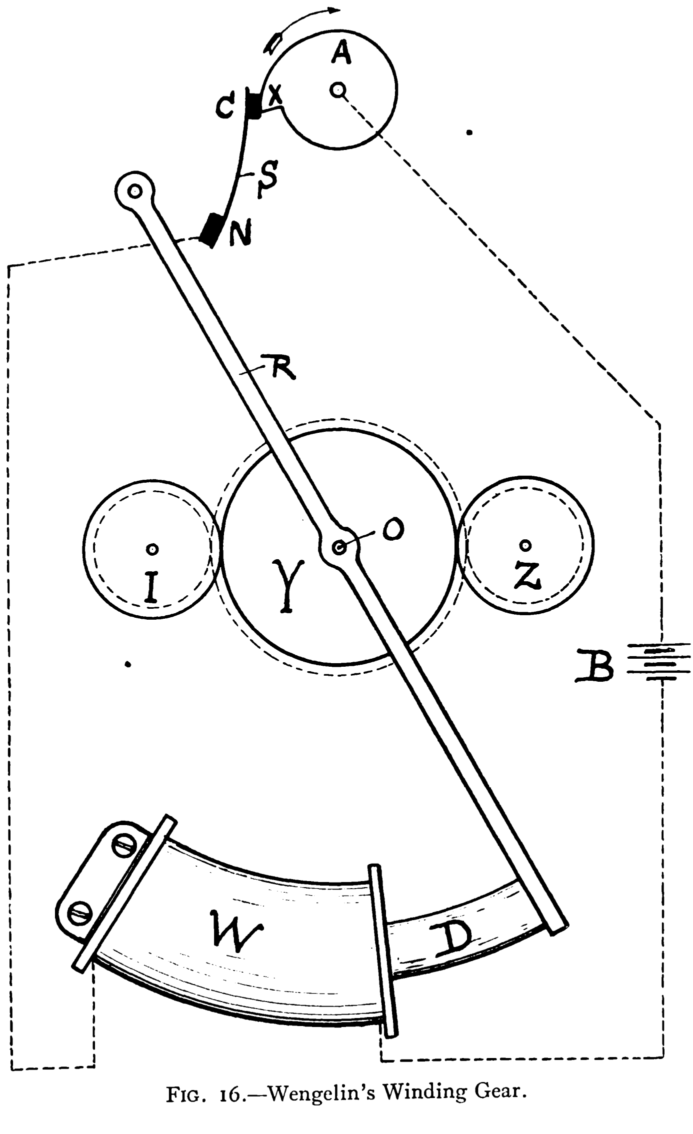


FIG. 16.—Wengelin's Winding Gear.

A wheel A rotating with the clockwork train has a projection X engaging a contact C mounted at the end of a long spring S, the lower end of which is rigidly attached to the bracket N. The rim of the wheel A is insulated, with the exception of the portion X. When contact takes place between X and C, the current from the battery B excites the solenoid W, attracting into its interior the iron core D which in turn operates the rod R, the latter being attached to the arbor O carrying the wheel Y. This wheel meshes into two more wheels Z and I. The partial turn of these wheels permits of the clock being wound up by a ratchet wheel and pawl. When the rod R has travelled a given distance, a pin projecting from the end of the rod depresses the spring S, resulting in the contact becoming broken at C, the rod R now returning to its normal position.

The number of times that the clock is wound in a given period will be decided by the number of revolutions completed by the wheel A in that period.

Steiger's Winding Gear.

The diagram (Fig. 17) shows the arrangement for winding the spring of the going train of a timepiece by means of an electric motor. An electric motor M of special design and having a permanent magnet for the production of the magnetic flux in place of the usual electro-magnet, has mounted on its spindle S a worm W, the latter gearing into a wormwheel R mounted on the winding arbor A.

Mounted on two other arbors of the going train of wheels are two cam-shaped discs D and E. These control the switching on and off of the current for operating the electric motor M. A special form of contact maker is necessary.

The spring contact O, one end of which is bent at L, is rigidly mounted on the strip J, a block of insulating material being inserted between the two at U. The strip J carries at one end a contact screw T, engaging a fellow contact H on the strip O; also an arm K which normally occupies the position shown in the diagram. During the rotation of the cam D the bent portion of the spring contact L enters the cavity of the former, and on completing the circuit between H and T, the motor M commences to run and winds up the spring of the clock through the worm gearing

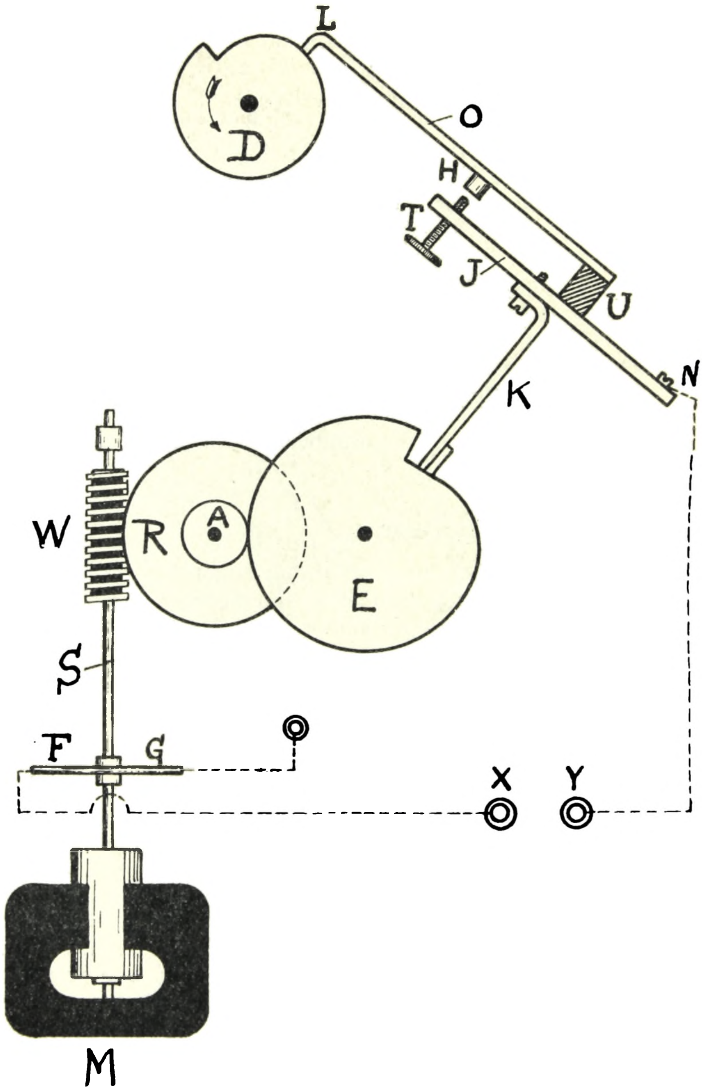


FIG. 17.—Steiger's Winding Gear.

To prevent the spring being overwound, the cam E slowly rotates and at the exact moment the rotated portion raises the end of the arm K. By this time the cam D has also rotated, and the end of the spring contact L has been raised. Things are so adjusted that the cam E has now made one complete turn, and the end of the arm K again drops into the cavity. This has the effect of breaking the circuit between the contacts T and H until such time as the cycle is repeated.

The current for operating the motor is taken into and out of the system by the terminals XY. One wire is taken from X to the motor brush F, the second brush G being connected to the clock frame, hence to the strip J, and on the completion of the contacts T and H by the wire N to the terminal Y.

Hackett's Winding Gear.

In Hackett's arrangement of winding gear (Fig. 18), the winding of the clock is effected by means of an electric motor automatically set in motion by the closing of a switch. The switch is operated by the clock weight when the latter has descended to a given point. A soft iron armature suspended from the bottom of the weight is attracted by a permanent magnet, causing a contact spring to become depressed, and thereby completing the circuit with the poles of the permanent magnet.

In Fig. 18 M is an electro-motor, and on its shaft is mounted a drum or pulley P along which are wound the coils of the rope R. The rope is then passed around the barrel W of the going train of the clock, and from its end is suspended the clock weight X. Attached to the base of the weight X is the case C containing a spring S, the upper end of which is fastened to the casing, whilst the lower end carries an iron armature N.

As the clock continues to go, the weight X will descend until the iron armature N comes within the vicinity of the permanent magnet O. Such being the case, the armature will be strongly attracted by the magnet O and the spring contact L will become depressed, resulting in the contact being completed between the spring L and the poles of the magnet O.

The circuit being now complete, the battery Y supplies current setting the motor M in motion, so that the weight X

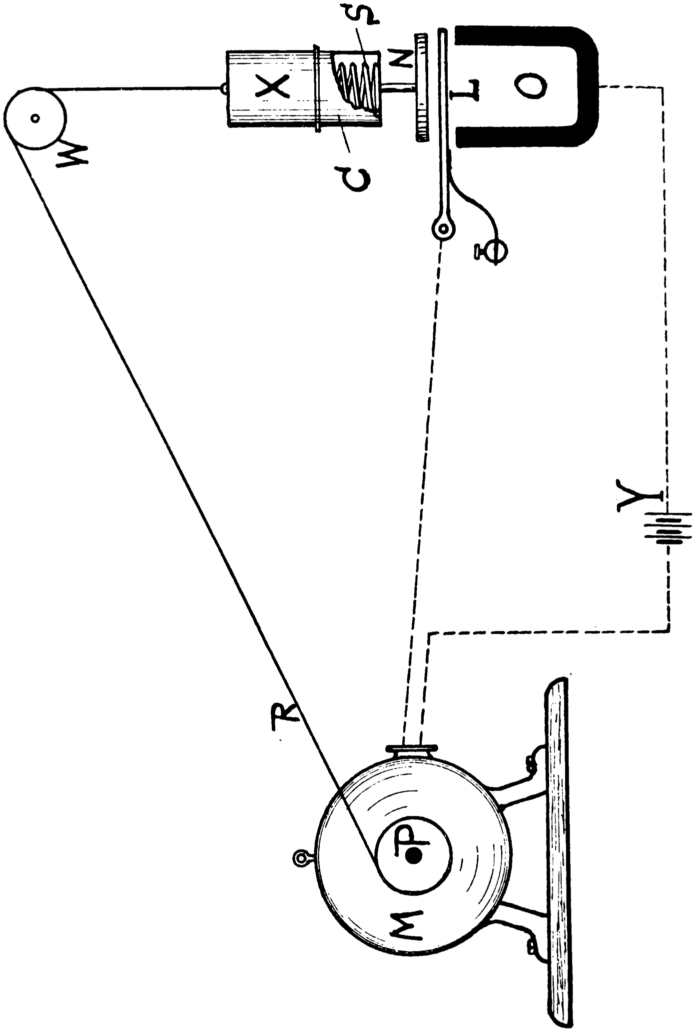


Fig. 18.—Hackett's Winding Gear.

will be again raised. But the iron armature N, since it is attached to the end of the spring S, does not move immediately with the rising weight, but only when the tension becomes too great for the attraction exerted by the magnet O. When the tension becomes too great, and the armature N leaves the poles of the magnet O, then the spring contact L returns to its normal position, and the motor stops on account of the circuit being broken between L and O.

Clocks Driven by a Weighted Arm Reset Electro-Magnetically.

Of clocks coming within this order, the following may be taken as typical examples :—

In 1895 Messrs Hope-Jones and Bowell were successful in obtaining a patent for improvements in and relating to clocks driven by the potential energy stored in a weighted arm, which on descending to a given point, has to be reset electro-magnetically; a projection on the arm completing an electric circuit causing an electro-magnet to become energised, which instantly attracts an armature pressing against the projection of the weighted arm and returns the latter to its normal or raised position.

Fig. 19 represents such a contrivance in which a weighted arm A pivoted at O, engages a ratchet wheel by means of a click. The ratchet wheel is loosely mounted on the arbor of the clock wheel, but connected to it by means of a spiral spring, so as to afford a means whereby the motion of the ratchet wheel may be communicated to the escapement wheel F, through the clock wheel and a pinion mounted on the arbor of the wheel F.

The pallets P, as in all clocks, engage alternately the teeth of the escapement wheel F, giving the pallets an oscillatory motion which is in turn communicated by the control rod L to the pendulum M.

Supposing the arm A to be in the position shown, then the weight W will tend to turn the ratchet wheel, and the spring mounted on the arbor O transmits the movement to the clock wheel, hence to the pinion mounted on the escapement wheel F. The length of the pendulum determines the number of vibrations that the former executes per minute, and directly governs the number of turns made by the escapement wheel F

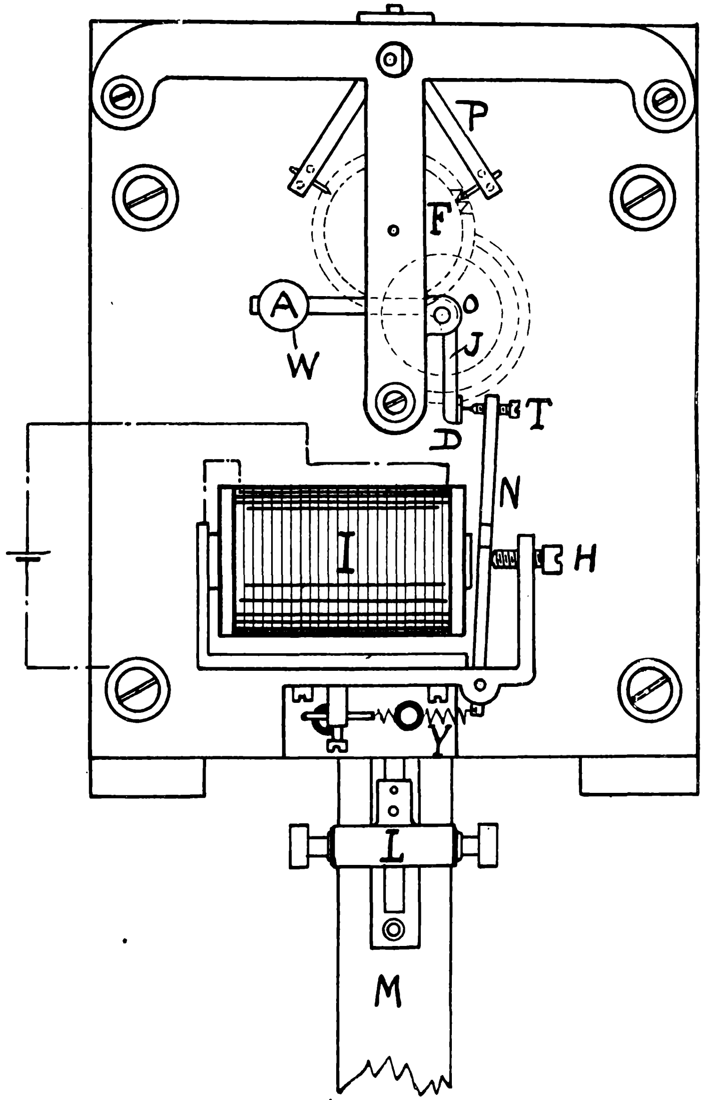


FIG. 19.—Clock Driven by Electrically Raised Weighted Arm.

in a given time. Again, the rate at which the wheel F revolves determines the rate at which the weighted arm descends.

On the descent of A the contact D on the projection J engages the contact screw T, thus closing the circuit containing the battery. The armature N is now attracted, and the screw T pressing on the projection J resets the arm A, the click picking up a number of teeth of the ratchet wheel.

The circuit is now broken between D and T, and the spring Y returns the armature N against the stop H. One end of the winding of the electro-magnet I is connected to the base of the clock, the remainder of the circuit being as shown. A detent drops into the teeth of the ratchet wheel, and prevents a reversal of the wheel when the arm is being reset.

The central idea in this design of clock is to retain only the two highest driven wheels of a clock movement, and to supply the motive power by means of a descending arm, thus dispensing with the usual spring or weight.

A slight difference in the mechanical arrangement is shown in Fig. 20. Here we have two weighted arms descending and reset alternately by means of two electro-magnets. By adopting this method the maintaining force is never removed entirely from the clock when an arm is being reset, but the preceding system is open to this objection.

In Fig. 20 the escapement wheel Z is dotted and the pendulum rod omitted. The principles involved when in operation are identical to those of the preceding system, therefore it is proposed only to describe the method of resetting the weighted arms, and to include the essential circuits for maintaining the system.

Two weighted arms AB are mounted on a common arbor C, each arm having a projection D for completing the contact with the armature levers FG when the arms have descended to their lowest positions. Mounted on the same arbor H are two ratchet wheels R, one being placed behind the other. Engaging into the ratchet wheels are two clicks, for communicating the driving force of the falling arms to the ratchet wheels, and then to the clockwork.

Supposing the arm A to have descended, and its projection D to complete the contact with the armature F, the armature will now be violently attracted by the electro-magnet N, and the arm will be reset, exerting a driving force on the wheel R. When the second arm B descends it will make contact with

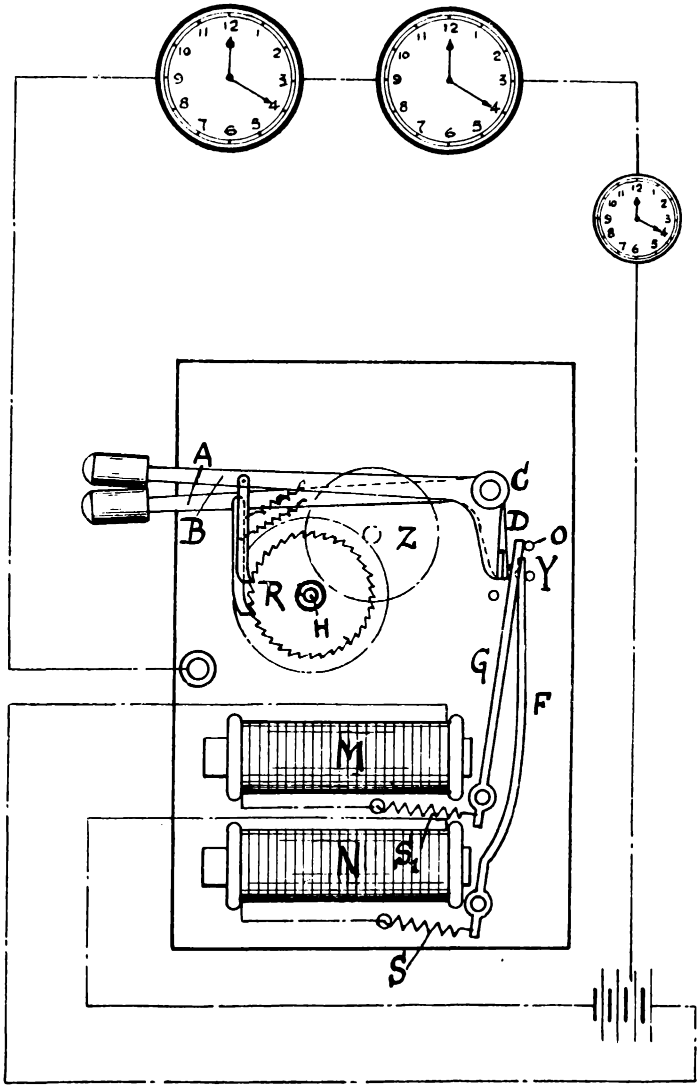


FIG. 20.—Electric Clock with Two Weighted Arms.

the armature G, and the electro-magnet M instantly resets the arm which now assists the arm A in driving the clock. The descending and alternate resetting of the arms AB renders the driving force supplied to the clock to be more uniform, and the maintaining force is never at any time completely removed from the ratchet wheels.

The spiral springs SS_1 return the armatures to their respective stops Y and O, also the smaller springs prevent the clicks from jumping out of the ratchet wheels. Advantage is taken of using the framework of the clock as an "earth," and a portion of the circuit is therefore taken to a screw as shown.

The electro-magnets are connected up in the manner shown: by this arrangement of wiring it is possible to operate either electro-magnet independently of the other.

A system of secondary clocks may be operated by being inserted in the circuit of the electro-magnets, the impulses being transmitted each time the arms are reset.

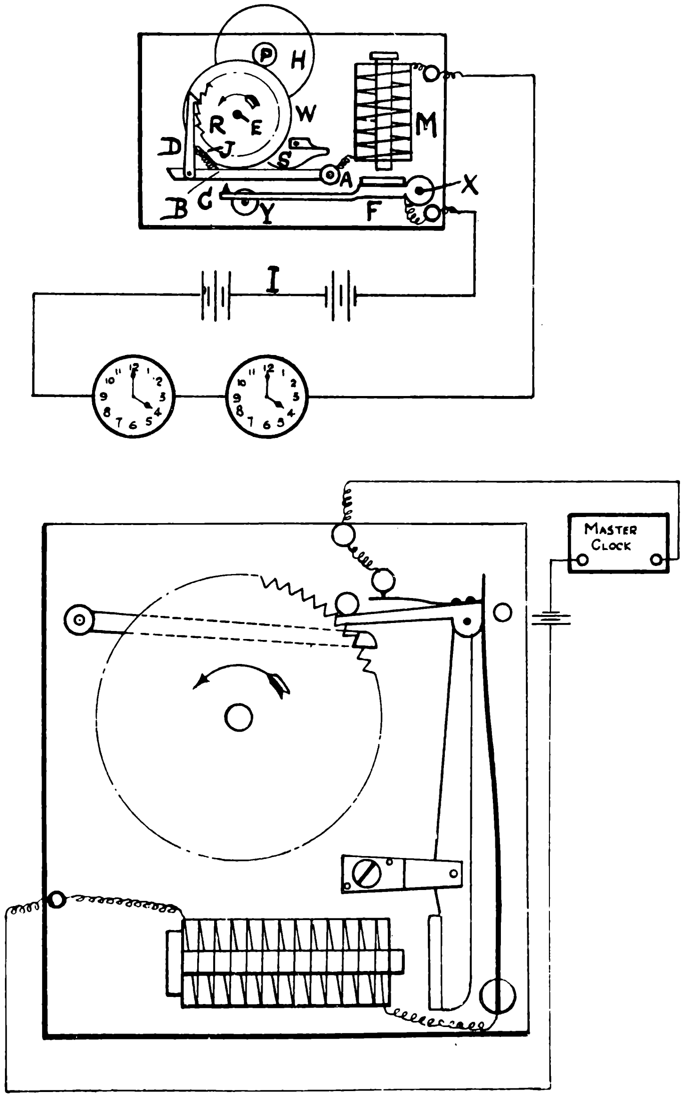
Another ingenious form of electrically wound clock is represented in Fig. 21, and patented by Messrs Hope-Jones and Bowell in 1897.

An arm B, pivoted at A, carries at its outer end the click D engaging the teeth of a ratchet wheel R, the latter being mounted on the arbor E, to which is also attached the wheel W driving the escapement wheel H through the pinion P. The electro-magnet M has set beneath its pole the arm F which is pivoted at X, the outer end of the arm having a contact C.

As the escapement wheel H revolves, its speed being regulated by a pendulum (omitted), the ratchet wheel R gradually turns in the direction of the arrow, and allows the arm B to descend slowly until it completes the circuit with the contact C. Immediately the circuit is complete, current flows from the battery I through the electro-magnet M, resulting in the arm F being attracted and the arm B consequently raised against the tension of the spring S.

The click D has now passed over a number of teeth of the ratchet wheel R, the spring J causing the click to engage a tooth of the wheel R and exert a driving force partly yielded by the depressed spring S.

It will be noted, however, that although the armature arm F has raised the arm B to the set position, no provision has been made for the opening of the battery circuit, whereby the armature F may be allowed to drop back on to the



FIGS. 21 and 21A.—Hope-Jones and Bowell's Electrically Wound Clock.

stop Y. To effect this purpose, one of the secondary clocks is equipped with a simple contact device which opens the circuit when an impulse is received from the primary clock. The cessation of current in the electro-magnet M allows the armature F to drop and to open the circuit between B and the contact C.

It would be rather out of place to describe here the mechanism of the secondary clock and its contact device, but a description will be given in the next chapter; suffice it to say that the mechanism is a "step by step movement."

Fig. 21A shows the *general arrangement of the master clock* and secondary clock.

Clocks having a weighted arm reset electro-magnetically, but released at regular intervals to impart an impulse to a pendulum will now receive our attention.

It is now proposed to discuss the third class of electrically wound clock, and under this heading come practically all the recent clock systems with which we are acquainted to-day.

Clocks operating on the principles about to be described are independent of variations in the strength of the current sources supplying energy to work the systems. They transmit impulses at regular intervals which are received by secondary dials: the latter contain only a few wheels and a pair of hands for registering the time on a dial plate. The secondary clocks of the various systems to be described will not be considered here, but will be discussed fully in a succeeding chapter.

Shepherd's Electric Clock.

In 1849 Charles Shepherd constructed an electric clock possessing many novel features, including an arrangement whereby a weighted arm could be raised electro-magnetically, and released later by the pendulum. The weighted arm was permitted to fall but a limited distance, but during its fall an impulse was imparted to the pendulum. The general design and the highly ingenious arrangement employed by Shepherd, which rendered it possible for his clocks to have a going rate superior to any of his predecessors, may be gathered from a perusal of Fig. 22.

In this diagram an attempt has been made to show as much detail as possible, so that a clear mental picture may be

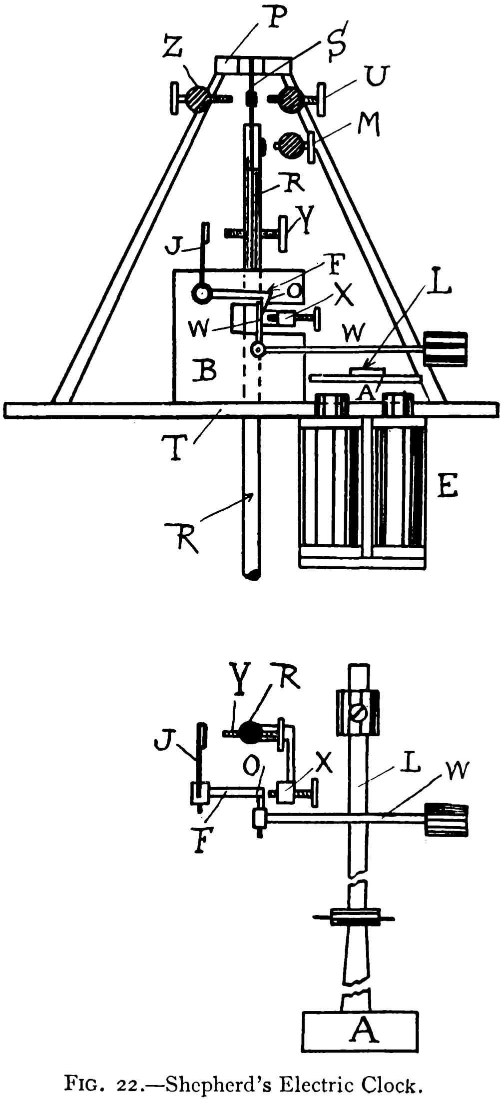


FIG. 22.—Shepherd's Electric Clock.

formed of Shepherd's electric master clock. The mechanism is mounted upon a table T. The end farthest removed has an A-shaped standard which supports the pendulum rod, the suspension spring S being attached rigidly to the projection P of the standard. The pendulum rod R extends downwards beneath the table and carries the pendulum "bob." Mounted slightly in front of the path of the pendulum's swing is the bracket B, upon which is mounted the weighted arm W, and a detent F for retaining the weighted arm when raised by the horizontally pivoted lever L. The front end of the lever L has attached to it at right angles to its length an iron armature A, the latter covering the poles of the electro-magnet E.

Mounted on each side of the A standard are insulating blocks with contact screws, one contact controlling the current for resetting the weighted arm. Two more contacts, one on either side of the pendulum, control the current for operating the secondary clocks. The vibrating pendulum by engaging these contacts, controls the current for the raising of the impulse arm and also for the working of the secondary clocks.

To receive the impulse from the weighted arm W the pendulum carries a small pallet X on to which the arm W falls: the latter is held in its set or raised position by the detent F.

Assuming such to be the case, an adjustable screw Y on the vibrating pendulum R engages the projection J of the detent F, causing the end O to be lifted, thus releasing the weighted arm W which falls on to the pallet X. The force of impact between the arm and the pallet imparts an impulse to the pendulum, and the latter commences its return swing. At the end of the swing of the pendulum the contact screw M, by engaging a fellow contact on the upper portion of the pendulum rod, completes the electric circuit for energising the electro-magnet E.

The electro-magnet E now attracting the armature A will cause the remote end of the lever L to be raised, causing the weighted arm W to be thrown back into its normal position and held there by the detent F. The next swing of the pendulum again lifts the detent, releasing the arm W to impart a fresh impulse. The duration of the impulse lasts until the arm W moving with the pallet X is arrested by the lever L.

For controlling the current for the operation of the secondary clocks, the contact screws Z and U mounted on

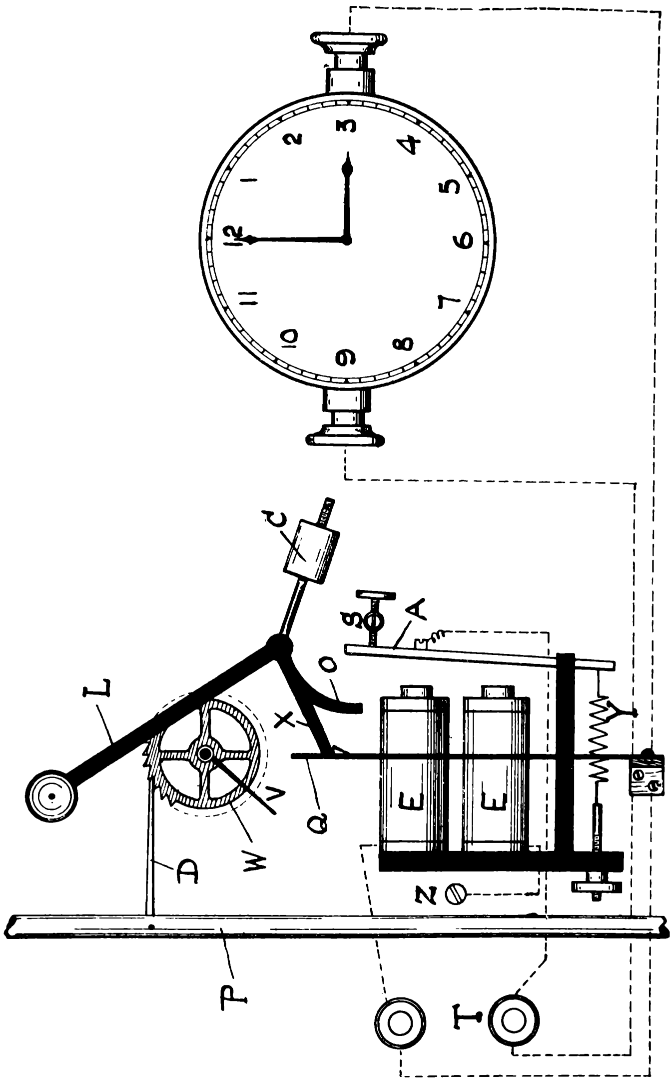


FIG. 23.—Stelje's Electric Master Clock.

either side of the pendulum rod will alternately engage the contacts on the pendulum rod. By the adoption of this method it is possible to employ two batteries for the working of the secondary clocks, thereby doing away with a current reverser, since the Shepherd secondary clock requires the direction of the current to become reversed at each impulse. It will be observed from the diagram that the impulses given to the pendulum are constant, and provided that the strength of the current energising the magnet E is strong enough to actuate the lever L, its varying strength does not affect the free vibration of the pendulum.

Stelje's Electric Clock.

The general arrangement of this system is shown in Fig. 23. The pendulum P carries a pawl D, which propels the toothed wheel W. A loaded gravity arm L is held in the set position by a detent Q, in which case the pin of the small arm X rests on a projection at the top of the detent.

Attached to the arbor of the wheel W is the vane V that pushes the detent to the left, thereby releasing the arm L prior to giving the impulse. As the arm falls, the projection O on coming into contact with the armature A closes the circuit. The attraction of the armature by the magnet E throws the arm back to its former position. The spring Y returns the armature to the stop S.

The circuits are clearly shown, the magnet being insulated from the base. The screw Z forms the "earth," also one of the wires from the terminals T is taken direct to the armature and made fast under a small screw. To counterbalance the weight of the small arm XO, a small counterweight C is introduced.

Hope-Jones and Bowell's Electric Master Clock.

Messrs Hope-Jones and Bowell patented in the year 1895 a number of electric clock devices, and in Fig. 24 is shown an arrangement for maintaining the vibration of a pendulum by means of two gravity arms situated on either side of the pendulum rod. The pendulum automatically switches on and off the current at the correct instant to either raise or release the gravity arms. The latter in their descent impart an impulse to the pendulum.

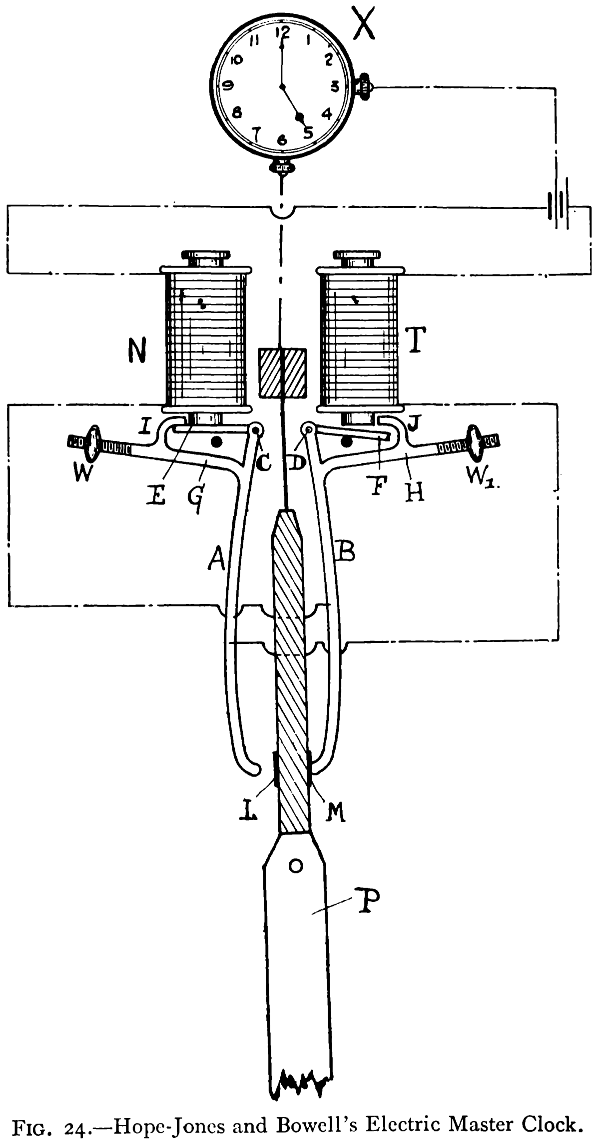


FIG. 24.—Hope-Jones and Bowell's Electric Master Clock.

Referring to Fig. 24, it will be observed that the two gravity arms A and B are pivoted at C and D; they are also provided with loose armatures E and F. The gravity arms have projections G and H, with hooks IJ extending upwards, while the ends are threaded and provided with balance weights W and W_1.

Attached to the pendulum rod are two contacts L and M, which engage the ends of the gravity arms A and B. The upper portion of the pendulum rod P is of metal, and forms part of the electrical circuit.

Supposing the pendulum to be swinging from right to left and the gravity arm B following the former, then the contact of B with M will allow the current to flow by the paths shown, and the electro-magnet N will securely hold the armature E, and incidentally the gravity arm A will be withdrawn to the left by the engagement of the armature E with the hook I.

The vibrating pendulum now passes the vertical, and the falling arm B will be prevented from following the pendulum beyond this point by the hook J being arrested by the armature F. Immediately on the cessation of the current in the electro-magnet N, the armature E is released and the gravity arm A in falling imparts an impulse to the pendulum P. At the same time the contact L engages the end of the arm A, and the electro-magnet T now becomes energised.

On the return of the pendulum the contact between L and A becomes broken in precisely the same way as it did in the case of the arm B, and the raised arm B descends and gives the pendulum an impulse. Continuing its vibration from side to side, the pendulum completes and opens the contact with the two gravity arms A and B, thereby permitting the arms to be reset and awaiting the return of the pendulum for the reception of the necessary impulse.

A secondary clock may be included in the circuit at X. The wiring of the circuits for the alternate excitation of the electro-magnets L and N will be as shown, the pendulum suspension forming part of the circuit.

"The Standard Time" System.

In this successful system a master clock of novel construction is employed to transmit electric impulses to a network of electric impulse dials, which are of the simplest construction and not likely to become deranged. Fig. 25 shows the mechanical details of the master clock used in connection with this system. It will be observed that a crutch rod L is the medium by which the pendulum receives its impulses. Pivoted on either side of the pendulum rod and its crutch rod L are two arms A and B. The former occupies the position shown, whilst B is held in a raised position by a spring catch C. Attached to the vibrating crutch rod L is the gravity pawl P, which turns the count wheel W one tooth forward every alternate swing of the pendulum.

Matters are so arranged that the count wheel W revolves once in half a minute, and during its rotation it causes the cross arm D, mounted on the count wheel arbor, to engage and depress the end of the release lever E. The free end of the lever E is hooked, and instantly engages the pin of the crutch rod R.

On the return swing of the pendulum to the right it causes the crutch rod R to withdraw the arm A, breaking the circuit at F which is normally complete.

At the maximum point of the pendulum's vibration the spring catch C is engaged by the end of the release lever E, and the arm is now free to impart an impulse to the crutch rod L; but at the same time the break contact X is closed (short-circuiting the clock circuit). The weight of this arm imparts the necessary power to keep the pendulum vibrating.

On the following swing of the pendulum the circuit is completed at the "make contact" F, and the electro-magnet M is energised, which instantly attracts the armature V attached to the arm B. This results in the arm B being thrown back into its former, or set position, ready for imparting the next impulse to the pendulum, also the electrical circuit is broken at X. By this time the cross arm D mounted on the arbor of the count wheel W is past the point of release action, and the pendulum swings freely for the next half-minute, when the release lever E is again depressed and the arm A is caught by the crutch rod L.

In arranging the circuit the secondary clocks are connected to the terminals S and T, while the battery wires are connected to the terminals K and I. In addition to the actuation of a system of secondary dials by a master clock or transmitter, The Standard Time Co. have devised an apparatus for operating bells or a "hooter" at any desired five-minute points in the twenty-four hours. The master clock

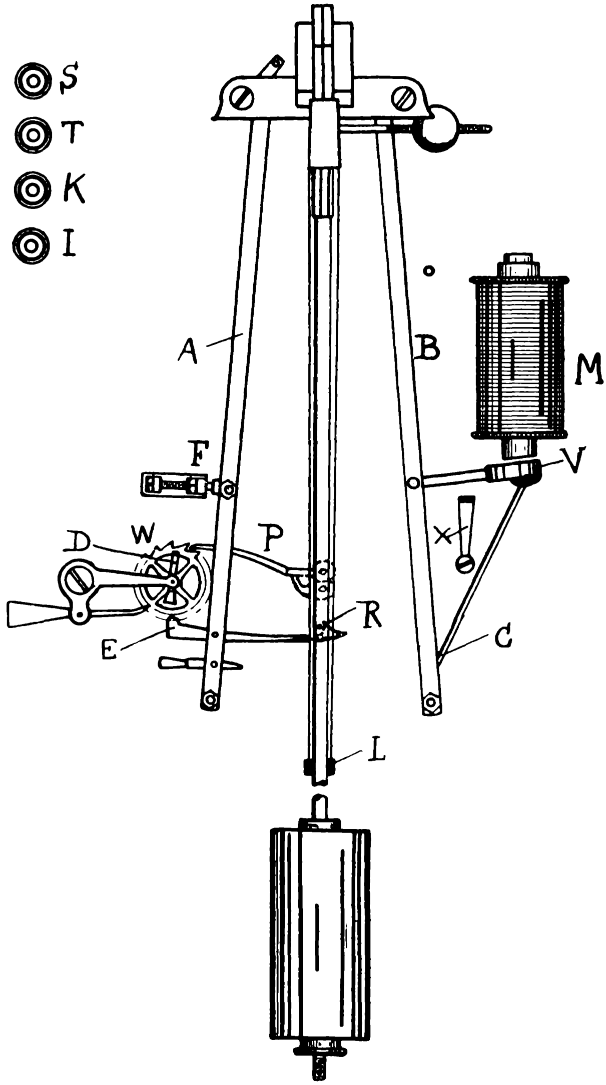


FIG. 25.—Electric Master Clock for "The Standard Time" System.

movement of this system is neatly fitted into a wooden case of pleasing design, and is equipped with a pendulum beating either "seconds" or "three-quarter seconds." If desired, the pendulum is accurately compensated.

Lowne's Electric Master Clock.

Messrs Lowne, of Catford, have long been manufacturing a highly reliable system of electric clocks. The master clock of the system is shown in Fig. 26.

The maintaining power of the "Lowne" master clock is a strong spring rewound at intervals by electrical agency. A specially shaped crutch lever L having various projections at its upper end is pivoted at P. The projection A carries at its outer end a pawl B for actuating the ratchet wheel R, and at every half-minute the arm C causes the contacts DE to be completed, resulting in the armature lever F being drawn down by the electro-magnet G. The circuit is, however, broken by the opening of the contacts H and I just before the armature F touches the poles of the magnet G. The attracted armature, however, is held in that position by the pin J of the pivoted member K, the pin running up the inclined portion at the extremity of F, and then moving a short distance inwards, thus locking the lever F.

On the return of the pendulum the crutch L, carrying the finger M, causes the end V of the member K to become depressed, thus releasing the armature lever F, which is instantly thrust upwards by the depressed spring O. The impulse pallet Q of the crutch normally enters the stirrup T of the armature lever, so that when L is thrust upwards the stirrup T engages the end of the pallet Q, and an impulse is imparted to the crutch, hence the pendulum. The next half-minute the cycle is repeated by the contacts DE being closed, and the armature lever F drawn down resets the impulse spring O.

Pivoted to the armature lever F is a small rod W carrying at its lower end a pin X which engages into a disc Y, a small portion of the disc being cut away so that it may turn a small distance in either direction before being arrested by the pin X. The disc Y is in positive connection with a heavier disc Z, which governs the movement of the lever W and regulates the speed of the armature. To prevent the back-turning of the ratchet wheel R a click N is introduced.

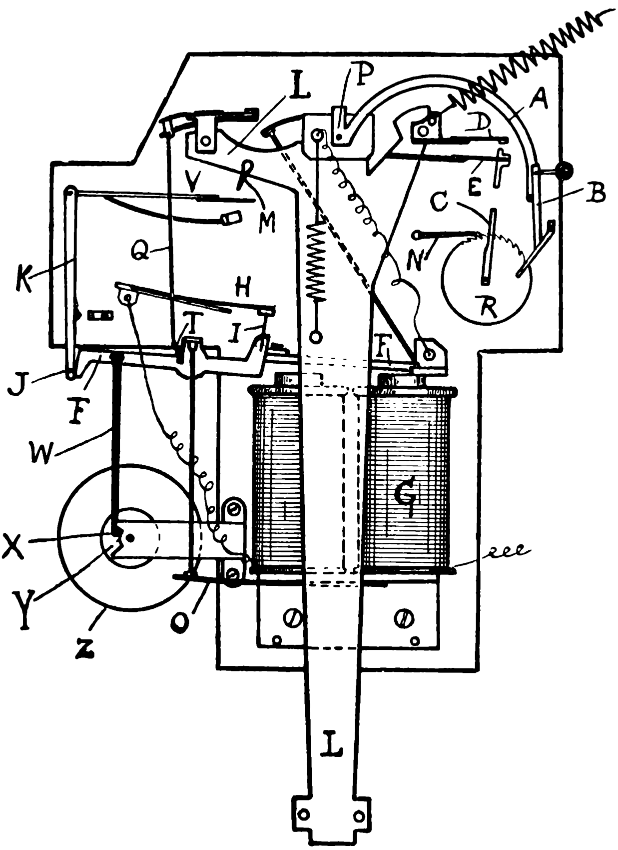


FIG. 26.—The Lowne Electric Master Clock.

The "Synchronome" System.

This is one of the earliest of the present-day electric clock arrangements, being introduced by Mr F. Hope-Jones, M.I.E.E., in 1895, and is now known the world over. In principle it is another example of a pendulum switch, the vibration of which is maintained by the impulses imparted by a falling gravity arm.

The gravity arm A (Fig. 27), of L formation, is pivoted at V, and normally assumes a horizontal position, being retained in that position by a spring catch. A roller B mounted on the end of the gravity arm A, when released by the spring catch C, runs down the impulse face of the pallet P attached to the pendulum rod R. A count wheel W, propelled by a pawl T from the pendulum R, has attached to its arbor a light vane V_1, which, on rotating with the count wheel W, pulls aside the lower portion of the spring catch C, and then the arm A freely falls and the roller B drops on to the pallet P.

The pendulum vibrating under the influence of the gravity arm A, the latter continues to follow the pallet until at a point of the arc of vibration the projection J of the arm A engages the contact E, closing the circuit with the armature F of the electro-magnet M. The attraction of the armature F throws the gravity arm A back on to its catch C, and the armature is returned by the agency of the spring S. The movement of the armature F is limited by the adjustable screws X and Y. A detent H ensures that the count wheel W shall not turn in the reverse direction when the hook T is picking up a fresh tooth of the wheel W.

In this system the impulse arm A is released each half-minute, and the current exciting the electro-magnet M passes through the external circuit in which are included the secondary clocks N_1. By adopting this arrangement the current necessary for operating the clocks is very little indeed, and the contact between the arm A and the armature contact E only lasts one-seventeenth of a second. It will be evident that only a small amount of current flows through the circuit at each impulse.

The external circuit may have any number of secondary clocks connected up in "series," which is the form of wiring most general. Cases exist where as many as 250 clocks are connected in "series" and operated from one master clock.

The great objection, however, to the adoption of this system of wiring is, should the circuit fail to transmit an impulse, then the time is lost by all the secondary clocks. Again, a breakdown of the circuit in any one of the secondary clocks results in the whole system becoming inoperative, but fortunately such cases of failure as cited are very rare. If desired an automatic cut-out may be used.

Batteries of fairly constant voltage, such as Leclanché cells

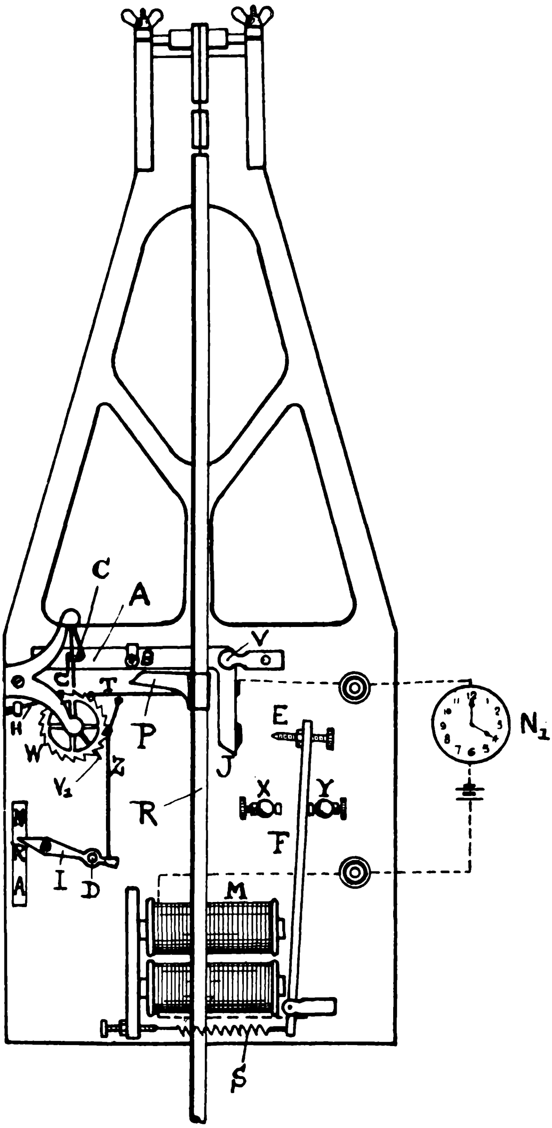


FIG. 27.—The "Synchronome" Electric Master Clock.

or other good forms of low voltage cells, yield good results when used in conjunction with master clocks of the type in which a weighted or gravity arm is raised to a given position, and then retained either by a spring catch or detent.

The paramount advantage of all master clocks in which the pendulum is kept vibrating by a mechanical arrangement operating on the principle previously described, is the absence of interference on the pendulum's vibration due to the variation in current strength supplied by the battery. As long as the source of current is sufficient to energise the electro-magnet M and reset the gravity arm A, the clock continues to function correctly. Should the current, however, at any time become reduced to the extent that the electro-magnet M is unable to raise and reset the gravity arm, then the pendulum will engage the arm on the return swing and assist the electro-magnet M in completing its work. In the event of the above state of affairs arising, an electric bell or lamp may be included in the circuit to give warning of the impending failure of the source of current.

The "Synchronome" Co. have provided in the master clock or time transmitter a novel arrangement, whereby the secondary dials may be readily set to time by the movement of a small lever. The movement of the latter has the effect of either retarding or accelerating the progression of the hands of the secondary dials.

The arrangement consists of a movable lever Z attached to the lower extremity of an index I, which is capable of rotation about the point D.

Now, suppose the index I is set at R (retard); the hook T is now raised and fails to propel the count wheel W.

The gravity arm A is thus prevented from falling, since it is not released through the spring catch being withdrawn by the vane V_1 of the count wheel W. This results in no impulse being given to the pendulum, neither do the secondary dials receive an impulse. This action arrests the hands of the secondary dials. To accelerate the hands of the secondary dials the index I is set at A (accelerate), thus enabling the hook T to release the gravity arm at every alternate swing of the pendulum. The hands of the dials in this instance will be advanced at the rate of half a minute each time the gravity dial is released. With this arrangement the system of secondary arms is under perfect and easy control from the master clock.

A remarkable improvement has recently been made in the design of the master clock by the addition of a crutch lever to engage the pendulum rod, which at once overcomes the difficulty experienced in the hanging of the pendulum and other fine adjustments that may have been previously necessary.

If the "Synchronome" master clock is equipped with an "Invar" compensated pendulum, the time-keeping qualities of the clock leave nothing to be desired.

"Palmer's" Master Clock.

Palmer, in 1902, patented an arrangement for an electric master clock of the form shown in Fig. 28.

A fairly heavy gravity arm B pivoted at V is retained in its set or normal position by a catch C, and released at regular intervals by a pin Q set in the face of the count wheel W, the latter being driven by a hook H attached to the pendulum rod R. When the gravity arm B has been released by the wheel W, the gravity arm falls on to the impulse pallet P, imparting an impulse to the pendulum. As the arm C still descends, a projection I carrying a screw S pushes aside the small catch L, immediately releasing a brass spring contact D; the contact screw being insulated from the spring.

This contact now engages a fellow contact X, and the circuit containing the electro-magnet M is now closed and current is taken from the battery N for the purpose of excitation. The armature E is now attracted, and the lower end of the pivoted armature presses on the inclined surface T and throws the arm A back to its set position. By this procedure the spring contact screw S ceases to depress the catch L, and the spring contact D is again depressed and locked by the upper end of the catch.

The number of impulses transmitted to the secondary clocks O will depend on the number of times that the gravity arm is reset in a given period. In this system, as in the preceding one, the duration of contact is short, and likewise the current used is very little at each resetting of the gravity arm.

The electrical circuit is clearly shown in the figure. One wire is permanently attached to the insulated contact screw D, and the base forms a path for the current flowing from the electro-magnet to the arm B, and hence through the contacts X and D, then eventually to the secondary dials O.

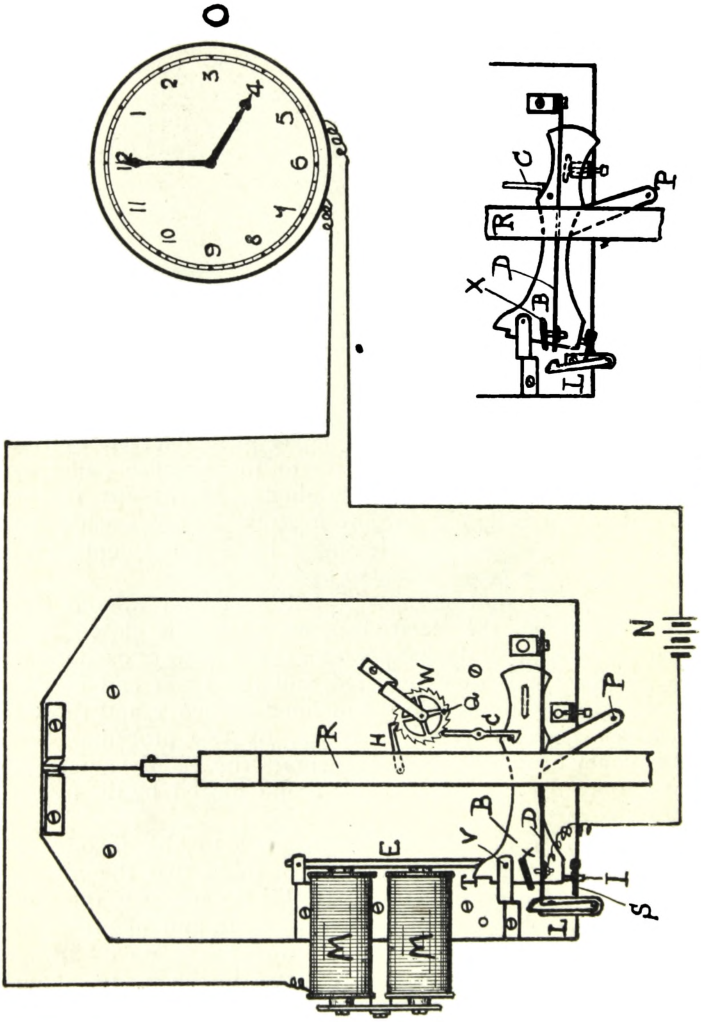


Fig. 28.—Palmer's Electric Master Clock.

The "Pulsynetic" System (Parsons and Ball).

Messrs Parsons and Ball were successful in perfecting and patenting a series of mechanical devices for maintaining the vibration of a pendulum. Since the mechanical details of devices described in the specification (No. 919—07) vary greatly, the principles of operation are, however, in many cases identical, and it is therefore intended to describe only the more promising and ingenious inventions of these illustrious inventors.

Reference to Fig. 29 will assist the reader in following more easily the construction and principles of working involved in one form of master clock covered by the above patent.

A gravity arm W pivoted at V carries at its outer end a plate P, the plate being insulated from the arm by a layer of insulating material G. The contact screw C situated at the lower end of P engages a contact D mounted on the pivoted armature A, also provided with an adjustable screw S. To return the armature A against its stop Z a spiral spring X is introduced. Now, supposing the pendulum R to swing to the left, a pin I attached to the detent E propels the count wheel T one tooth forward, and continues this performance until an abnormally deep cut tooth allows the pin I to enter sufficiently for the bent end F of the detent to rise and withdraw by the pin N the pivoted detent J.

When the upper portion J has been pulled to the left, the lower portion moves to the right and unlocks the gravity arm at O. The arm W now descends, and the roller Q runs down the face of the impulse pallet Y and supplies the requisite impulse to maintain the pendulum's vibration. The descent of the arm is arrested by the screw C completing the contact at D and allowing the electro-magnet M to become energised. On this taking place, the armature A is attracted and the gravity arm W is thrown up on to the catch O and retained there by the detent J. The screw S causes the contact to become broken, and arrests any further movement of the armature.

The circuit consists of the current source or battery and the secondary clocks. The base and metalwork of the clock forms part of the circuit, one end of the winding of the electro-magnet being connected to the plate P.

In another design of "master clock" the impulse is

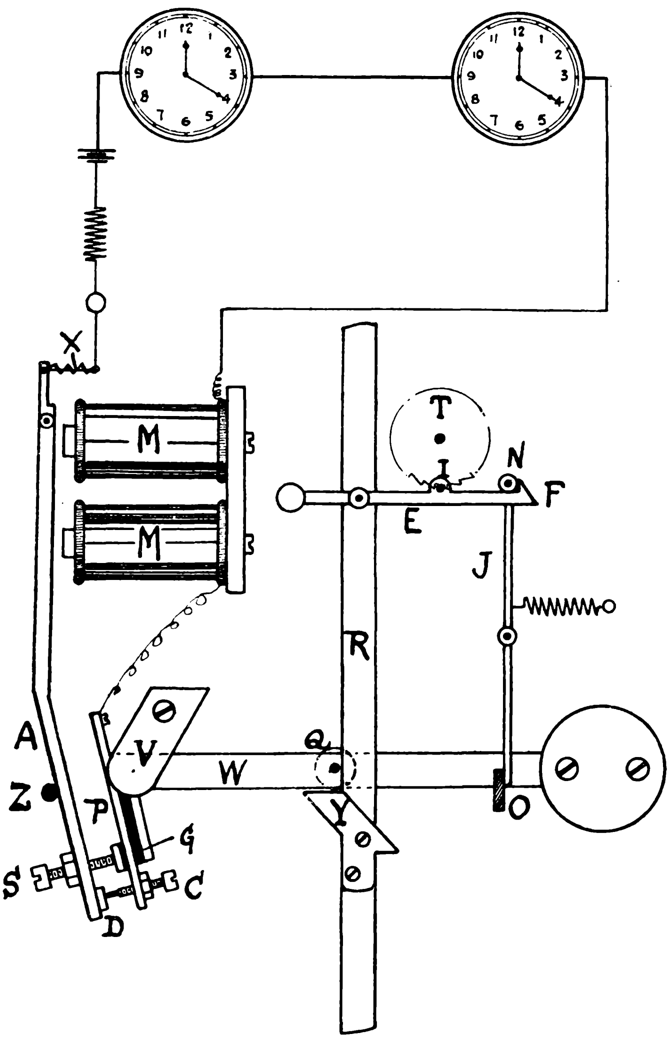


FIG. 29.—The " Pulsynetic " Electric Master Clock.

transmitted to the pendulum by the same type of gravity arm, but applied below the pendulum "bob." In this instance the detent locking the gravity arm is inverted, the hooked end supporting the raised gravity arm, the pin O being abandoned.

There is, however, another slight variation in the arrangement of the impulse pallet. When the impulse is applied above the "bob," as in the preceding Fig. 29, the pallet V will take the position shown, but must be reversed if the impulse is applied beneath the "bob."

The type of transmitter or master clock adopted and used extensively in connection with the "Pulsynetic" system is shown in Fig. 30, and differs somewhat in mechanical detail from the types just described. This transmitter embodies all the latest improvements that experience has proved to be necessary and essential for the accurate transmission of electrical impulses for the propulsion of secondary dials.

Departing somewhat from the arrangement for propelling the count wheel T by the detent E in Fig. 29, the detent A is pivoted at B, and propels the count wheel by a small projection C engaging the teeth of the wheel T. One tooth of the wheel T has an extra deeply cut tooth D into which the projection C sinks, and the end E of the detent becoming raised, pushes aside the spring S, releasing the gravity arm F from the catch L. Normally when C is oscillating with the pendulum rod P, the end E merely enters the looped portion V of the spring S without pushing it aside and releasing the arm F. Considering further the released arm F, it will be observed that the latter carries a small roller R, and when the arm commences to descend, the roller R runs down the inclined plane I of the pallet M and imparts an impulse to the pendulum. The click X falls into the teeth of the count wheel T and prevents its reversal whenever the projection C picks up a fresh tooth.

In Fig. 30 the resetting magnet and its appurtenances will not be considered, since this part of the mechanism remains unchanged, and it would only be a repetition of the method of resetting the gravity arm outlined when describing Fig. 29.

A rather novel method of advancing the secondary clocks in circuit with the "transmitter," should occasion demand, may be effected by holding down the cord Y attached to the detent A. The end E now depressed engages the spring S at N and pushing it aside, allows the arm F to fall, completing the

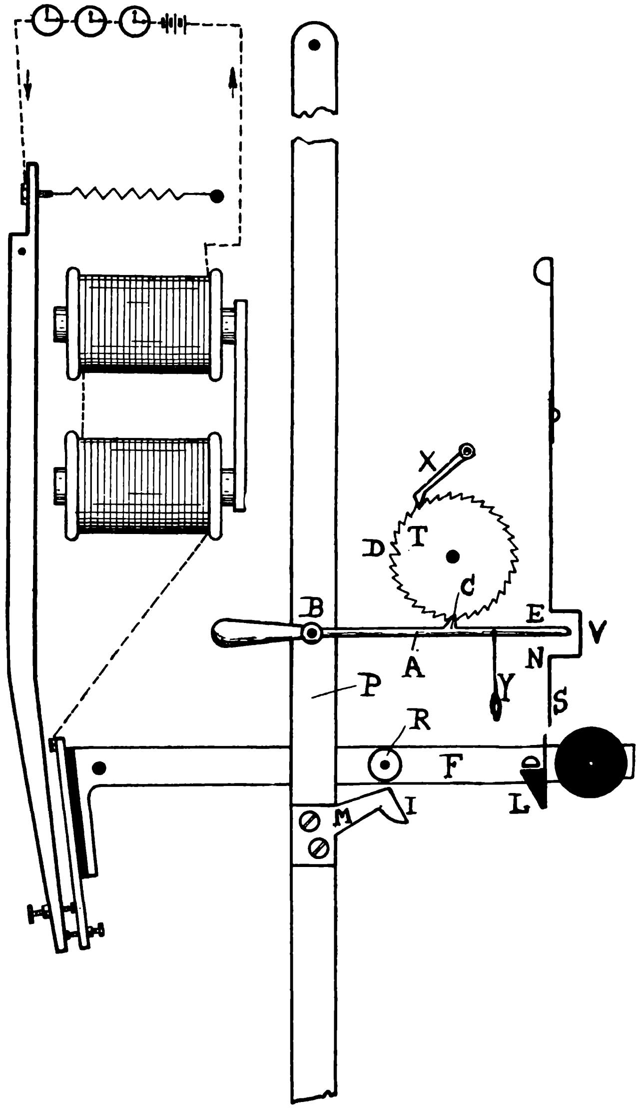


FIG. 30.—Standard "Pulsynetic" Electric Master Clock.

contact between the armature and plate contact of the gravity arm. An impulse is then sent out to the secondary clocks. By adopting this course the contact is completed every two seconds. Under ordinary conditions it is each half-minute.

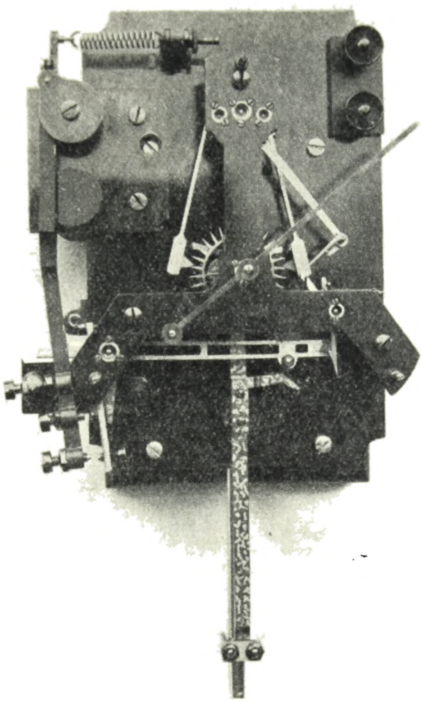


FIG. 31.—The "Thornbridge" Transmitter.

The secondary clocks are, of course, advanced at the rate of half a minute every two seconds, and continue to do so as long as the cord is held down.

Like the "Synchronome" system, the duration of contact between the armature and the gravity arm at each impulse is very short, and does not occupy more than one-thirtieth of a second.

The " Pulsynetic " system is now the registered trade name of the foregoing mechanisms, although formerly they were known as the " B.P." system, after the names of Ball and Parsons, the inventors.

The system has been marketed by Messrs Gent & Co., of Leicester, with great success and who have gained a world-wide reputation for their clocks.

The " Thornbridge " Transmitter.

Another very high-grade instrument manufactured by Messrs Gent is the " Pulsynetic Patent Thornbridge " impulse transmitter, which is equipped with a " Sinevar " pendulum, and guaranteed to keep time within two seconds per week.

By fitting the instrument with jewels to all actions and with a special pendulum having a fixed bob and regulator, the transmitter becomes an observatory instrument, and may be regulated to have a time rate of 0.5 second per week.

In this form of transmitter the gravity arm is released at every alternate swing of the pendulum, and even then with the minimum of friction at the point in the pendulum's vibration where its time-keeping is least disturbed. The electrical contact which takes place at each alternate swing of the pendulum is very suitable for the operation of the secondary dials, in which the seconds hand moves every two seconds.

The transmitter is so designed that the metalwork is bolted directly to the stonework of the observatory building, and the working parts and pendulum are covered by a glass cylinder, so that the pendulum vibrates under constant pressure or partial vacuum, and any barometric error is eliminated.

Walden's Master Clock.

An ingenious mechanical arrangement for maintaining the vibration of the pendulum P is shown in Fig. 32. The gravity arm W terminating in a sector S has a series of pins projecting from its face, enabling the pendulum to receive an impulse at every alternate swing; the gravity arm being reset at half-minute intervals. As the pendulum swings to the left with the crutch lever X, the pallet T pushes aside the detent D and

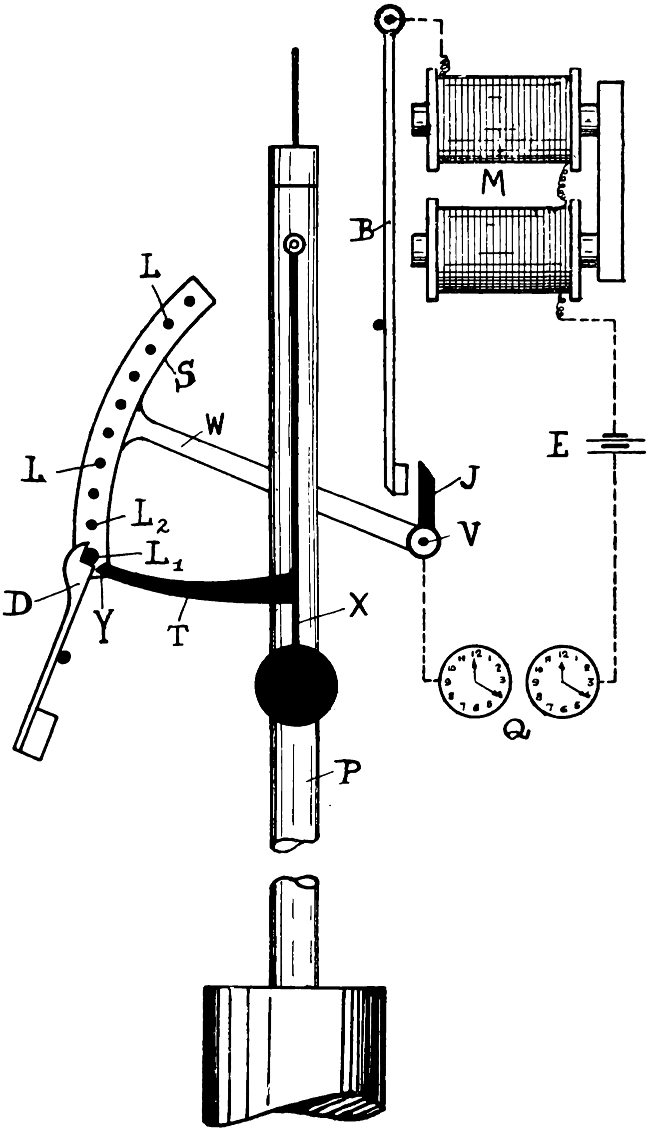


FIG. 32.—Walden's Electric Master Clock.

disengages the pin L_1. On the return swing an impulse is imparted to the pallet by the released gravity arm W through the medium of the pin L_2, situated immediately above it. During the interval that the impulse is being imparted the pin L_2 is sliding down the inclined face Y of the pallet T, and is finally arrested by the detent D until such time that the latter is again pushed aside for the reception of the next impulse by the pallet T.

The sector is usually provided with fifteen impulse pins, and when the last impulse has been imparted to the crutch lever X, the projection U at the pivoted end V of the arm W, now coming into contact with the armature B, completes the electrical circuit. The electro-magnet M attracting the armature throws the arm W back to its set or highest position. This position is represented in the diagram, the lowest pin L_1 of the sector being locked by the detent D. As there is naturally a rebound of the arm X on resetting, the pin L_1 is accordingly of larger diameter than the rest, so as to withstand the forces called into being when the arm is released by the armature B.

The external circuit, consisting of the secondary dials Q and battery E, is clearly shown and requires no further explanation. By employing a "seconds" pendulum and fifteen pins on the sector S, the clock will then transmit impulses at each half-minute to the secondary dials Q.

Murday's Transmitter.

In a primary clock the circuit by which a current is transmitted to secondary clocks is closed at regular intervals by a projection on the pendulum. Attached to a pivoted insulating block A are two arms XY, the ends of which rest on the notched cams CD (Fig. 33), carried by arbors of the time train, which may be driven by the pendulum acting on a ratchet wheel W. Attached to the insulating block A are two springs TU having cylindrical contact pins MN at the adjacent free ends, which lie near the path of a third pin O, carried by an arm Q on the pendulum. At the instant when the ends of the arms XY pass into the respective notches on the cams CD, the block A is tilted so that as the pendulum makes its next swing the pin O passes between the contacts MN and thus closes the circuit.

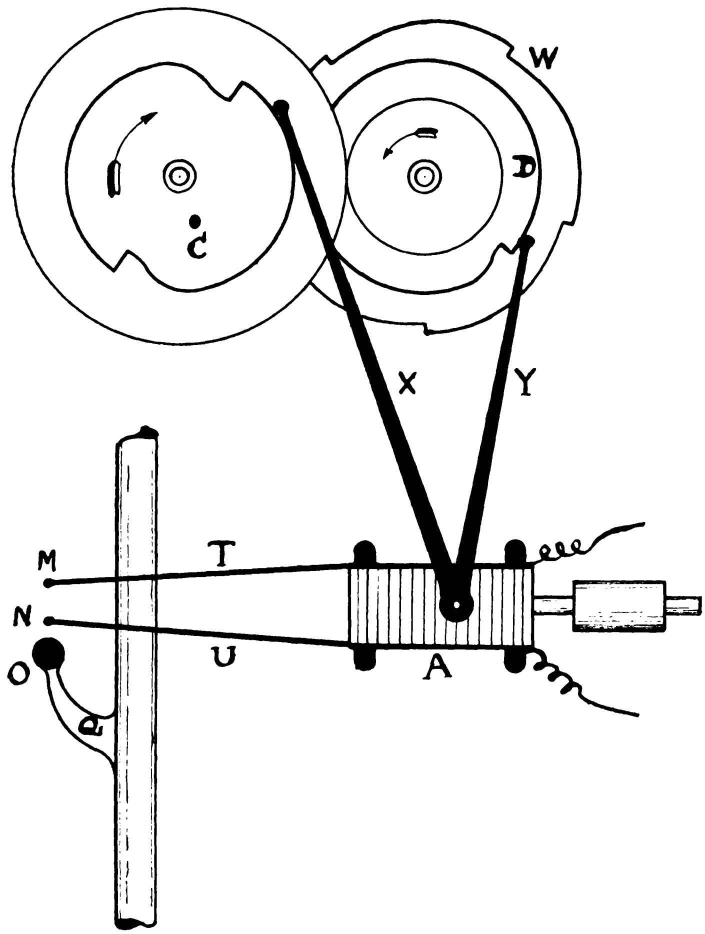


FIG. 33.—Murday's Electric Transmitter.

Immediately afterwards the pins MN are again raised clear of the pin O.

In a modification of the above method, Murday suggests that the contact device may be applied to any clock from which it is required to transmit a current at each swing of the pendulum. Such being the case, the levers or arms XY are then dispensed with and the block A is fixed.

If the clockwork is driven from the pendulum, two clicks with counterbalances attached to the pendulum engage the ratchet wheel W, so that the latter is alternately pulled and pushed around by the clicks as they oscillate with the pendulum.

The "Silectock" System.

The master clock controlling the secondary or receiving clocks of this system consists of a pendulum which occasionally receives electro-magnetic impulses. There are no violently moved parts in the master clock, and the impulses imparted to the pendulum are silent, but adequate to enable the clock to continue its duty of transmitting time impulses to the receiving mechanisms. The design is such that a pendulum rotates a count wheel, and when the pendulum moves to the left a click jumps over the teeth of the count wheel. On the return swing of the pendulum the click pulls the count wheel one tooth forward. The count wheel makes a complete revolution each half-minute.

For the purpose of closing the contacts and thereby transmitting an impulse to the receiving mechanism of the secondary clocks, one tooth of the count wheel is of abnormal depth, enabling the driving click to drop and engage a peculiar shaped member, which instantly depresses the contact springs of the secondary clock circuit. By this method sufficient pressure at the contact points of the springs does not deprive the pendulum of much power, although any energy withdrawn from the pendulum is later given back by the springs on the return swing of the pendulum. Two pairs of platinum contacts are provided, one pair for the clock circuit and the other pair for the shunt or short circuit, according to whether the clocks are actuated by a battery or from the electric light mains. The motion imparted to the contact springs in conjunction with the method of cutting out the shunt, except for the instant prior to breaking the circuit, results in sparkless action.

The pendulum receives the requisite energy from the current source by the " Hipp " device. A small trailer of the " Hipp " pattern is attached to the frame or crutch rod, and when the trailer depresses the notched block the circuit is closed, and the electro-magnet becoming energised, exerts a pull on the pendulum; resulting in the restoration of the pendulum's arc of vibration, at the same time allowing the trailer to pass freely across the block without depressing it. When the arc of vibration becomes reduced by a predetermined amount, the trailer again depresses the contact spring and the pendulum receives a fresh impulse. By this means the vibration of the pendulum and the accurate functioning of the master clock are assured.

The moving parts of the mechanism of the clock perform their duty so silently that no noise is heard when the system is in operation.

The " Silectock " master clock is manufactured in two sizes, and are fitted respectively with pendulums beating " half-seconds " and " full seconds." In both of the master clocks the workmanship is of the highest order. Jewelled pivots are provided, and the steel parts are carefully hardened and polished to resist wear.

The Silent Electric Clock Co. claim that the time rate of the small " half-seconds " master clock is marvellously accurate, and the mechanism is so simple as to render them easily erected by those who have never handled electric clocks. If desired, the pendulum rod can be supplied in special steel with negligible coefficient of expansion.

The " Silectock " system may be equipped with a battery-warning indicator; this gives an audible warning when the current falls below the working strength. Two forms of indicators are used: a small milliamperemeter which yields a reading at any half-minute by pressing a key switch, or a single-stroke bell may be introduced so as to give a blow at each half-minute.

CHAPTER V

ELECTRIC SECONDARY DIALS OR IMPULSE CLOCKS

IN this chapter we shall pass under review various mechanisms that have been devised, and of which many have been successfully applied for the conversion of the electric impulse received from the master clock into rotary motion for the actuation of the hands of the secondary clock. The mechanical details of such clocks are often of the simplest nature; in some only a ratchet wheel propelled step by step by an electro-magnet and the essential dial wheels are needed.

In reality a secondary clock is an arrangement for recording the number of impulses received in a given time, and by correctly proportioning the number of teeth on the wheels and pinions contained in the wheelwork. The impulses are computated into seconds, minutes, and hours, which may be read off the dial of the clock by the position assumed by the hands.

Clocks coming under this section are generally distinguished from other forms of electric clock mechanisms by being designated as dials, impulse clocks, secondary clocks, journeyman clocks, sympathetic clocks, or step by step movements.

It is scarcely possible to include in this chapter all the mechanisms suggested or used in the working of secondary clocks by the numerous inventors of the last few years. We may, however, mention the following as ranking amongst the most successful and ingenious.

Bain's Electric Clock.

The earliest secondary clock must be attributed to Alexander Bain, and was devised by its inventor to operate in conjunction with his master clock, which transmitted at every alternate swing of the pendulum an electric impulse. The electric impulse exciting momentary an electro-magnet, resulted in the attraction of an armature, to the lower extremity of which was

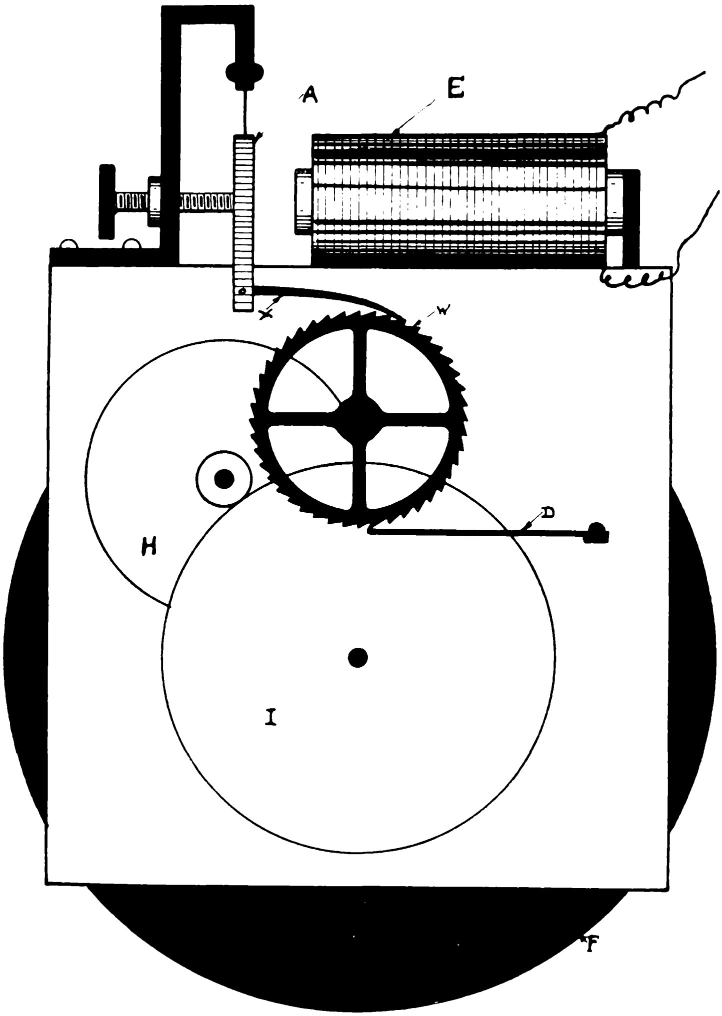


FIG. 34.—Bain's Electric Secondary Clock.

attached a pawl. The attracted armature caused the pawl to pass idly over one tooth of a ratchet wheel, and on the waning of the magnetism it was propelled one tooth forward by the armature, the latter and its pawl being returned to their normal position by the assistance of a spring.

If the ratchet wheel has sixty teeth and the pendulum of the master or transmitting clock is thirty-nine inches in length, it will then complete the contact sixty times in one minute, and the reception by the secondary clock of the sixty transmitted impulses will cause the ratchet wheel to rotate once in that period. By employing a simple train of wheelwork, the movement of the ratchet wheel becomes greatly reduced before it is communicated to the dial wheels actuating the hands of the clock.

Fig. 34 shows in full detail the arrangement adopted by Bain, and subsequently improved on by contemporary and later inventors.

An electro-magnet E suitably fixed has A for its armature, the upper end of which is attached to a standard by a stiff spring. The lower part of A carries a pin on which is pivoted the pawl X. The pawl X each time that the armature A is attracted by the current flowing around the electro-magnet E moves forward over one tooth of a ratchet wheel W. On the circuit becoming broken by the pendulum the electro-magnet E loses its magnetism. The armature A remàins no longer attracted, but falls back again under the tension of the spring; but in doing so the pawl draws the ratchet wheel W one tooth forward. The wheelwork H and I are so proportioned that the hands move forward at the correct rate. The detent D prevents the ratchet wheel revolving in the reverse direction, F represents the dial of the clock.

Shepherd's Secondary Clock.

Fig. 35 represents the essential features of the electro-magnetic clock employed by Shepherd in conjunction with his master clock, described in Chapter IV.

A large bar magnet M mounted on the vertical spindle S is free to oscillate in a horizontal plane between the poles of eight electro-magnets E. The electro-magnets are so wound that when excited, like poles face each other. The spindle S carries an arm A, the end of which is forked and engages the

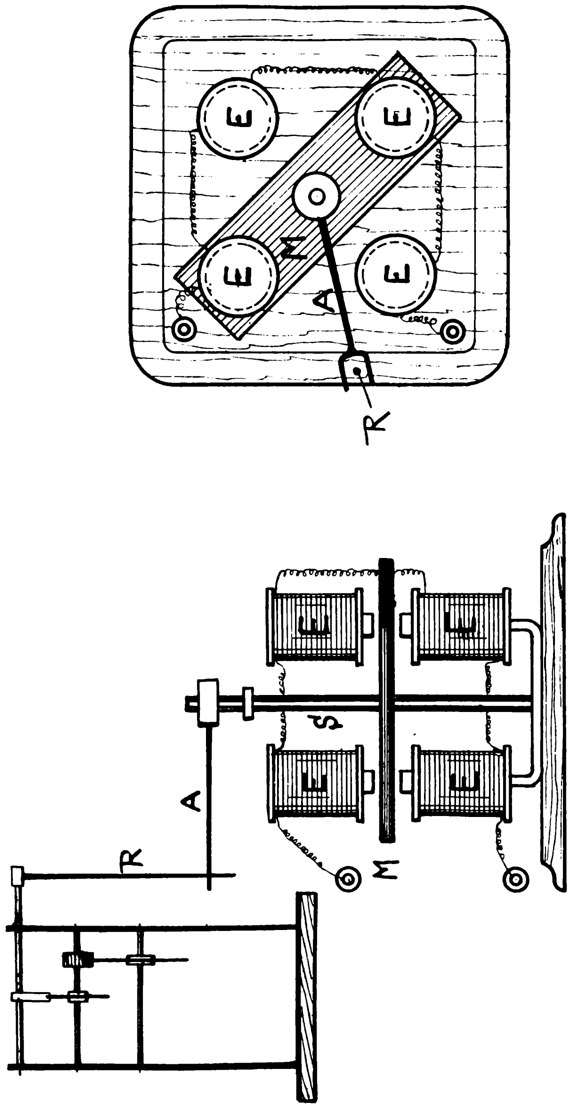


Fig. 35.—Shepherd's Electric Secondary Clock.

crutch rod R actuating the pallets. An escapement wheel receives a forward movement from the pallets, and as is customary in some systems, the hands are driven at the correct rate through a train of wheelwork.

The principle of the clock depends on the fundamental law of electro-magnetism, that when the direction of the flow of current is reversed in the electro-magnet E, the polarity also becomes reversed.

Continual reversal of the current flowing in the electro-magnets sets up a reaction between themselves and the bar magnet M, causing the latter to oscillate from side to side, moving the arm A with it. The oscillatory movement of the arm A moves the crutch rod R from side to side thus moving the pallets, which drive the teeth of the escapement wheel forward at each oscillation.

It will be observed, from Fig. 22, that the pendulum rod of the master clock is equipped with two sets of contacts for controlling the current from two batteries, and each excursion of the pendulum from one side to the other completes the circuit of one or other of the batteries. By this means it is thus possible to reverse the direction of the current flowing around the electro-magnets at each swing of the pendulum, and the reaction set up by the magnets tends to send the bar magnet M from one extreme to the other. Any movement of M is then communicated to R by the arm A, the movement of the bar magnet M being directly governed by the impulses transmitted from the master clock.

Stelje's Secondary Clock.

The essential details of this clock are shown in Fig. 36. An electro-magnet M receiving an impulse from the master clock attracts the armature V attached to the rod T. At the lower extremity of this rod is pivoted the pawl I for the driving of the ratchet wheel Z, the movement of the armature being adjusted by means of the screw E. The hands of the clock receive their motion from the dial wheels DW. There is no spring to return the armature to its normal position, but merely the weight of the moving parts are relied on to perform this office.

It will be noted that the ratchet wheel Z is propelled by the attraction of the armature V, which is opposed to usual practice, where it is generally arranged for the armature to drive the ratchet wheel assisted by a depressed spring when

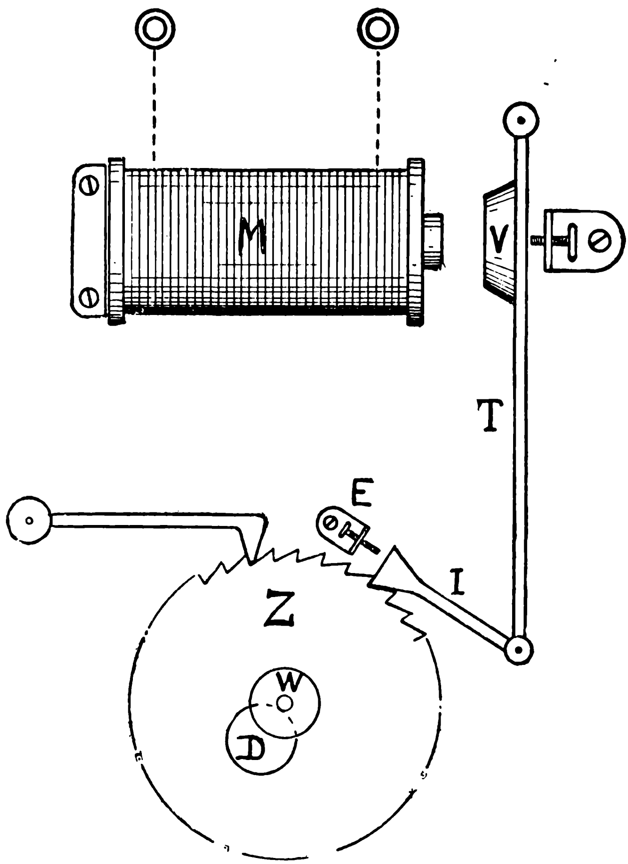


FIG. 36.—Stelje's Electric Secondary Clock.

returning to its normal position. Strictly speaking, the attraction of the armature by the electro-magnet depresses a spring, endowing it with potential energy, which it expends in driving the ratchet wheel forward on the release of the armature by the cessation of the magnetic force temporarily possessed by the electro-magnet.

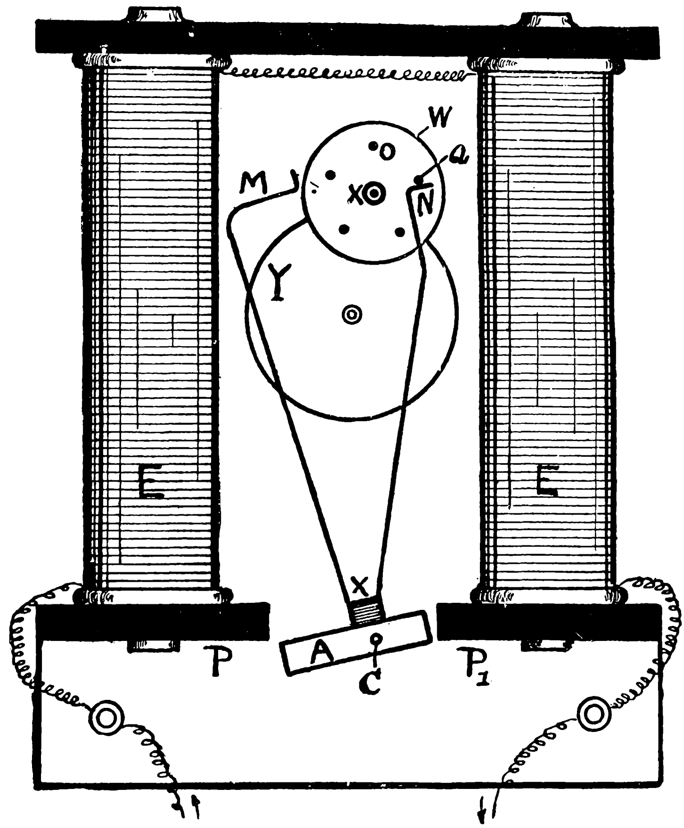


FIG. 37.—The Swift Electric Secondary Clock.

Swift's Electric Impulse Clock.

The "Swift" clock is of unusual design, and consists of a disc from the face of which project a series of pins, these being driven forward by specially shaped pallets receiving an oscillatory movement from an electro-magnet.

The specially designed electro-magnet E (Fig. 37) has its pole pieces at PP_1. Mounted in the magnetic gap is the armature which is pivoted at C. The armature A is not central, but pivoted a little to one side. The lug X carries two long pallets MN, their upper ends being specially shaped so that they engage the pins O projecting from the disc W. The armature A being attracted by the poles PP_1, the pallets MN oscillate and the shape of their ends is such that the disc W is driven forward whenever any of the pins in the disc are engaged.

Supposing that the electro-magnet attracts the armature A and moves the pallets to the right, M then engages and drives forward one of the pins through a certain angle, at the same time the pallet N unlocking the pin opposite, thus allowing M to perform its work. When the armature is released from the poles PP_1 it immediately drops the pallet. M ceases to drive the pin it previously engaged, whereas on the other hand the second pallet N is moving to the left and engages the pin Q. Again the disc is driven through a certain angle. It will be evident that the pallets MN drive the disc W forward by two distinct movements.

In the diagram five pins are shown, but this is decided by the number of impulses transmitted in a given period, and also by the ratio of the gearing employed in the clock. It will be noted that the pinion X mounted on the arbor of the disc W engages a larger wheel Y, and from the latter the dial wheels receive their motion. Swift suggests the use of a star wheel to replace the pin disc, also the introduction of a polarised armature between the pole pieces PP_1.

Bowell's Secondary Clock ("Silectock" System).

Mr G. B. Bowell, of The Silent Electric Clock Co., devised a novel method of propelling the hands of the secondary dial by the rotation of a cam-shaped armature, attracted alternately by an electro-magnet and then by a permanent magnet. Reference to Fig. 38 will assist the reader in grasping the principle involved in Bowell's mechanism. A cam-shaped armature A suitably mounted on an arbor rotates freely within four pole pieces NSEM.

The pole pieces NS have a horse-shoe magnet attached to them, the electro-magnet is fixed to the pole pieces EM. When in operation the electro-magnet creates a stronger mag-

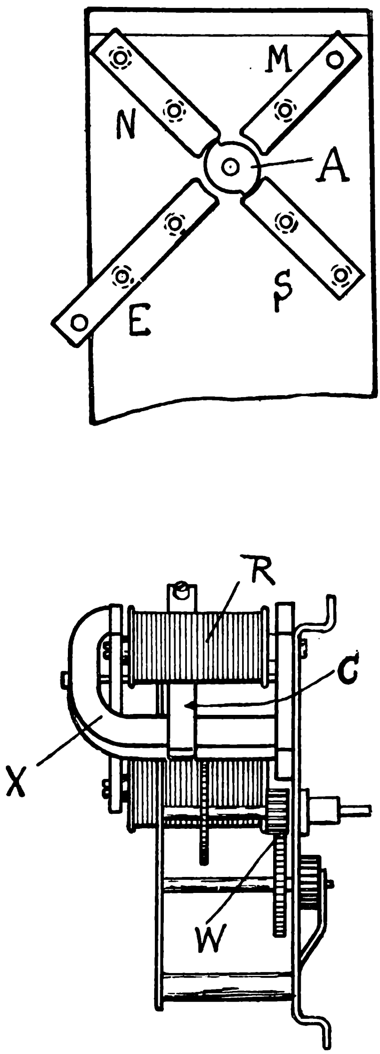


FIG. 38.—The "Silectock" Secondary Clock.

netic field than that of the permanent magnet, with the result that the cam-shaped portions of the armature are attracted and the armature takes up a new position within the poles E and M. The current now ceasing, the magnetic field set up between the pole pieces NS due to the permanent magnet becomes predominant, and immediately turns the armature from the position last assumed under the influence of the electro-magnet, so that the cam-shaped portions of the armature are now within the pole pieces NS. In other words, during each impulse the armature rotates through a quarter of a revolution by two distinct movements.

On the reception of the next impulse the electro-magnet overpowers the field set up between N and S and once more the armature is attracted by the poles EM. The magnetic effect now vanishing from the electro-magnet, the magnetic field between NS compels the armature A to come within its influence.

The permanent magnet X has an adjustable keeper C to control the intensity of the field between NS, whilst R represents the electro-magnet which is fixed at right angles to the permanent magnet.

The hands of the clock receive their motion through an efficient train of wheelwork W. The characteristic of this clock is the absolute silence with which it operates, there being no levers or driving clicks, consequently the usual ratchet wheel is not required. When in operation the armature moves quietly from one set of poles to the next set of poles; also the armature is locked in all positions by the magnetic field, and detents can thus be dispensed with.

The "Silectock" Turret Receiving Mechanism.

The Silent Electric Clock Co. have introduced five different standard forms of receiving mechanisms for large turret clocks.

The movement is designed to withstand hard work, and since the hands of such clocks are exposed to the force of the wind and snow, the power required at intervals to drive them against such forces must be very great, and to this end special worm gearing has been introduced for the purpose.

In some instances it has been found convenient to mount the receiving mechanism actuating the hands of the clock and the pendulum of the master clock on the same base, the whole being erected behind the dial. This arrangement is specially suitable for clock chambers of moderate size, where the mechanism can be attended to with ease.

In a further modification, patented in 1911, two armatures are employed placed at right angles on an arbor, each armature operating alternatively. An electro-magnet actuates one armature, while the second armature is influenced by a permanent magnet. With this arrangement the arbor carrying the armatures will progress by two distinct movements of ninety degrees whenever the circuit is completed or broken. The magnets with their armatures and appurtenances are situated at either end of the arbor, a worm being centrally mounted on the arbor gearing into a wormwheel from which the hands receive their motion. By paying special attention to the shape of the pole pieces of the magnets a uniform turning movement is possible.

To demagnetise the pole pieces of the permanent magnet

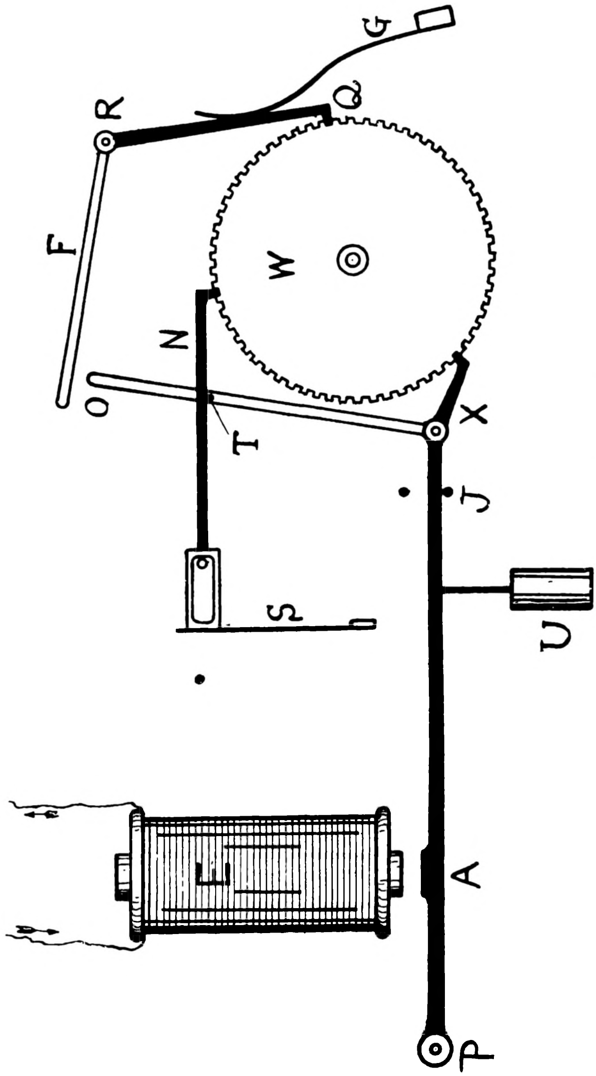


FIG. 39.—Lord Grimthorpe's Electric Secondary Clock.

a small solenoid is inserted in series with the electro-magnet, and becomes active whenever the latter is energised.

Lord Grimthorpe's Electric Clock.

When the electro-magnet E (Fig. 39) attracts the armature lever A pivoted at P, it causes a peculiarly shaped click X to become raised and to pass over a tooth of the ratchet wheel W, which has 120 square cut teeth. The upper portion of the click X has a pin T projecting from its face and lifts the detent N out of the wheel W. The end of the detent is slotted and is thereby permitted to move forward slightly under the influence of the spring S. The travel of the detent is, however, limited since it only rests on the top of the tooth. A second detent F pivoted at R, has its tail portion raised by the end O of the click X, so that the portion Q of the detent enters and locks the ratchet wheel. By this action on the part of the raised lever A it is impossible for the ratchet wheel W to move, and any movement of the wheel can only be effected by the fall of the lever A. Supposing now that the impulse which has raised the lever A ceases, then the latter returns to its normal position on to the pin J assisted by the weight U. The portion X of the click attached to the lever A will engage into the tooth of the wheel W and propel it forward. Immediately the detent N will drop into the approaching notch of the wheel, and the end Q of the detent F will slightly rise against the tension of the spring G to allow the tooth of the wheel to pass.

When this change has taken place it will be observed from Fig. 39, that the detent N has now been pushed forward depressing the spring S; but it is impossible to move the wheel forward. Likewise it is impossible to move the wheel backward, since it is locked in this direction by the portion Q of the detent F. This movement is highly suitable for turret clocks since the hands of the clock are locked when the clock is inactive, and even then it is impossible for the wind or other forces to move the hands through more than the exact angle because of the locking detent N.

The magnet E may be energised at regular intervals from a standard or master clock.

The "Synchronome" Secondary Clock.

This clock consists of a large ratchet wheel of 120 teeth mounted on an arbor; this also carries the minute hand of the clock from which the dial wheels are driven. The teeth of the ratchet wheel are of peculiar shape and resemble somewhat an inverted Λ.

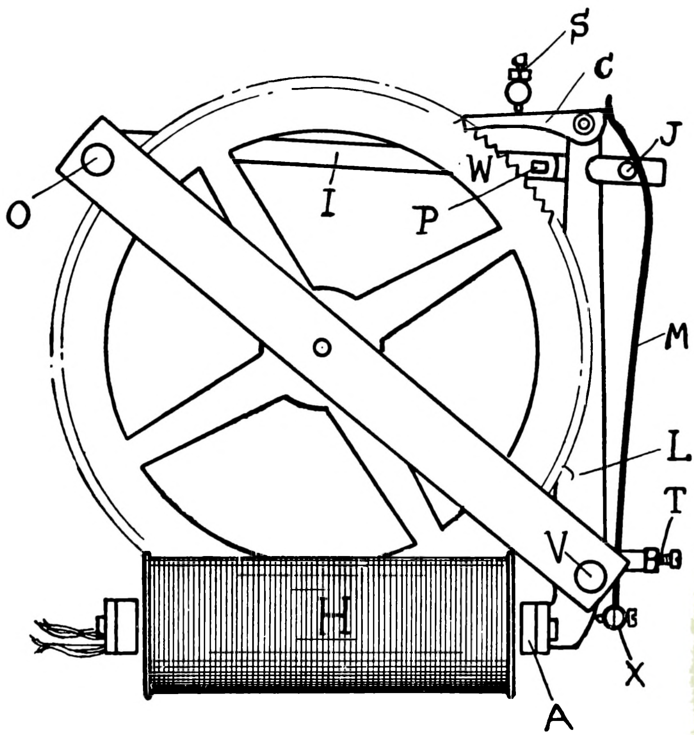


FIG. 40.—The "Synchronome" Electric Secondary Clock.

Fig. 40 shows an electro-magnet H actuating a pivoted lever L by attracting the armature A attached thereto. The upper end of the lever L has a pivoted click C engaging the teeth of the ratchet wheel W.

The novel feature of the "Synchronome" arrangement is the means provided for the locking of the wheel W by the screw S, preventing any movement of the hands until the click C is released; also the means provided whereby it is impossible for the wheel to move forward during the interval that the armature is being held by the electro-magnet H. Assuming that an impulse from the master clock previously described has been received, the armature is attracted, and since the lever L is pivoted at V, its upper portion and the click C will be withdrawn from the tooth of the wheel. In the meanwhile the click will have picked up a fresh tooth, and the release of the armature A enables the spring M to return the whole to the normal position. The click C propels the wheel W until arrested by the adjustable screw S, the wheel being then securely locked and any movement of the hands made impossible.

There is one mechanical detail that has not been considered, and that is the part that the lever I plays in the working of the clock. It will be observed that this lever is pivoted at O, and carries at its outer end a stud J and the stop P. Now, when the armature has been attracted and the lever L has withdrawn the click C, the wheel W would in the ordinary course of events be at liberty to move forward; but to prevent this from happening the lever L is notched and embraces the stud J, holding down the stop P and thus locking the wheel.

On the release of the lever it is immediately driven forward by the spring M. The stud J no longer held allows the lever I to lift, and the wheel W moves forward by lifting the stop P. The stop P thus performs two duties: that of preventing the back-turning of the wheel W, also premature progression of the wheel during the impulse interval.

The end of the spring M is rigidly held by the pillar X, and the tension on the end of the driving click may be adjusted at will by means of the screw T. To set the hands of the clock the driving click C has to be lifted by raising the pivoted arm I.

Murday's Secondary Clock.

In Murday's arrangement of secondary clock the poles of an electro-magnet M (Fig. 41) are so shaped that an armature B is free to move within them; the armature being mounted on an arbor provided at its outer end with a small cam E, and to limit the movement of the armature it is equipped with two springs XY, which strike against the poles of the electro-magnet M.

When in action the armature B is attracted by the poles PP^{1} of the electro-magnet, and by the attraction the armature turns the arbor together with the cam E. The cam E then lifts a lever N pivoted at O and provided at its outer end with a click D, which engages into the teeth of a large ratchet wheel W, from

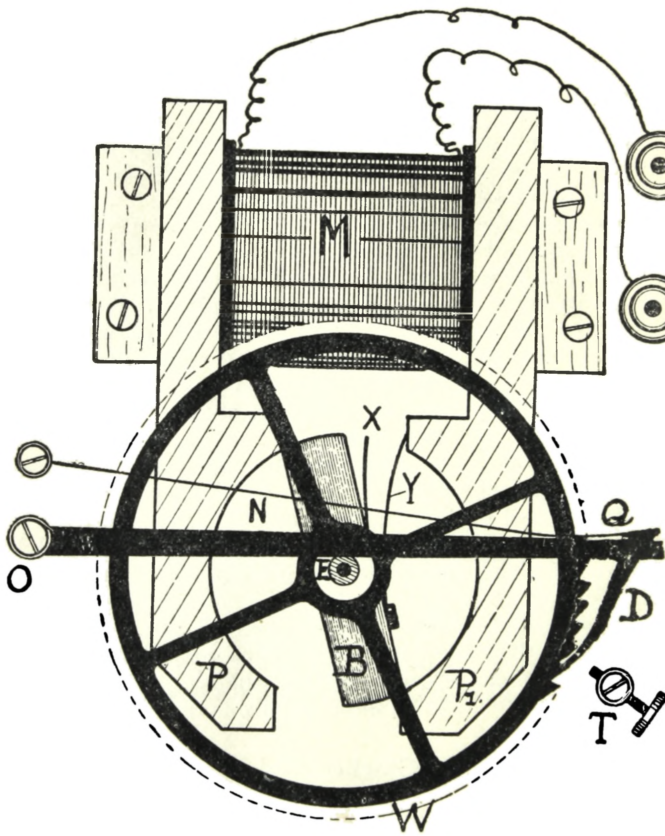


FIG. 41.—Murday's Electric Secondary Clock.

whence the clockwork derives its motion. To return the lever to its normal position and ensure the propulsion of the wheel W a strong spring Q is introduced, the travel of the click being limited by the screw T.

Each impulse received by the electro-magnet attracts the armature until any further movement on its part is arrested by the springs XY, which then assist the armature in returning to its former position.

In a modification of the above arrangement the lever N is abandoned, and the click receives its movement direct from the cam E.

Murday, in another type of secondary clock, arranges that the armature B equipped with a slotted arm shall engage a pin attached to a vertical rod, which will then have a vertical movement, the lower end of the rod having a pin moving in a curved slide, effecting thereby the rotation of a horizontal arbor. A small worm mounted on the arbor drives a worm-wheel, and by this means the hands of the clock are propelled through a clockwork train.

Electric Impulse Clocks by The Standard Time Co.

To work in conjunction with the master clock of the "Standard Time" system, a very simple and highly efficient impulse movement has been devised by the above firm.

The operation of the receiver or impulse dial is exceedingly simple. The movement consists of a pawl or back stop and an impulse click, moving by gravity a single toothed wheel once every half-minute through the medium of an armature attracted by an electro-magnet, the latter being energised by the regular impulse from the transmitter. A spring joint is used to support the armature, eliminating to a great extent friction and the tendency of pivots to bind through rust or thick oil. It is also customary to equip each electro-magnet with a suitable non-inductive shunt.

For the driving of the hands of a turret clock the Standard" electric "impulse turret movement" actuated by a master clock is often employed. This movement is unique, in that it has two magnets, the armatures of which are mounted on the long arm of the lever. A separate locking ratchet is used, which ensures the hands being locked at all portions of the stroke. There is also a "magnetic brake" attached to one armature to prevent bouncing. With the small pattern movement three pairs of exposed copper hands for 4-ft. dials can be safely driven, while with the large pattern three pairs of hands for 6-ft. dials may be driven.

Existing turret clocks can be driven by this method, doing away with the cumbersome movement, pendulum and weights; also winding is not required by the "Standard" electrical movement. The existing hands, connection rods, and the dial wheels can be utilised.

Parsons and Ball's ("Pulsynetic" System) Impulse Clock.

Parsons and Ball's arrangement of impulse clock is shown in Fig. 42, its novel features being the roller armature and the pivoted pawl for propelling the ratchet wheel. Referring to the diagram, it will be observed that the pole of the electro-magnet E is shaped so as to allow the roller armature R to run up its surface whenever E becomes excited. By this action the arm B is elevated, and its upper end with the pivoted pawl C moves to the right taking the latter with it.

The pawl has a toe piece T which drops on to the heel of the fixed member S when the arm B is moved to the right, thus preventing overdriving of the ratchet wheel Z, since there would be a tendency for the pawl to drop and engage more than one tooth of the wheel.

The withdrawal of B from its normal position also causes the spring M to become depressed, which on the cessation of the magnetism exhibited by E, returns B and in doing so drives the wheel Z one tooth forward. A click N prevents the back-turning of the wheel Z. More often, however, the pole face of E is square, and actuates a plain armature attached to the arm B below the fulcrum point instead of the special roller armature cited above.

Secondary clocks equipped with the "Pulsynetic" in-audible movements render them absolutely inaudible to the occupants of the room, and are thus highly suitable for use in libraries, hospital dormitories, etc.

The "Pulsynetic" Impulse Clocks.

The "Pulsynetic" impulse movements are divided into three sizes or classes:—

Class 1.—Simple locked movements having glazed dials, and varying in diameter up to 18 in.

Class 2.—Simple locked movements built up on brass

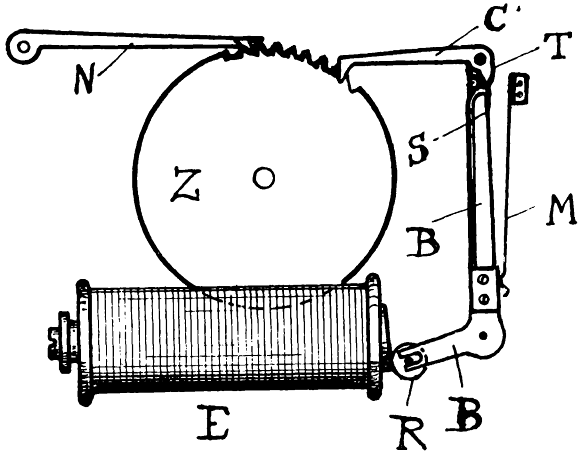


FIG. 42.—The "Pulsynetic" Electric Impulse Clock.

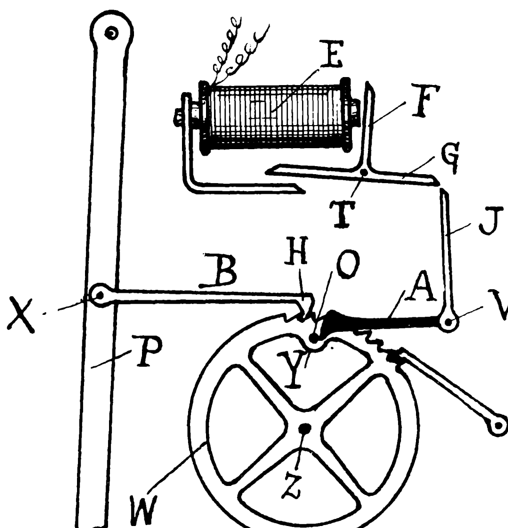


FIG. 43.—"Pulsynetic" Waiting Train Movement.

bases having glazed dials, and the limiting diameter of which is 3 ft. 6 in.

Class 3.—Double locked movement mounted on substantial bases, and suitable for the driving of the hands of large turret dials, the mechanism being arranged behind the glass dials, or for large clocks under cover in which the hands are exposed, but not to the pressure of the wind or rough weather.

In cases where the dials are of large diameter, the special

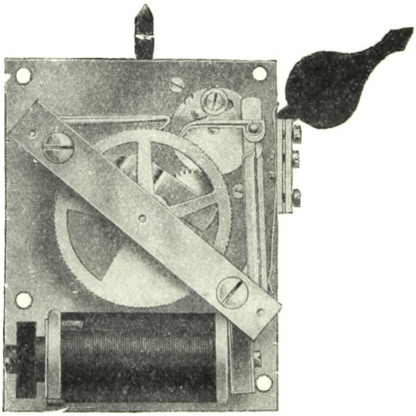


FIG. 44.—The " Pulsynetic " Impulse Clock.

" waiting train " turret movement is employed. This mechanism is described in Chapter VII.

The Class 1 movement is the size fitted with contacts for the ringing of bells, operating hooters at prearranged times. This system is most essential in factories and institutions where uniform time on various clocks is maintained, and it is necessary to employ sound signals for ringing on and off, starting and ceasing work, etc. In many cases where there is a variation in the time rates of the various clocks, dissatisfaction and confusion often arise, and the " Pulsynetic " impulse clock removes these grievances since the factory has one time throughout.

Messrs Gent, from experience, suggest that the duration of contact for bell-ringing should be thirty seconds, but it is possible with the above system to use signals of shorter duration if desired.

To avoid disputes among workpeople through faulty workmen's check clocks, the electrical " escaping " mechanism may replace the usual pendulum or balance wheel supplied with such clocks. The " escaping " of the wheelwork then takes place at half-minute intervals, whenever an impulse is received from the " Pulsynetic " transmitter. Although the workmen's recorders stamp the minute only, and the electric impulses are received at each half-minute by a simple device combined in the recorder escapements, the hands and type wheels advance in steps of one minute as desired. This useful device can be fitted to the greater number of workmen's check clocks now on the market.

The " Reflex " Pendulum Control.

The " Reflex " pendulum control is an elegant and brilliant invention, by means of which the pendulums of any number of clocks may be synchronised, such means not demanding electrical or mechanical connection with the wheelwork of the clock it is desired to synchronise.

The synchronisation of the pendulums is effected by periodic half-minute or minute impulses, such as sent through a circuit by a master clock, which automatically adjusts the tension of a spring or other suitable arrangement, thereby influencing the rate of the pendulum for the purpose of synchronisation.

The device possesses the unique merit that it may be utilised for controlling the existing pendulums of workmen's recorders. At the same time, however, it will be observed that when the " Reflex " pendulum control is employed no radical changes have to be made nor any part removed from the recorder. Indeed, the mechanism is so simple, but at the same time so effective, that only a spring attachment is clamped to the pendulum, while the controlling magnet is rigidly fastened to the case of the clock and then connected up with the " time circuit " of the master clock.

The recorder mechanism is wound up in the usual manner and continues to function as intended by the manufacturer; the addition of the " Reflex " movement merely causes the pendulum of the recorder to keep time with the "transmitter" and the other clocks of the circuit.

Whenever the "Reflex" movement is applied to any make of workmen's recorder, the following points should be borne in mind :—

1. The introduction of the "Reflex" control does not free the manufacturer of the recorder from his responsibility, especially since the control device can be removed in such a short space of time as five minutes.

2. The entire mechanism, including the type wheels and dial of the recorder, are operated by the clockwork originally supplied by the manufacturer.

3. Should the impulses derived from the electrical "time circuit" fail at any time, the working of the recorder is not effected in any way; the pendulum of the latter continues to vibrate under the influence of the clockwork, thus the interruption of the electric impulses does not materially interfere with the checking and costing system.

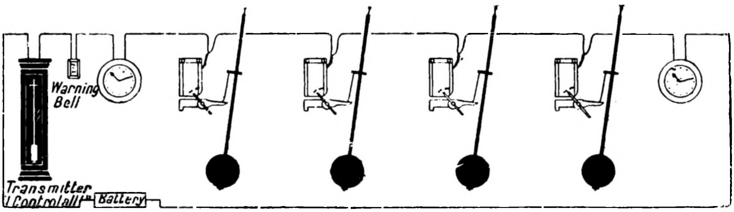


FIG. 45.—The "Reflex" Pendulum Control.

To describe the "Reflex" pendulum control briefly: it consists of two essential parts, viz., the "vibrator," which is readily clamped to the pendulum rod, an operation demanding no great display of skill, neither is any drilling or tooling required. The other element of mechanism is screwed to the recorder case and is termed the "stator."

The spring "vibrator" is pivoted to a bracket clamped to the pendulum rod; a suitable stop formed on the bracket prevents the spring "vibrator" from turning on its pivot when it is being deflected.

Consider now the mechanism of the "stator." which consists of an electro-magnet connected with the "time circuit," so that whenever a periodic impulse is received from the " transmitter " a specially shaped armature is actuated. The latter is pivoted at its outer end, while the end nearest the pendulum rod is provided with a rack. Under normal conditions the armature rests on to an adjustable screw; the rack end being down allows the spring " vibrator " to swing above it.

At each half-minute (or minute) the periodic impulse from the " transmitter " energises the electro-magnet of the " stator "; immediately the armature is attracted, thereby elevating the rack. But the end of the spring " vibrator " whilst making its excursion from right to left is engaged by one of the teeth of the rack, and the momentum of the pendulum causes the spring " vibrator " to become deflected. It will be evident that whenever the spring " vibrator " is arrested by the rack it will have a tendency to terminate sooner the vibration of the pendulum, and during the next or return swing of the latter the straightening out of the spring " vibrator " will assist the swing of the pendulum, causing it to arrive at the end of its swing a little sooner.

When installing the " Reflex " system to a recorder it is necessary to rate the clock so that the latter has a slight losing rate, say about two minutes per day of twenty-four hours. This is best done by turning the key of the " stator " to the OFF position. Then on turning the key of the " stator " to the ON position the clock will beat in unison with the other " Pulsynetic " clocks connected to the " time circuit." So effective is the " Reflex " control that with a pendulum beating eighty-eight per minute, as is customary in some time recorders, it will deal effectively with a loss of as much as ten minutes per day. The precision and simplicity of the " Reflex " movement has resulted in its having been fitted to practically all makes of workmen's recorders.

The makers and patentees are Messrs Gent & Co. Ltd., of Leicester, who also make a larger pattern suitable for public or other turret clocks.

The " Pulsynetic " idle machine recorders have been introduced to give a record of the time during which a machine has been idle, and so assist the management in keeping the productive machinery fully occupied during working hours.

The recorder shows, by means of a chart, the time of day at which any of the machines become " idle," and the duration of such " idleness," and the record on the chart makes the work of investigating the cause of idleness a straightforward matter, thus the removal of the cause is greatly facilitated.

When a machine becomes idle, even for half a minute, a mark is made on the record chart in the column against the number of the machine; and if the idleness is continued, a

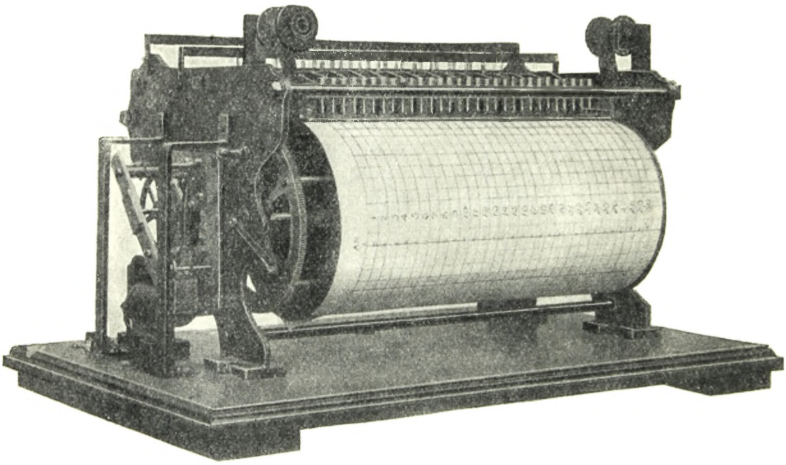


FIG. 46.—" Pulsynetic " Idle Machine Recorder for Thirty Machines.

line is made for the period of time that the machine is idle. If the machine is started, the line ceases, only to be made again, however, should another period of idleness occur.

The operation of the recorder is electric, and requires a wire to be run from each machine to the recorder, a common return wire serving for all machines. The drum of the recorder is electrically driven by a " Pulsynetic " transmitter, and where one already exists this may be employed. Each machine to be recorded is provided with a contact, which is brought into operation automatically when the machine becomes idle. This contact is termed a " contact unit."

In cases where the machine is of that class which must, of necessity, be producing if running, then the contact unit is operated by the striking gear if belt driven, or by a switch if motor driven.

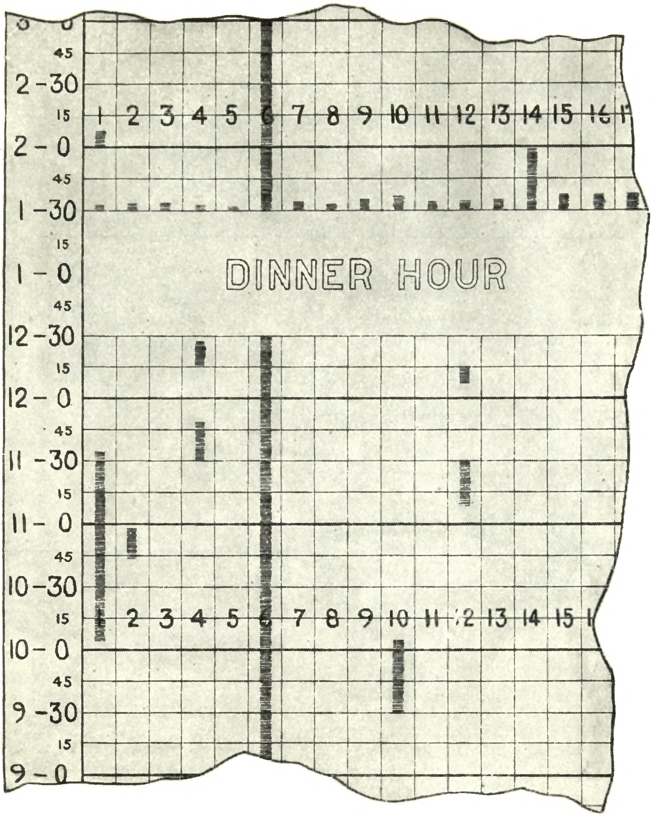


FIG. 47.—Portion of a Chart with Black Lines Indicating that some Machines were Idle.

In the case of machines which may not be producing, although running, a special contact unit has to be designed to suit the actual working conditions of the machine. It is often found desirable to arrange that the period of working be recorded either by the work as it passes from the machine,

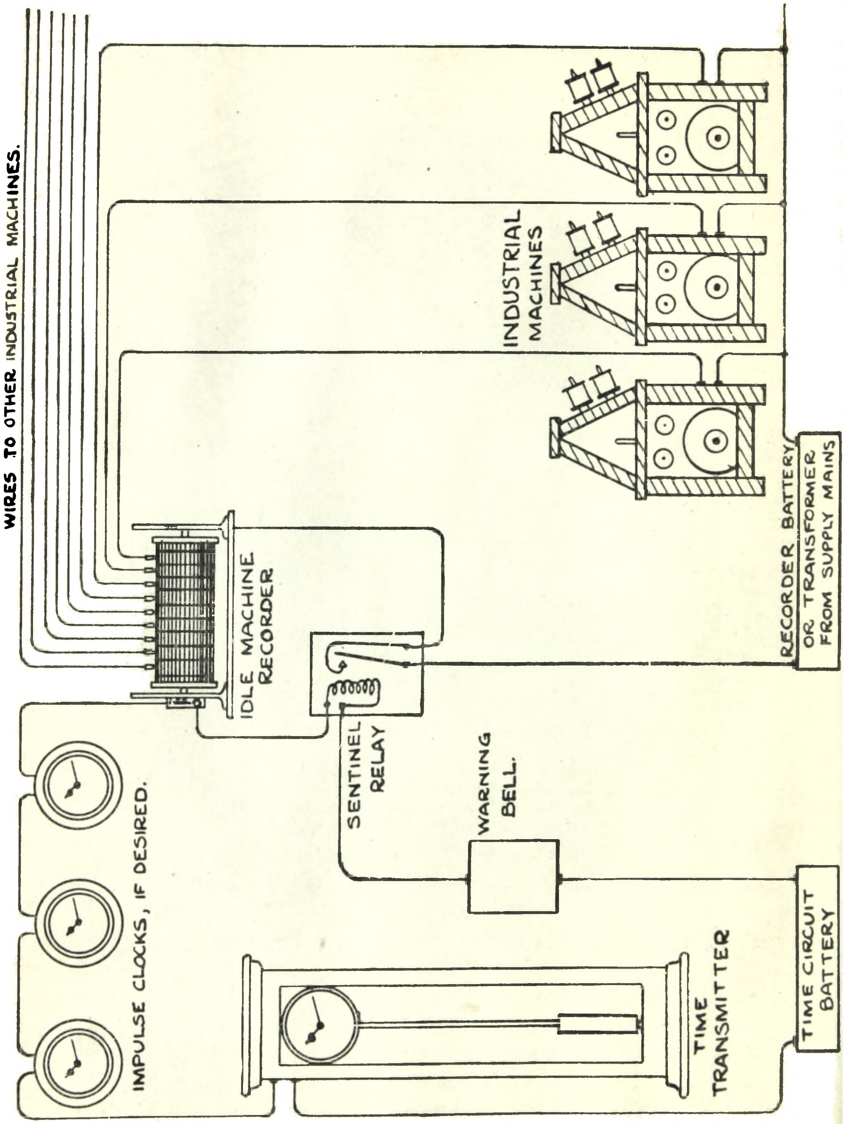


FIG. 48.—Wiring Diagram showing Recorder connected to Machines.

or by a frequently recurring action of the machine, which only takes place while it is producing.

In the lace trade, for example, every rack of lace produced by the machine is recorded, and an absence of the periodic dots on the record sheet shows a period of idleness.

The records on the chart are made by means of a "typewriter" ribbon, and the marks produce an impression of same on the chart each half-minute that a machine is idle, the impressions merging into a line if the machine is idle for a few minutes.

One "Pulsynetic" transmitter is capable of driving any number of recorders on one circuit, and is also capable of driving any number of electric impulse clocks on the same circuit.

Another very ingenious instrument manufactured by Messrs Gent is the output recorder, which instead of making a line, causes a dot to be made on the record chart each time a given amount of material is made, or an article or an operation completed. With this type of recorder the frequency of the intervals at which the dots are required, or rather the frequency at which the operations are completed, has an important bearing on the construction of the machine, and in some instances calls for rapidly moving paper, thereby avoiding the dots on the paper running into one another and thus becoming illegible. The paper of the output records travels much faster than in the case of the idle machine recorder, the speed depending on the frequency of production.

Parker's Secondary Clock.

The customary ratchet wheel W (Fig. 49) is driven forward tooth by tooth by the pawl C, the latter being pivoted to the vertical lever L at Y. A projection D of the pawl C extends upwards, and is equipped with a screw X for the prevention of overdriving the ratchet wheel W by the screw butting against the end of the lever L and restricting the play of the pawl. The screw X also performs the office of locking the pawl and the tooth on which it rests, so that any movement of the ratchet wheel is impossible between the periods of reception of the impulses from the master clock. The electromagnet E attracts the armature A, actuating the lever L with

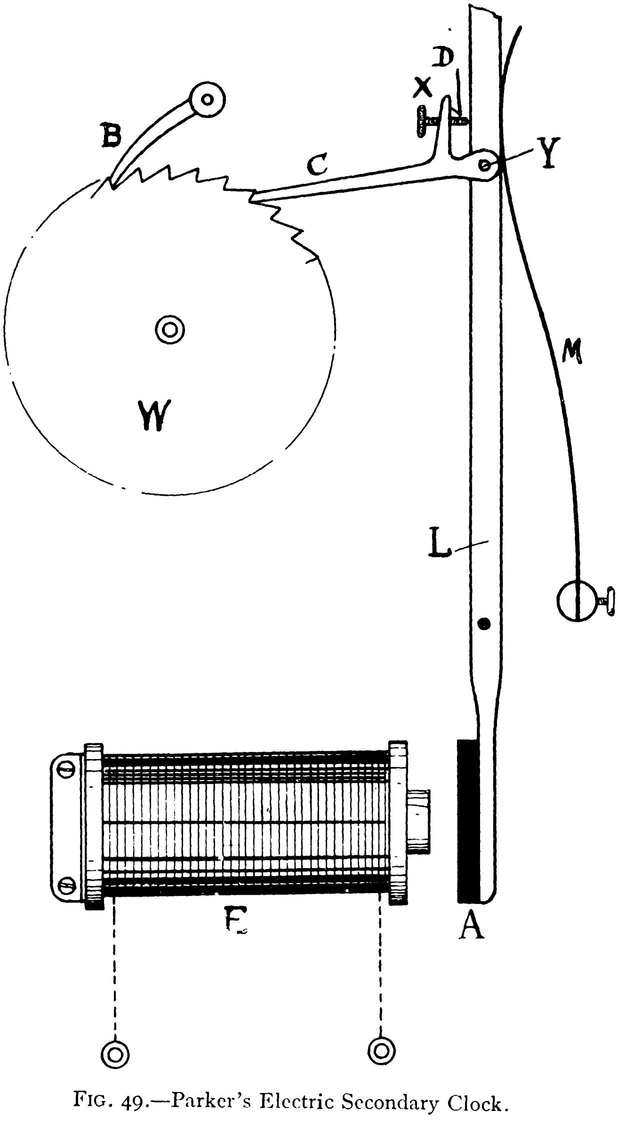


FIG. 49.—Parker's Electric Secondary Clock.

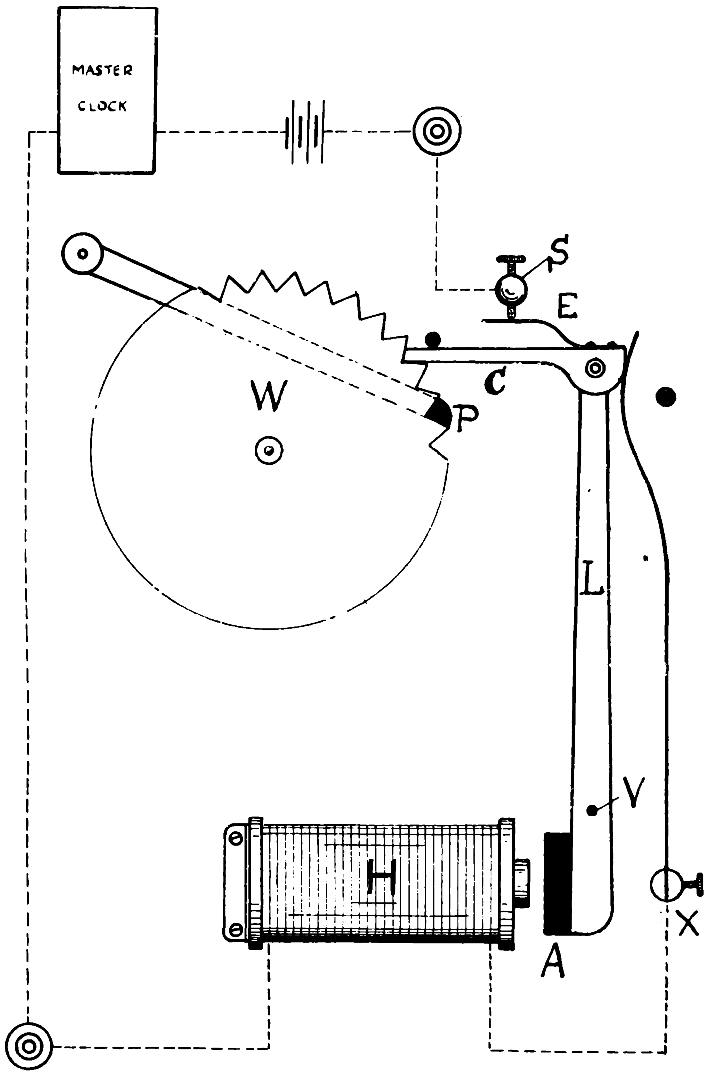


Fig. 49A.—Hope-Jones and Bowell's Electric Secondary Clock.

its pawl C. To return the armature to its normal position, and for driving the ratchet wheel forward, a spring M is introduced. A small detent B prevents the wheel W from turning back when the pawl is engaging a fresh tooth during the energisation of the electro-magnet E.

Hope-Jones and Bowell's Secondary Clock.

The construction of the secondary clock used in conjunction with the master clock described in Chapter IV., Fig. 21A, will be better understood by reference to Fig. 49A. It consists virtually of a "step by step" movement having a large ratchet wheel with as many teeth as there are impulses transmitted by the master clock per hour. The wheel is propelled by a click actuated by a powerful electro-magnet, the latter deriving its power from the impulse transmitted by the master clock.

An electro-magnet H (Fig. 49A) actuates a pivoted lever L by attracting the armature A attached thereto. The upper end of the lever L carries a pivoted click C engaging the teeth of the ratchet wheel W. Assuming that the gravity arm B (Fig. 21) has been raised, and is still retained by the electro-magnet M, then the electro-magnet H (Fig. 49A), also being in the same circuit with the battery I becomes excited and attracts the armature A, which actuates the lever L causing the click C to be withdrawn, and at the same time to pick up another tooth of the ratchet wheel W. But in doing so the contact spring E breaks the circuit at S and the gravity arm B (Fig. 21) is instantly released by the electro-magnet M, the lifting lever F dropping on to its stop, while the gravity arm B continues to drive the clockwork. Considering now the secondary clock, the contact between S and E having been broken, the electro-magnet H becomes inactive and releases the armature A with its lever L. The latter is immediately driven forward by a stiff spring M, the lower end of which is rigidly fixed to a pillar X. The click C when being driven forward, engages into a tooth of the wheel W and propels it until the click is arrested by a stop O. In this position it is impossible to move the wheelwork of the clock. It will also be observed that the contact spring E once more completes the circuit with the screw S, awaiting the next impulse to be transmitted from the master clock.

CHAPTER VI

ELECTRICAL STRIKING GEARS

THE first attempt to announce the hour by the corresponding number of blows sounded on a gong or bell by electro-magnetic means seems to have been made by Shepherd in 1849, and since that date many ingenious forms of striking gear have been introduced. In this chapter it is only proposed, however, to deal with the more interesting striking gears, and those most likely to meet with universal adoption.

Shepherd's Striking Gear.

Fig. 50 shows diagrammatically the arrangement adopted by Shepherd. A wheel H mounted on the "seconds" arbor of the clock carries a pin I which engages the contact P situated at the end of the insulated arm L. Matters are so adjusted that at the stroke of the hour the pin T of the hour wheel M has raised the arm L, this being effected by the projection X. The pin I of the "seconds" wheel now makes contact with P. The electro-magnet E included in this circuit draws down the armature lever A. The outer end U being withdrawn from the "locking plate" Z, completes the circuit at S.

The completion of the circuit between S and A allows current to flow from a second battery D, thereby energising an electro-magnet Y which actuates the pivoted armature W. The latter is provided at its outer end with the hammer O for striking on the gong B. A ratchet wheel R also receiving its movement from a pawl carried by the armature lever W is the means whereby the "locking plate" Z is revolved. Each time that a blow is struck on the gong B the ratchet wheel R is progressed tooth by tooth. The interval that elapses between each blow struck on the gong is determined by the period of oscillation of the bar magnet Q of the secondary clock. At the end of its oscillation the magnet completes the circuit with the contact C, then the magnet Y becomes energised. By the excitation of the latter, the "locking plate" Z is indirectly

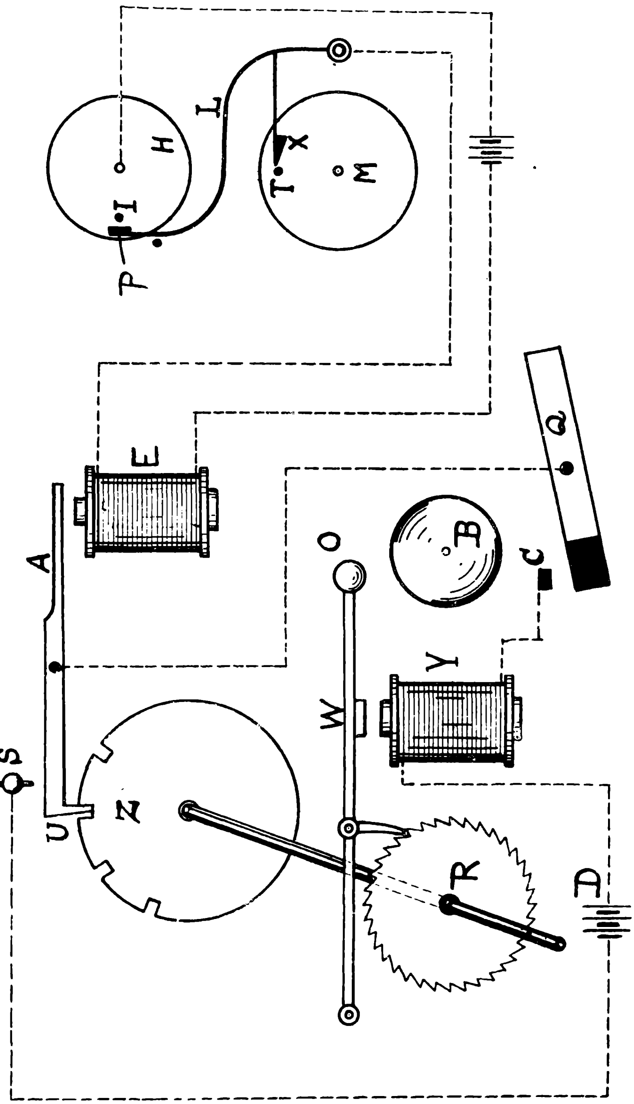


FIG. 50.—Shepherd's Electrical Striking Gear.

moved forward until further movement on its part is arrested by the lever U dropping into a notch and breaking the circuit at S.

It will be observed that the exact instant at which the releasing magnet E is energised is decided by the pins of the wheels H and M. The mechanism may be divided in two groups, *i.e.*, the "releasing portion," comprising the wheels HW and the arm L for closing the circuit of the releasing electro-magnet E. The second portion consists of the "locking plate;" with its ratchet propelling gear and the mechanism for announcing the hour by the correct number of blows on the gong B; also may be included the system of contacts by which it is possible to obtain a period of rest between each blow sounded on the gong.

Neale and Powell's Striking Gear.

The mechanical arrangement of this system, patented in 1908, is shown in Fig. 51. The principle involved is rather different from the preceding (and following) systems; indeed, only one electro-magnet is employed, and the customary train of wheels and fly to govern the interval elapsing between each blow of the hammer struck upon the gong has been abandoned.

An electro-magnet E having a yoke A of the shape shown has rigidly attached to its lower end the armature B. The outer end is free to vibrate, and has mounted upon it the hammer C and a pivoted pawl D extending downwards, the point of which engages the ratchet wheel F. Referring to the armature B, it will be observed that it is of heavy proportions, being overwound with a coil of wire W. The armature virtually behaves as an electro-magnet.

Mounted beneath the armature B is the member G rigidly fastened at H, the outer end being free to vibrate and having attached to it a short distance from the end the detent I, which drops into the notches of the locking plate J. To set the mechanism in motion the member G is raised until contact takes place between K and L, thus energising the electro-magnet E with its special armature B through the medium of the coil W. The member G being held by the attraction of the energised armature B, electrical contact between the points K and L is maintained. But the energised magnet E by the attraction of the armature B with the member G, the portion O

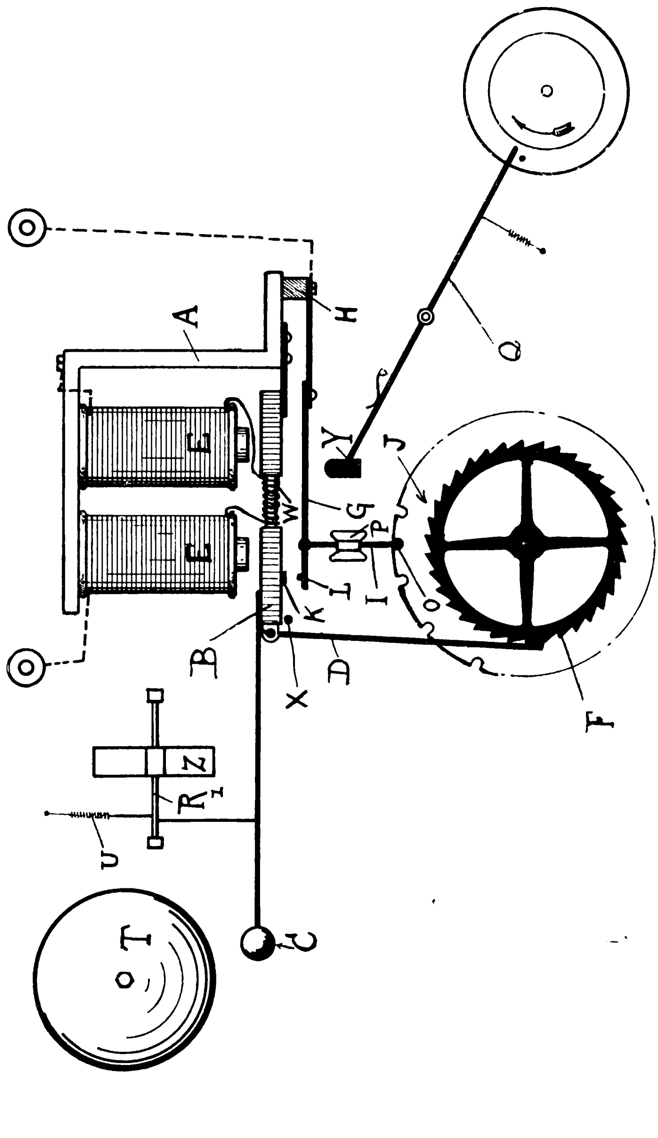


FIG. 51.—Neale and Powell's Electrical Striking Gear.

of the detent I is arrested by the stop P, resulting in the contacts K and L being separated. Losing its magnetism, the electro-magnet E releases the armature B, which immediately falls with the pawl D and the hammer C.

When the armature B has fallen to its lowest position, the contact K again engages its fellow contact L, and the armature B is again attracted by the electro-magnet E. Each time this occurs the pawl D propels the ratchet wheel R one tooth forward until the point O drops into a notch of the locking plate, then placing the member G in such a position that when the armature B falls to its lowest point it becomes arrested by the pin X, causing the contacts KL to remain open. The pivoted lever Q actuated by the clockwork at the stroke of the hour causes the end Y to be raised, lifting the member G and the detent I out of the locking plate J, thereby completing the circuit at the contacts KL.

This has the effect of setting the mechanism in motion by the completion of the electric circuit, and consequently the energising of the electro-magnet. To govern the speed with which the blows are struck on the bell T by the hammer C, a small fly is introduced at Z. A cord attached to the rod of the hammer C is wrapped around the arbor R and attached to a spring U. The drop of the armature B causes the cord to be wound around the arbor R_1 against the tension of the spring U, and by this means the drop of the armature is retarded by the resistance offered by the air when the fly Z rotates.

Parsons and Ball's Striking Gear.

Fig. 52 shows an arrangement patented in 1906 by Messrs Parsons and Ball.

The arrangement, strictly speaking, consists of two sets of contacts included in the same circuit, one set being employed for closing the circuit, while the second set performs the function of breaking the circuit which is normally held closed. To make the system more lucid the contacts for closing the circuit are operated mechanically, and held in that position by an electro-magnet. The second set of contacts for breaking the circuit are operated by another electro-magnet actuating a slow moving armature.

A pawl deriving its movement from an armature propels

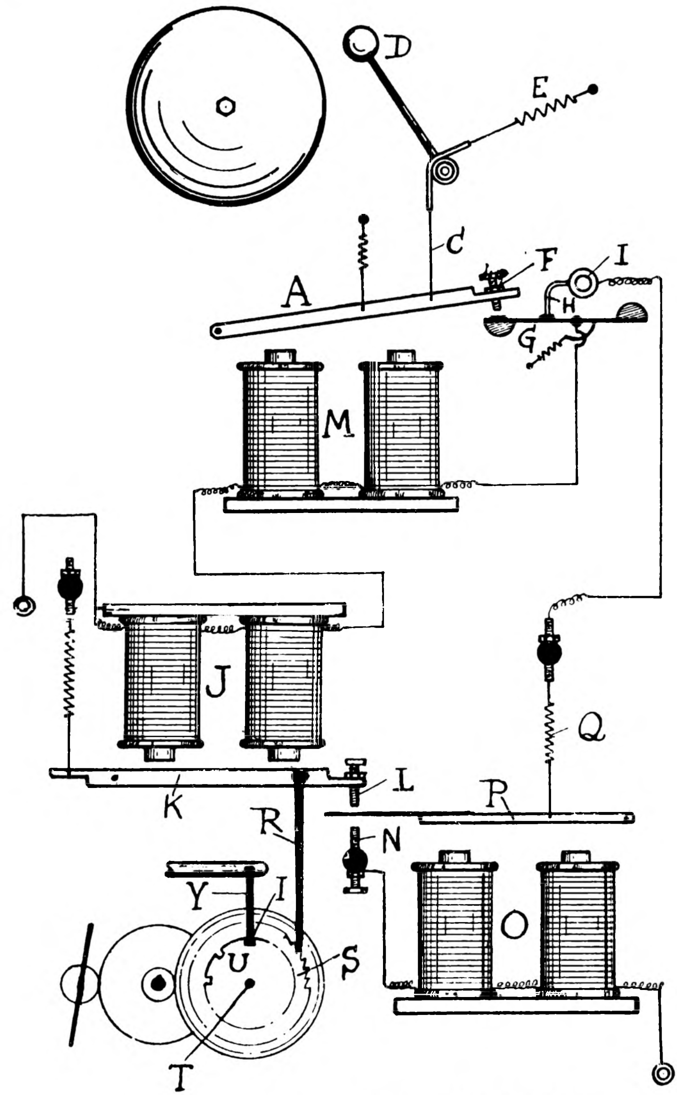


FIG. 52.—Parsons and Ball's Electrical Striking Gear.

tooth by tooth a ratchet wheel mounted on the arbor carrying the locking plate, also a tooth wheel gearing into the usual train of wheels, the highest driven wheel having a fly attached to its arbor for regulation purposes.

An electro-magnet M (Fig. 52) has situated near its poles the pivoted armature A, the oscillation of which pulls down the cord C, actuating the hammer D against the tension of the spring E. The outer end of the said armature carries the contact screw F for depressing the pivoted switch arm G. Normally a contact piece engages the contact wire H which is attached to the bracket I.

The electro-magnet J being inverted, actuates the pivoted armature K, the latter carrying at its outer end a screw L beneath which is situated a fellow screw N.

A third electro-magnet O actuates a third armature P, also pivoted and provided with a spring Q. The play of the armature P is restricted by the screw contacts L and N.

Pivoted to the armature K is a pawl R engaging into the teeth of the ratchet wheel S, which is mounted on an arbor T. On the arbor also are mounted the "locking plate" U and the wheel gearing into the pinion of another wheel, the latter driving the fly. Under ordinary conditions the detent Y drops into a notch of the "locking plate" U, but when Y is lifted at each hour by the clock mechanism or any other means that may be provided, the armature K in dropping allows the pawl R to progress the ratchet wheel S forward, thereby preventing the projection I of the detent from dropping into a notch and arresting any further movement of the wheel S. The armature K, however, in falling not only propels the wheels S, but it completes the contact between the spring Q and the contact screw N. Immediately all the electro-magnets MJO become energised, and in the former instances their respective armatures are attracted, whilst the electro-magnet O holds its armature, maintaining contact between the spring Q and the screw N.

The attraction by M of the armature A causes the cord C to be pulled down and a blow struck on the bell Z. But in performing this office the screw F engages the arm G, the depressing of which breaks contact between itself and the wire H. Instantly the electro-magnets release the various armatures, but the functions performed by the armatures differ greatly.

The armature A having returned by the assistance of the spring E, permits the arm G to restore contact between itself and the wire H. Again the armature K, formerly attracted by the magnet J, when released falls and propels the wheel S one tooth forward; also the screw L situated at its extremity has depressed the armature P and restored contact between Q and N.

This results in the circuit being closed once more, and the cycle is repeated each time a blow is struck on the gong Z. By the introduction of the wheel train and fly to retard the fall of the armature K, a pause becomes possible between each blow struck by the hammer D.

The ratchet wheel S is propelled gradually until the projection I of the detent Y again drops into a notch of the "locking plate" U, thus preventing any further movement of the latter until such time as the detent Y is again raised at the next hour. In this instance the armature K will be in the raised position, as represented in Fig. 52. When in this position it is ready to propel the wheel S, and later complete the circuit between the spring Q and the screw N.

Hope-Jones and Bowell's Striking Gear.

Another form of striking gear is shown in Fig. 53, consisting of a heavy pivoted arm A, which is raised at intervals by the electro-magnet E through the agency of the pivoted armature B. The arm A has a pawl C engaging into the teeth of the ratchet wheel R attached to the arbor D, also carrying the special locking plate P, which has instead of the usual notches cut in its rim a series of insulated blocks for the contact piece F to rest on each time the circuit is broken. A system of wheelwork driven from the arbor D compels the fly G to rotate and act as a governor.

Pivoted to the armature B is the contact arm X, the outer end being insulated by being inserted in an insulating sleeve T. Normally the armature B and the arm X rest on the stops W and Y. The upper end of B carries a screw contact S for completing the circuit whenever it engages the projection J of the arm A.

In the figure the contact spring F is shown in the position it would assume when the mechanism is in operation. Then F would be in electrical contact with the locking plate P, and

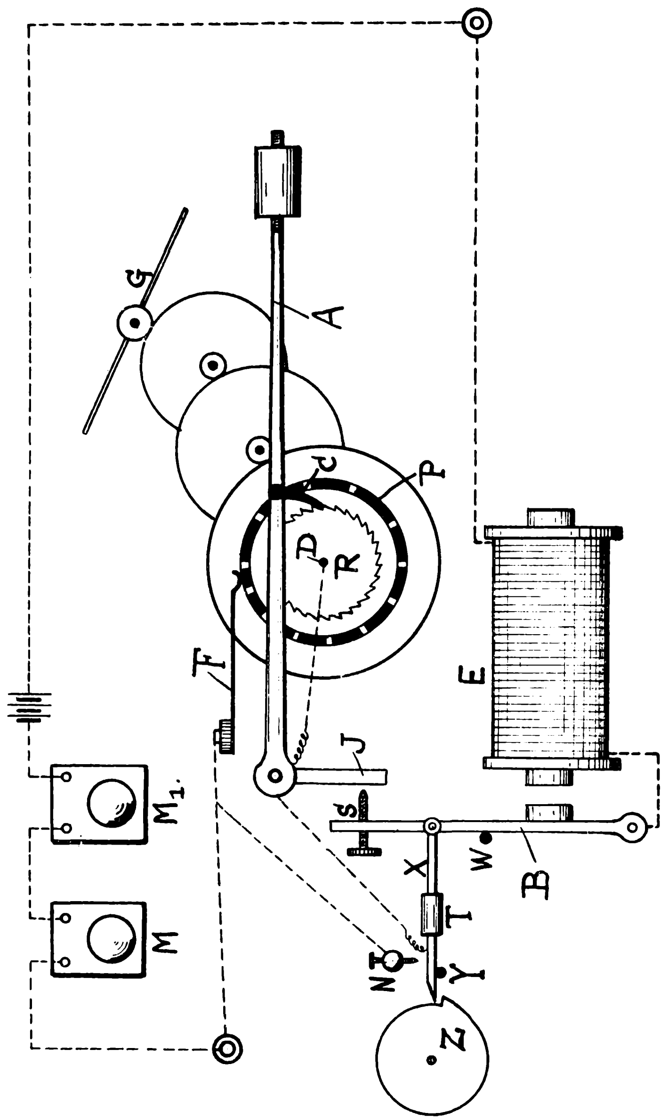


FIG. 53.—Hope-Jones and Bowell's Electrical Striking Gear.

when the latter has turned sufficiently for the tip of F to bear on one of the insulating blocks, then the circuit is broken and the mechanism becomes inactive.

To close the circuit at the correct instant and thereby set the mechanism in motion, the arm X must be raised by the cam Z; the latter is usually driven off the going train of the clock until contact is made with the screw N. The electro-magnet E now becoming energised, causes the armature B to be attracted, allowing the screw S to engage the projection J, throwing the weighted arm A upwards whilst the pawl C passes over a tooth of the ratchet wheel R. The weight of the arm A now commences to drive the wheelwork, the speed of the latter being governed by the fly G. On the arm A falling to a fixed point the projection J again completes the circuit at S, and the energisation of the electro-magnet E causes the arm A, through the intervention of the armature B, to be again raised into an effective position, the pawl C engaging another tooth of the ratchet wheel R. Each time that the arm A is reset the bells MM_1 receive an impulse which is announced by a blow being given on either gong. This performance is continued until the locking plate P has turned sufficiently for the contact spring F to bear on an insulating block, when the circuit is automatically broken.

To restart the striking mechanism contact must be established between X and N. The locking plate is, of course, divided up into twelve unequal portions, each portion determining the duration of contact between itself and the contact F, which directly determines the number of times that the arm A is reset, and consequently the number of blows announced by the bell.

In the system suggested by Kirchhofer, the striking is carried out by means of an electro-motor, which also winds the mainspring of the going train of the clock. A pin projecting from the minute arbor of the clock shortly before the hour withdraws a pivoted catch, thereby setting into motion a rack-striking gear such as was introduced into long case clocks of the last century. The rack-striking gear is, of course, an old idea, and was invented by Edward Barlow in the seventeenth century, although sometimes it is credited to Thomas Tompion who certainly applied it about 1675.

Electrical Chiming Gears.

There are other arrangements wherein the electric current may be utilised to operate electro-magnetic mechanisms and announce the passing of the hours by an increasing number of blows struck on a bell or gong. Indeed, certain signals or number of blows may be struck on a bell as is customary on ships. To this end Withers in 1911 patented an arrangement wherein a bell imitated the strokes of a ship's bell, double blows being given at the hour and an odd number of blows given at the half-hours.

In like manner chiming barrels have been entirely electrically driven, and in place of the old-fashioned hammers delivering blows on tubes or gongs, electric bell hammers perform this function.

A series of pins correctly spaced on the chime barrel project, and instead of actuating pivoted levers and pulling down cords, which raises the hammers of the old system of chimes, the pins merely engage contact fingers suitably placed.

Whenever a pin completes the contact with a finger, the electric bell movement of that particular circuit causes a blow to be given to the gong. It is necessary to have a contact finger for each row of pins, and likewise an electric bell movement to strike the gong. Provision has, of course, to be made for the letting off of the chime barrel at the correct periods, and also for arresting the barrel.

In the simplest form of chiming gear the barrel is independently driven by either a spring or weight driven clockwork train regulated by a fly, the pins engaging the contact fingers, and the gongs are struck in the correct order by electric bell hammers.

If Westminster chimes are adopted, then four bells or gongs with their respective electric bell movements are necessary, and in this case the chime barrel will be equipped with forty pins projecting from its periphery. In this system of chiming the following peals are sounded at each quarter-hour :—

First quarter - -	One peal—4 notes.
Second quarter - -	Two peals—8 notes.
Third quarter - - -	Three peals—12 notes.
Fourth quarter - - -	Four peals—16 notes.

To separate one peal from the next, an interval is arranged equal to about two and a half times the interval that elapses between the sounding of each note. But there is no fixed rule.

For instance, Lord Grimthorpe suggests at least two and a half times the interval elapsing between each note sounded in a peal, whilst at Cambridge it is as much as three times.

To this end the chiming barrel will have to be divided into four sections and pinned accordingly, the sections being unequal. To release the barrel at the correct instant, a pivoted stop may be withdrawn by an electro-magnet, the stop normally engaging one of the four pins projecting from the side of the chime barrel. Once released, the barrel commences to rotate until the next projecting pin is arrested by the stop.

The current for energising the electro-magnet to withdraw the stop is controlled from the going part of the clock, and consists of a weighted arm (reset by a separate electro-magnet), which is held by a catch. Mounted on the "minutes" arbor of the clock is a four-armed cam, one arm for each quarter-hour. When an arm of the cam has reached its highest position it has raised the weighted arm, which is then allowed to drop after the lifting face of the cam has passed the vertical. The weighted arm in falling causes a projection at its pivoted end to complete the circuit by engaging a spring contact.

The electro-magnet effecting the release of the chime barrel is then energised, and the barrel commences to rotate. But the pivoted stop on being withdrawn, closes the circuit between a pair of contacts, energising thereby the resetting magnet of the weighted arm. The latter is instantly thrown back into its normal position and the circuit again broken, while the chime barrel continues to run until the stop arrests it by engaging the next pin projecting from the face of the barrel. The periphery of the chime barrel being of metal, it is in electrical contact with the arbor on which it is mounted, also forming a convenient means of electrifying the pins.

As the contact fingers engage the pins in the prearranged order, the various circuits are thus completed. Each finger since it is connected to an electric bell circuit, sounds a blow as each pin passes the former.

With Westminster chimes the bells will have to be struck in the following order:—

First quarter	-	1, 2, 3, 4.
Second quarter	-	3, 1, 2, 4; 3, 2, 1, 3.
Third quarter	-	1, 3, 2, 4; 4, 2, 1, 3; 1, 2, 3, 4.
Fourth quarter	-	3, 1, 2, 4; 3, 2, 1, 3; 1, 3, 2, 4; 4, 2, 1, 3.

"Pulsynetic" Electric Striking and Chiming Mechanism.

In conjunction with any "Pulsynetic" system of impulse clocks (large, small, or turret pattern), electric striking

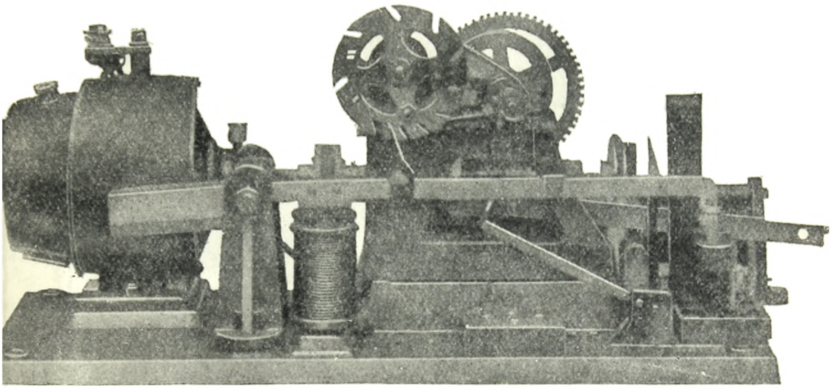


FIG. 54.—"Pulsynetic" Motor-Driven Striking Mechanism.

mechanism may be used. The ordinary quarter, Westminster, or ting-tang chimes may be sounded by installing simple chiming gear.

The motor-driven striking mechanism is operated by an electric motor using direct current from the power mains. A rotating cam actuates a lever, which in turn—by means of a wire connection—lifts a drop hammer, which falls by its own weight and strikes a bell. A buffer spring lifts the hammer slightly off the bell so as to allow the bell to give forth its full volume of sound.

It has been proved by experience that the striking of bells by a drop hammer is the best method of sounding the hours on bells of large size. In fact, church bells of two tons in weight are struck by this mechanism. The mechanism is timed by an " hourly contact maker " driven from the " impulse circuit."

In the " waiting-train " driven pattern the striking mechanism is timed and operated by a " waiting-train " turret movement, and is driven by the hour spindle of the latter. It counts out and transmits the correct number of electric impulses to an electric hammer, the latter striking the bell. If desired, direct current may be employed, or even current from a primary battery may be used. The circuit is cut

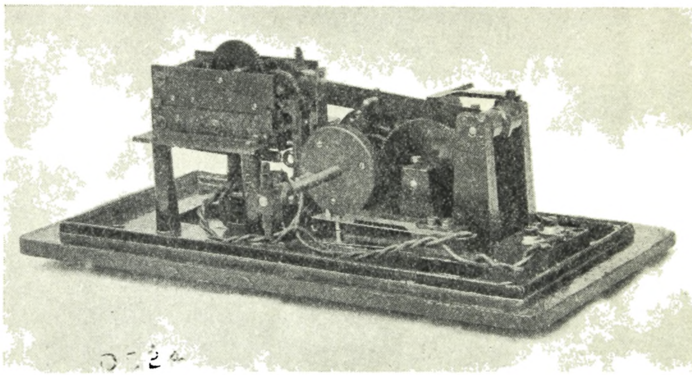


FIG. 55.—" Pulsynetic " Waiting-Train Driven Striking Mechanism.

off at each blow the instant the bell is struck, hence a primary battery of Leclanche cells may be successfully employed.

The pattern usually employed for chimes on tubular and other bells for private residences is also equipped with an " impulse movement," and operates from the impulse circuit instead of by a " waiting-train " movement.

To produce the Westminster or other chimes, the cams and their equivalent are replaced by a barrel pinned to the correct stanzas for the chimes chosen.

Fig. 55 is a photograph of the " waiting train " movement driving a striking mechanism, whilst Fig. 85 depicts the " waiting-train " movement operating a chiming gear.

A four-lever chiming gear operated by an electric motor is shown in Fig. 83: the illustration being very clear, a description of the mechanical details of the contrivance is unnecessary.

CHAPTER VII

THE SYNCHRONISING OF ELECTRIC AND OTHER CLOCKS

THE hands of any weight or spring driven clock may be corrected or synchronised at regular intervals, and the clock brought to time by the agency of the electric current.

By no means is the practice restricted to clocks of the above variety, but an entire system of electrical impulse dials may be synchronised at certain intervals. Needless to say, there are many synchronising systems performing daily in the larger cities.

Clocks in any shape or form synchronised from a central or master clock are sometimes termed "sympathetic" or "affiliated clocks."

Barraud and Lund's Regulator.

The above was one of the earlier arrangements wherein an attempt was made to synchronise a number of affiliated clocks from a standard timepiece at each hour. Behind the dial of each clock and just above the twelve o'clock position on the dial were pivoted two L-shaped levers carrying pins at their lower ends, the pins projecting through the dial sufficiently to embrace the long hand of the clock. The upper portions of the levers being slotted, each engaged a prong of the forked end of an armature lever which was drawn down each hour by an electro-magnet, energised by the impulse received from the standard clock. By the attraction of the pivoted armature the forked end became depressed, with the result that the prongs of the fork moved along the slots of the levers, causing them naturally to move towards one another. Should the long hand of the clock be slightly in the rear, it was moved forward; on the other hand, if the hand was ahead it was set back.

In Fig. 56 the electro-magnet M attracts the armature B,

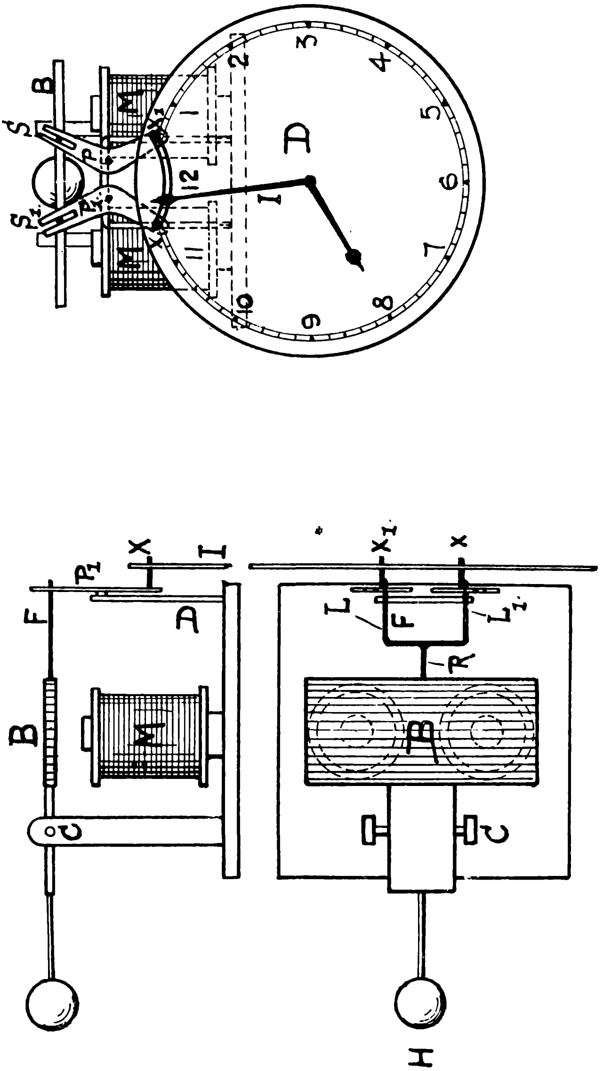


FIG. 56.—Barraud and Lund's "Regulator."

which is pivoted at C. The forked end F of the armature rod R has two prongs LL_1 engaging into the slots SS_1 of the pivoted levers PP_1. Set in the lower ends of the levers PP_1 are the pins XX_1, the latter passing through the dial D of the clock.

When the impulse has been received and the electro-magnet M releases the armature B, it is returned to the normal position by a counterweight H. This action also has the effect of the withdrawal of the pins XX_1 to one side so as not to impede the forward movement of the minute hand I.

To complete the circuit for the transmission of the impulse from the standard clock a simple device is included in the clock movement. Usually a projection moving with the wheelwork completes the circuit with an insulated contact at the stroke of the hour. The impulse may be transmitted hourly or every twelve hours; in the former case it would be termed an "hour regulator."

Hipp's Synchronising System.

Dr Hipp introduced for this purpose the arrangement shown in Fig. 57. An armature B actuated by an electro-magnet M is pivoted at C, and normally held in the position shown by a spring S. Projecting downwards from the armature is a trigger T for holding in the raised position the arm A. The latter is pivoted at W, and has a projection J extending downwards, so that on being released by T it comes within the domain of a pin X mounted on the face of a wheel I. Attached to the arm A is a small block of steel R, shaped so as to resemble an inverted Λ.

Should an impulse be received by the electro-magnet M, the armature is attracted and the trigger T releases the arm A which instantly falls, and a pin X mounted on the wheel comes within its path.

Assuming now that the hands of the clock are slightly behind the twelve o'clock mark of the dial, then the pin X will be driven ahead by the Λ of the arm A, and the clock brought to time. Again, should the hands be ahead of the correct position, the pin X will be retarded slightly and the clock is corrected. A pin P_1 projecting from the side of the hour wheel engages the end of the fallen arm J, raising it sufficiently for the trigger T to retain it in the reset position.

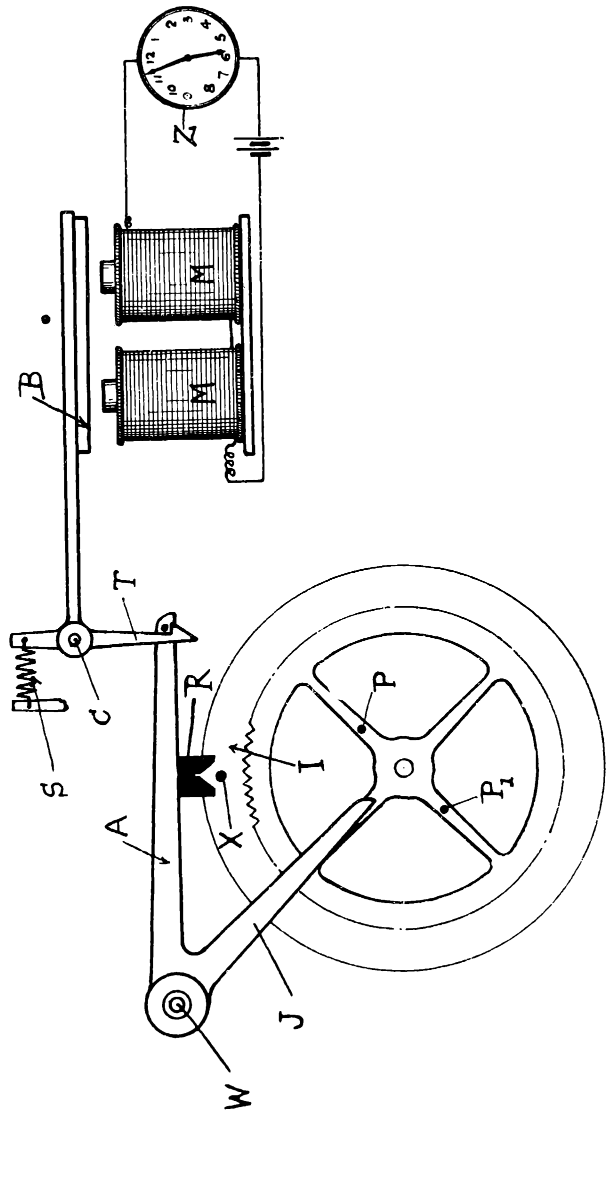


FIG. 57.—Hipp's Synchronising System.

By employing a pair of contact springs operated by the two pins PP_1 projecting from the hour wheel, the circuit is completed and the system synchronised once every six hours.

The satisfactory working of the system depends entirely on the time-keeping qualities of the standard clock Z, and its use is generally restricted to inferior clocks of the pendulum variety, either spring or weight driven.

Modern Synchronising Systems.

In many of the modern systems of electric clocks, provision is usually made to include in the circuit some form of synchronising mechanism for correcting at regular intervals any error in the time rates of the secondary clocks. Generally speaking, the principles involved in each system are identical, but the mechanical arrangement of details differs, and for this reason it has been thought advisable to include here a description of a few synchronising systems.

Of recent years the mechanism required for the propulsion of the hands of turret clocks has undergone a change—almost revolutionary, as far as electrical movements are concerned. The introduction of the "waiting train" movement by Messrs Gent & Co., of Leicester, marks a new era in the history and progress of electrical turret clocks. This system has many novel features, inasmuch that the hands are driven by a powerful "motor pendulum," the vibration of which is maintained by electro-magnetic agency.

The pendulum, through a simple arrangement of gears, propels the wheelwork from which the hands of the clock derive their movement, the pendulum being given a gaining rate. At a predetermined instant the mechanism of the clock movement automatically raises a pawl, disconnecting temporarily the pendulum from the wheelwork, until such time as the connection is again restored by a half-minute impulse transmitted from a master or synchronising clock operating an electro-magnetic releasing gear. The temporary pause of the wheelwork has earned for itself the trade term of "waiting train" movement.

In practice this system has been very successful, and one instance of its employment may be cited for the driving of the hands of the 25-ft. dials of the Royal Liver Building at Liverpool.

The transmitter operating in conjunction with the "waiting train" movement may be an ordinary type of master clock sending out half-minute impulses, and in a great number of cases it is situated in a room at the base of the tower. When this plan is adopted the master clock is unaffected by vibration and other disturbing elements.

Another characteristic of the "motor pendulum" is its maintenance by an electro-magnet, the current for the energising of which is controlled by a "Hipp" contact device. Contact is only completed and hence current drawn from the source whenever the pendulum seeks assistance. Should the pendulum experience any unusual resistance, it may obtain sufficient assistance by the completion of the circuit through the "Hipp" device as often as desired. In other words, the latter acts as an electrical governor.

The "Pulsynetic" System. (Waiting Train Movement.)

Fig. 43 represents the essential features of this impulse release movement as suitable for turret clocks.

The crutch or pendulum rod P has pivoted to it at X a pawl B engaging the teeth of the ratchet wheel W. A projection on the ratchet wheel W at Y carries a pin O. The latter in the course of its path raises the end of the detent A, which is pivoted at V and has a projection J extending upwards. The descent of the detent is gauged by a stop.

Situated above the end of the arm J is an armature F, also pivoted at T. The portion G of the armature lever is set so as to allow of the escape of the end J when the portion F is attracted by the electro-magnet E. Normally, when the projection J rests against the stop, the pin O is approaching the highest position of its path, engaging later the end of the lever A and raising it until the portion J has moved to one side sufficiently for the end G of the pivoted armature to drop, and assume the position shown in Fig. 43.

By this time, however, the lever A has engaged the end H of the pawl, and has lifted it clear of the teeth of the ratchet wheel, so that any further progression of the wheel W becomes impossible. The pendulum, however, continues to swing idly seeking an impulse less frequently than before.

Matters are so arranged that the "motor pendulum" has a

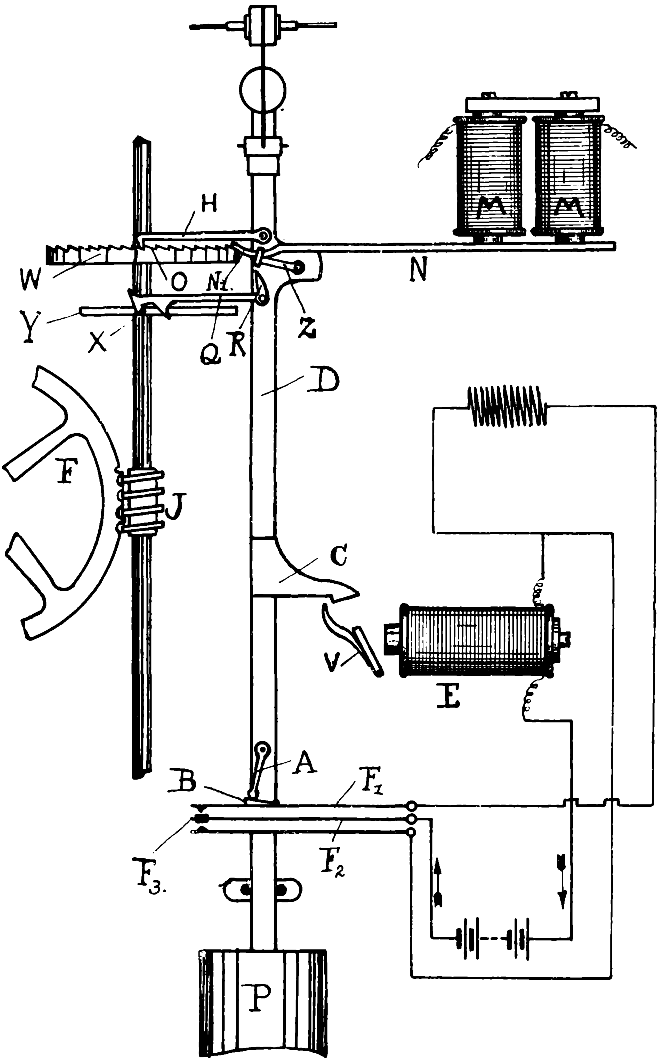


FIG. 58.—" Pulsynetic " Waiting-Train Movement.

gaining rate. It has now to await the reception of the impulse transmitted from the master clock at the half-minute or minute, as the case may be. The impulse now energising the electro-magnet E, the armature F is attracted, releasing the end of J, thus allowing the arm A to drop, and consequently the pawl B. The next swing of the pendulum pulls the wheel W one tooth forward, bringing the hand of the clock to time.

At about twenty-seven seconds to the half-minute the pin O again raises the arm A, and the pendulum motor becomes inactive until the whole system of levers is released by the impulse transmitted exactly at the half-minute by the master clock. About fifty-seven seconds to the minute the pin O once more raises the arm A, and the cycle is repeated.

The wheelwork of the clock is driven through a system of worm gearing from the arbor Z. By the adoption of worm gearing the power exerted by the pendulum is very great and also efficiently utilised.

Another form of the "waiting train" system is shown in Fig. 58, and differs very much from the preceding movements in mechanical details. The central idea, however, has been retained of driving the hands of the turret clock for a given period by a "motor pendulum," and then allowing the latter to become automatically inoperative for a short interval until released by the impulse from the master clock.

The secondary clocks are driven for a short period by an electro-motor, the duration of such periods being less than that of the periodical intervals of the impulse currents from the master clock. The motor is so arranged that it produces a slow motion, and in special cases the motor is supplanted by an electro-magnetically driven pendulum P (Fig. 58), the vibration of which is maintained by means of an electro-magnet E. An armature V of the latter imparts an impulse by engaging a pallet C on the crutch D each time the swing has diminished sufficiently for a finger A to depress a notched block B, and close the circuit of an electro-magnet through contacts $F_1F_2F_3$. The pawl H on the pendulum drives a wheel W on the worm spindle J, which drives the minute wheel F.

Before an impulse is received from the master clock, the pawl H drives the wheel W until it falls into a space O, from which a tooth has been omitted, the pawl then swings idly with the pendulum until the next current impulse is received and energises the electro-magnet M. The armature N being attracted, the arm N_1 lifts a pivoted catch Z, allowing a second pawl Q pivoted to the crutch to drop, so that it engages a pin X on a second disc Y on the worm spindle and as the pendulum swings, rotates that spindle, permitting the pawl H to continue driving for another period. During this movement

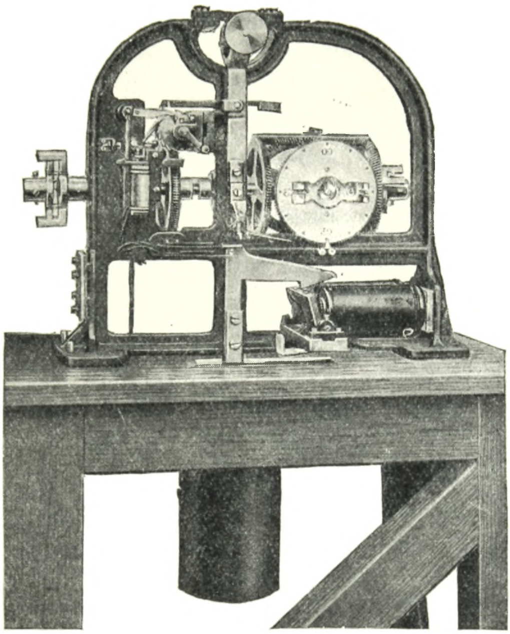


FIG. 59.—The " Pulsynetic " Waiting-Train Movement.

the pin X lifts the notched extremity of the pawl Q, so that its arm R is again engaged by the catch Z.

In a modification, however, the electro-magnet is adapted to raise a movable tooth to bridge the gap in the wheel W when the current is received from the master clock.

The motion work and hands are made in accordance with the latest mechanical turret clock practice. The hand spindles when exposed to the weather are constructed with gun-metal bearings in lieu of steel, which entirely prevents rusting of the spindles. This is often the case with large mechanically driven turret clocks.

"The "waiting train" movements are made in four sizes:—

1. For driving four dials up to 5 ft. in diameter, or two dials up to 5 ft. 6 in. in diameter.

2. For driving four dials up to 8 ft. in diameter, or two dials up to 9 ft. in diameter.

3. For driving four dials up to 15 ft. in diameter, or two dials up to 16 ft. in diameter.

4. For four dials up to 20 ft. in diameter, or two dials up to 25 ft. in diameter.

The extreme flexibility of the driving power of the movements makes it possible for the mechanism to drive much larger dials than those stipulated. There is practically, however, no limit to the size to which these movements may be made. The "waiting train" movement is by no means restricted to the driving of the hands of turret clocks, but may be used successfully for the driving of recording instruments, advertising devices, and in fact for the operation of any slowly revolving apparatus.

The introduction of the "waiting train" has rendered possible electric-turret clocks of the largest dimensions, possessing going rates that cannot be surpassed by turret clocks mechanically driven.

J. J. Hall, Esq., F.R.A.S., probably the greatest living authority on horology, has expressed his admiration for the "waiting train" system.

The "Silectock" Synchronised Master Clocks.

The Silent Electric Clock Co. have devised a form of synchronised "master clock," enabling an entire system of secondary clocks to register Greenwich mean time.

The daily time signal transmitted by the General Post Office causes an electro-magnet to "zeroise" the count wheel of the master clock by a simple cam mechanism.

In the ordinary course of events the mechanism will not affect the count wheel at all, but should the clock require correcting, the count wheel is actuated to such an extent that the clock is brought to time.

By the addition of an ingenious mechanical device the clock is automatically cut off from receiving a stray signal, except within a space of a minute and a half, during the time the Post Office line is clear and the signal should appear.

Provision has also been made for the master clock to receive the hourly signal from The Standard Time Co., of London, or for the reception of any other hourly signal that may be transmitted.

The Post Office standard sub-chronopher control clock, when installed in provincial post offices receives the daily time signal from London, and then distributes it to their own circuit of local offices.

Synchronisation may be carried out by another method: the armature of an electro-magnet arrests the progression of the count wheel for exactly the length of time it has gained since the previous correction.

Time Transmission in England.

About the middle of last century accurate time signals were first transmitted from Greenwich Observatory, when the clock at London Bridge Station and the public clock at the old Post Office in Lombard Street were connected with the mean time clock of the Observatory.

Messrs Dent, of Cockspur Street, were instrumental shortly afterwards in connecting up their huge "time ball" with Greenwich, and this ball has daily fallen at 1 P.M. for about seventy years, its release being effected electrically by a signal from the above Observatory.

The Postmaster-General, some years later, decided to transmit the signal to all the principal railway stations and post offices in the country.

To-day the signal received from Greenwich at the General Post Office is automatically transmitted to all parts of the country by a chronopher, whereas in 1840 a member of the Observatory staff used to visit the London clockmakers every Monday morning and supply them with Greenwich mean time, by means of a chronometer duly synchronised at the Observatory.

Time Transmission in America.

The transmission of "time" and the synchronising of clocks in America has now reached a state bordering on perfection, and the practice is conducted on an extensive scale. Each day a signal is transmitted from the United States Government Naval Observatory the instant that the sun reaches the seventy-fifth meridian, and is received by every telegraph office in the country. By this means it is possible to synchronise clocks in outlying districts.

A leading telegraph company of the U.S.A. has now a department entirely devoted to the business of selling accurate "time," and have of necessity equipped their offices with many ingenious and delicate instruments. The central idea is to transmit "time" from a master clock, which in turn is synchronised daily from the Washington Observatory. In many of the larger cities, viz., Chicago, New York, San Francisco, etc., are located auxiliary master clocks, the latter being in turn electrically connected to the master clock at the main office.

The auxiliary master clocks synchronise a special form of self-winding secondary clock which is supplied to the general public, and is operated by dry cells. The self-winding secondary clocks are thus synchronised by having their hands set forward or retarded, and are thus brought to "time."

Hope-Jones and Bowell's Synchronising Mechanism.

In Fig. 60 two electro-magnets MN are set in the vertical plane, and pivoted at V is a forked lever L. One end S acts as an armature and is free to play between the poles of the magnets. The other end of the lever L engages a pin P projecting from the rod R, forming part of the frame F. The frame F is set in such a manner that whenever the rod R is moved either up or down, the lower ends AB grip the suspension spring T of the pendulum X, and change the free length of the latter. This has the effect of varying the rate of vibration of the pendulum.

By the upward or downward movement of the frame F the pendulum may be set with either a gaining or losing rate.

The current exciting the electro-magnets MN is controlled by a simple form of commutator G, which is attached to the arbor of one of the wheels of the clockwork and rotates with the latter.

The commutator has two segments, JH, insulated from one another by the material W, the whole being mounted on the arbor D.

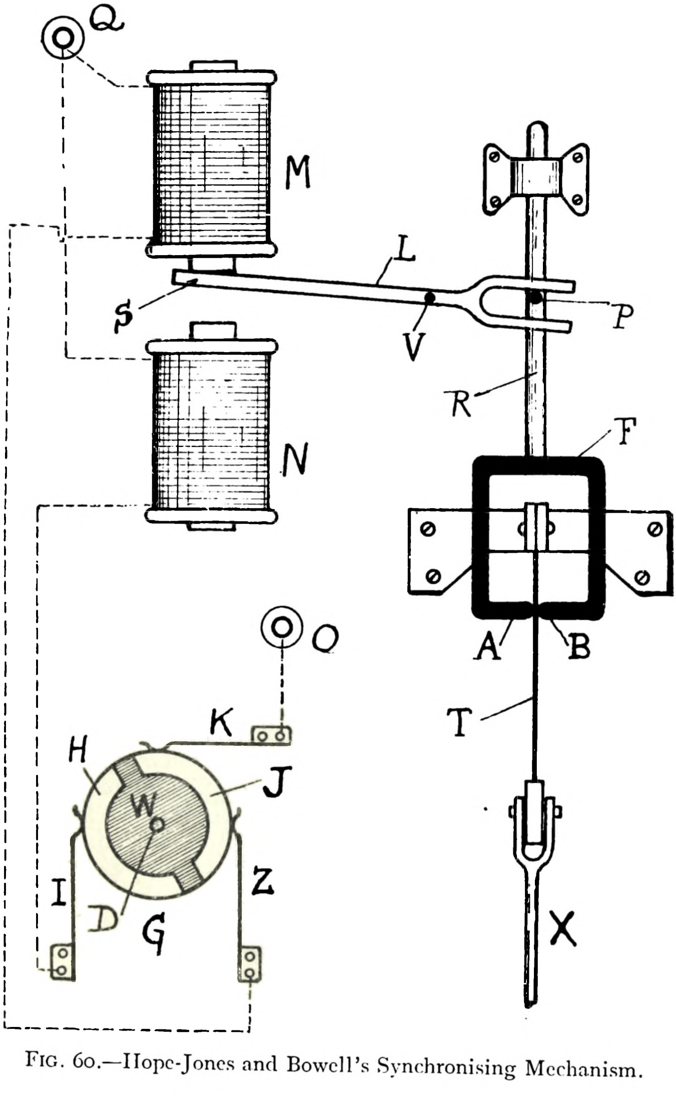


FIG. 60.—Hope-Jones and Bowell's Synchronising Mechanism.

Contact with the segments and the electro-magnets MN is established by means of three contacts IZK, the latter being connected to the terminal O, while one end of each coil of the magnets MN is run to the terminal Q.

As the commutator rotates with the wheelwork, the various contacts and segments will engage each other, and the impulse received from the master clock will pass by way of these paths to the electro-magnets.

When in operation the master clock transmits an impulse at a predetermined instant. Should the clock to be synchronised be either fast or slow, the commutator G will be set in a relative position to the contacts IZK.

Supposing the clock to be slow, then the commutator will assume the position shown in the figure, and the impulse will pass from O through the contact K to the segment J, hence to the electro-magnet M, and then to the terminal Q. Since the impulse has excited the electro-magnet M, the armature S will be attracted and the pin P at its outer end will be forced down. This means that the frame F has now been lowered, and the points A and B instantly change the effective length of the pendulum. In other words, the pendulum has now been shortened and consequently it will vibrate faster, thus giving the clock a gaining rate.

At the next impulse the opposite may be the case—the clock may have gained considerably. Then the commutator will have changed its position, and the contacts affording a path for the current to excite the electro-magnet N, will draw the armature S down and raise the end L. The frame having been raised a given distance, the points A and B once more change their position, and the free length of the pendulum becomes once more changed. In this instance it will be increased and the clock will lose, so that in a short period of time it will have a correct going rate. The limits of variation permitted by the moving frame F are only those essential for accurate time-keeping.

There is another arrangement designed for electrically synchronising the hands of large turret clocks which may be driven by any agency, patented by these inventors in 1895. A form of gap switch is conjointly operated by a dial movement which receives its impulses from a standard clock, and by the centre wheel of the clock movement itself.

An electro-motor through a reducing train of wheels turns the centre wheel, which has attached to one of its arms a part of the gap switch. Mounted on the arbor of the centre wheel is a ratchet wheel carrying through the medium of a spiral spring an arm, which normally rests against a stop projecting from the face of the ratchet wheel. The latter is propelled by a pawl actuated by an armature of an electro-magnet. Impulses transmitted from a master clock propel the ratchet wheel at regular intervals until the arm overtakes the contact stud on the centre wheel and completes the circuit.

The electric motor now runs and turns the centre wheel forward until the contact between the stud and arm become separated, when the motor stops through the circuit being opened. Really in this arrangement the electro-magnetic mechanism governs the train of wheels under ordinary working conditions through the agency of the gap switch; and in the event of the synchronising current failing at any time, on the restoration of the current the clock will be synchronised and brought to time.

To reduce as much as possible the frequent starting and stopping of the electric motor, special electrical appliances may be placed in the motor circuit to reduce the speed of the motor, such as "rheostat," composed of carbon plates inserted between the stop on the centre wheel and the arm of the ratchet wheel. When the plates are pressed tightly together the resistance becomes reduced, but when the stop and arm have become slightly separated, the plates likewise press less closely and the resistance increases. This has the effect of slowing down the speed of the motor until the arm overtakes the plates once more, and pressing the plates into close contact, causes the resistance to become reduced and the speed of the motor increased.

CHAPTER VIII

MISCELLANEOUS ELECTRIC CLOCKS

PRACTICALLY all the clocks that have been described in the preceding chapters rely on a pendulum for their time-keeping qualities; that is, the pendulum is a form of regulator. But electric clocks devoid of pendulums have been constructed.

In 1862, Koosen, a native of Saxony, exhibited a novel form of clock in which a small electro-motor acted as a regulator in place of the usual pendulum. By equipping the motor with a very sensitive governor of the centrifugal type which actuated a switch, it was found possible to keep the speed of the motor almost uniform by opening and closing the circuit. The spindle of the motor was geared to the wheel-work of the clock, and the time rate of the clock was found to be fairly good. Koosen's idea of control has been followed up and modified by numerous inventors.

Aron and Wiener devised a method whereby a clock may be driven by a simple form of electro-motor acting through a light mainspring. Matters are so arranged that the current is automatically switched off at intervals. But the motor possesses sufficient momentum to keep it running during the currentless intervals, since it is fitted with a flywheel. The rotation of the flywheel is maintained by electrical agency as long as the circuit remains closed by a make and break switch.

A ratchet wheel through a double-toothed pawl actuates the switch, also the ratchet wheel being driven by a worm from the motor spindle winds up the mainspring, one end of the latter being attached to the wheel, whilst the other end is fastened to the arbor driving the clockwork. A few teeth of the ratchet wheel are movable, and are so constructed that they may move radially in a slot formed in the ratchet wheel. As the mainspring is wound by the electro-motor, the outer coil of the spring engages a pin and the movable teeth are drawn inwards.

When this portion of the wheel arrives opposite the worm on the motor arbor, the teeth have been withdrawn beyond the influence of the worm, and propulsion ceases and the switch remains open. The momentum stored in the flywheel now maintains the speed of the motor until the mainspring gradually unwinds itself, and expanding the spring, causes the movable teeth of the ratchet wheel to be pushed out and again engaged by the worm. Immediately the worm commences to rewind the spring and the switch is again closed, enabling the motor to receive fresh energy. This action is repeated periodically. The energy taken from the current source and the momentum stored in the flywheel ensures the continuous running of the motor, resulting in the time rate of the clock being fairly accurate.

Murday's Electrically Driven Balance-Wheel Clock.

In Murday's arrangement for maintaining the oscillations of a balance wheel, the impulses are imparted to the arbor of the balance wheel by an armature actuated by an electro-magnet.

Attached to the oscillating wheel is a simple contact device of the "Hipp" variety which depresses a spring contact, and allows current to flow through the electro-magnet whenever the arc of oscillation becomes reduced beyond a certain point.

Fig. 61 shows diagrammatically the movement of the clock wherein the balance wheel W is mounted on the vertical arbor S, the balance spring Y having one end rigidly fastened to the framework T, while the other end is attached to the balance wheel arbor S.

Attached to one of the arms of the wheel W is a wiper A, which after a predetermined interval, drops into the notch of the block C and completes the contact with D by depressing the spring E.

An electro-magnet F, now energised, attracts the armature G having a bent rod H, the latter imparting an impulse to the member I, which is mounted on the arbor S. In this manner the balance wheel W receives an impulse and is thus enabled to maintain its oscillation, only seeking fresh impulses from the electro-magnet whenever the arc of oscillation becomes greatly reduced. The wiper A then fails to pass over the block C.

The oscillatory motion of the arbor S affords a convenient means of operating the hands of the clock by the intervention of the arm J and a Y-shaped lever. The portion K of the

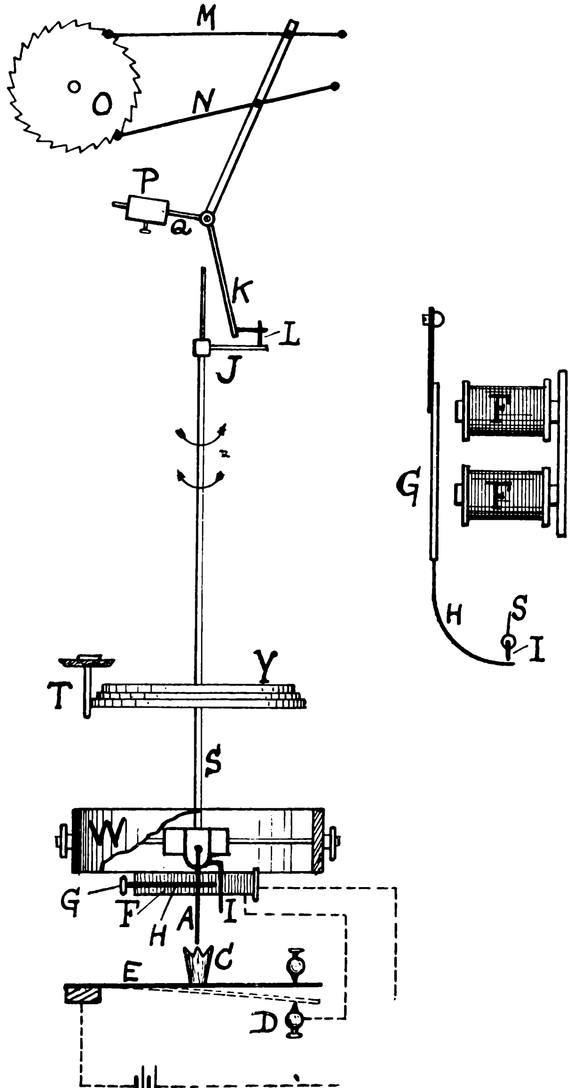


FIG. 61.—Murday's Electrically Driven Balance-Wheel Clock.

lever is forked at its lower extremity and embraces the pin L, so that the partial rotation of the arm J naturally causes L to vibrate. This movement is converted into a rotary one by the aid of the pivoted pawls M and N, which in turn alternately propel the ratchet wheel O of the clockwork.

A counterpoise P is introduced on the third arm Q, so as to make the movement of the lever K as uniform as possible.

Reid's Electric Clock.

Reid suggests that the vibration of a torsion pendulum may be maintained by means of electro-magnets acting on an armature situated beneath the balance wheel, and energised whenever a system of contacts are completed by the rotation of a ratchet wheel. The ratchet wheel receives its movement from a pallet fastened to the pendulum ribbon. The pendulum ribbon A (Fig. 62) has suspended from its lower end the balance wheel W; also beneath it is the armature B, which rotates within the field of the pole pieces PP_1 of the electro-magnets MM_1. Mounted on the upper portion of A is a small pallet or pawl C for the propulsion of the ratchet wheel D. Engaging into the teeth of the ratchet wheel is an ivory roller I mounted on the pivoted arm H. Each time that the pawl C propels the wheel D one tooth forward, the roller I will be raised with the arm H. Advantage is taken of the movement of the arm H to complete the contact between Q and O, thus energising the magnets MM_1.

By the attraction of the armature B the disc W is kept oscillating, and the wheelwork of the clock is driven directly from the wheel D. By means of a sliding frame the effective length of the torsion pendulum becomes capable of adjustment by simply changing the position of the suspension head.

In a modification of the electrical arrangement for maintaining the oscillation of the pendulum, the balance wheel W carries a simple form of split commutator, to which is connected the ends of a coil of wire. Two light conducting brushes bear on the sections of the commutator and afford a convenient means of conveying the current to and from the coil. The coil will be caused to oscillate within the field of the pole pieces of two permanent magnets; but with this arrangement, however, the current is constantly flowing through the circuit.

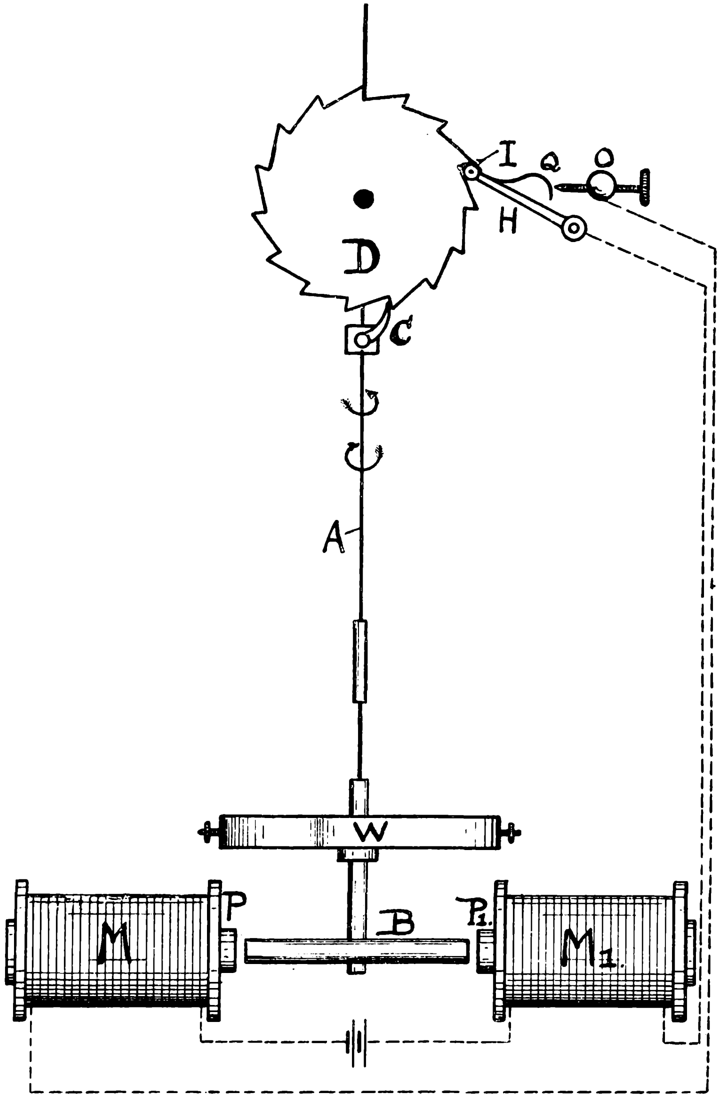


FIG. 62.—Reid's Electrically Driven Balance-Wheel Clock.

The idea of the commutator is to reverse the direction of flow of the current at each oscillation.

Alternating current may be utilised in the operation of the clock by the introduction of two coils to replace the permanent magnets. The coils would have to be placed in series with the coil of the balance wheel if this expedient is decided on.

Haddan's Electric Clock.

Haddan's arrangement, patented in 1906, is yet another form of the balance-wheel movement wherein the oscillations of the wheel are electrically maintained. The clock is self-contained, and very little energy is required to drive the mechanism; in fact, it is reduced to a minimum by mounting the electro-magnet on the balance wheel.

As the balance wheel oscillates from side to side, the two extremities of the electro-magnet pass within the vicinity of a fixed armature, and it is in this position that the current is permitted to energise the electro-magnet, the current for excitation being conveyed to the electro-magnet by means of fixed contacts (springs) engaging pins projecting from the face of the balance wheel. A small cam oscillating with the arbor of the balance wheel, actuates through a roller a bell-crank lever, the outer end of which has a rod extending downwards, and propels a ratchet wheel one tooth forward each time the bell-crank lever is raised by the cam.

A small worm gearing into a wormwheel suffices for the propulsion of the hands.

Clocks Controlled by Wireless Waves.

The possibilities of the transmission of time by Hertzian waves are being realised daily, and any lengthy discussion of the wireless apparatus used would be quite out of place in the present treatise.

From recent experiments, some very promising results have been obtained by the transmission of time by wireless signals from centralised wireless transmitting stations, some of the energy radiated into space from the transmitting station being received by suitable instruments, thus making it possible to synchronise a system of electric clocks.

By the transmission of wireless time signals it is quite an easy matter for a ship to locate her position in terms of latitude and longitude, if equipped with a receiving wireless outfit.

The Eiffel Tower and other "broadcasting" stations have adopted the practice of transmitting time signals daily. These signals are readily received by the simplest receiving apparatus and the time-keeping qualities of any timepiece may be easily checked.

The Reithoffer and Morawetz System.

One of the earliest systems of wireless electric clock control was suggested and patented by Reithoffer and Morawetz in 1906.

On referring to Fig. 63, it will be observed that the system is divided into two sections: the transmitting portion of the system situated at A, and the receiving portion of the system with the secondary dials shown at B.

It will perhaps be more convenient to describe the transmitting and receiving apparatus separately, and then the principles involved when in operation.

A standard or master clock closes periodically a switch D controlling the current flowing from the battery C to excite the primary coil P_1 of an induction coil. The adjustable resistance R_1 affords a ready means of controlling the current flowing through the primary coil, whilst an interrupter I ensures that the spark shall be as uniform as possible. Included in series with the primary coil P_1 is an electro-magnet M, also the high resistance X_1 and the tapping transmitter T. The latter device prevents sparking at the contact points whenever the switch D is opened by the master clock.

To produce the essential wireless waves for controlling the distant secondary clocks, the secondary coil S_1 of the induction coil has its ends connected to the balls Y, which are situated a small distance apart. Across the intervening space pass a series of electric sparks which is the seat of the radiated wireless waves.

To render the transmitter more efficient, one of the balls Y is connected to the earth plate W. The essential details of the receiving mechanism of the transmitted waves is shown also in Fig. 63 at B.

A specially pivoted mercury switch U closes the circuit and allows the electric oscillations received by the aerials XX to

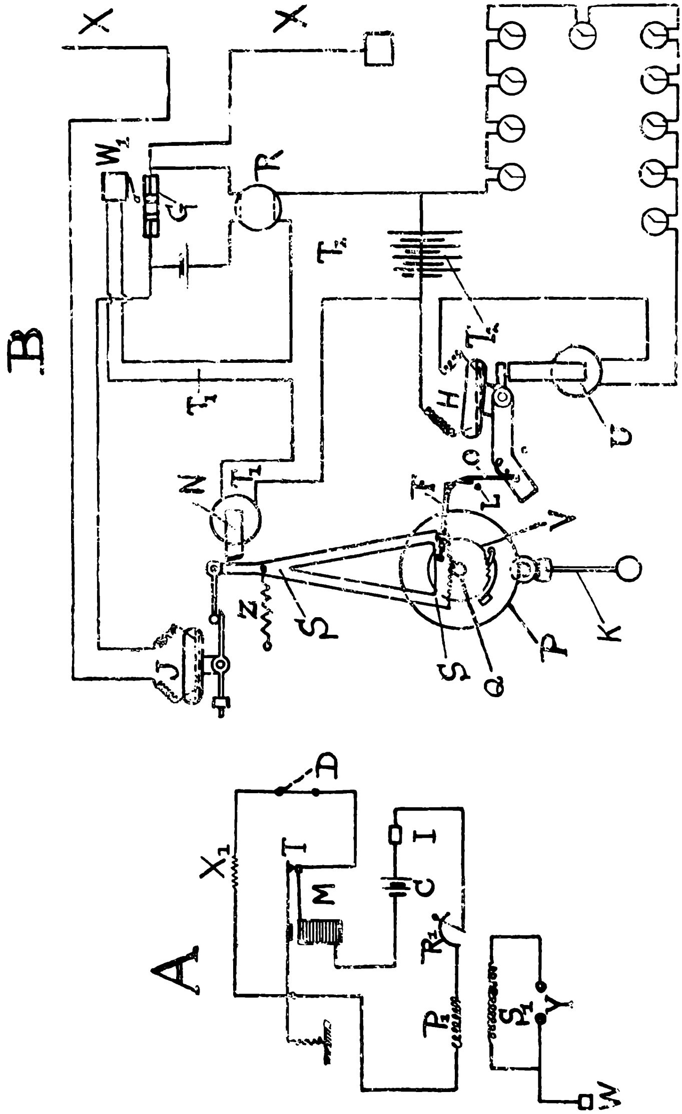


FIG. 63.—The Reithoffer and Morawetz System for Controlling Clocks by Wireless.

affect the coherer G, which then actuates the relay R, closing a local circuit T_1 containing a tapper W_1. Included in the same circuit is an electro-magnet N which attracts the toothed sector S causing an arm attached thereto to depress the mercury switch J, and thus open the circuit so that no further oscillations affect the coherer. The lower end of the pivoted sector S when attracted, propels the spur wheel Q together with the ratchet wheel V. Mounted on the sector S is a detent F which disengages the pawl O from the stop L, causing the rocking switch H to descend and temporarily close the circuit T_2. The secondary clocks are inserted in the latter circuit, also an electro-magnet U for breaking the circuit whenever it is completed.

A spiral spring Z slowly returns the sector to its normal position just before the reception of the next wireless impulse.

It will be noted that the sector merely supplies potential energy to affect the rotation of the disc P, which has to be controlled by an escapement wheel and pendulum K.

Boult's Electric Clock Controller.

A. J. Boult, in 1910, patented a peculiar device for controlling a number of clocks by causing a ball of magnetic substance to travel periodically along a fixed path. The ball by attracting at a given point along its path a pivoted permanent magnet closed a system of contacts, thereby permitting of the energising of an electro-magnet, which attracted and endowed the ball with sufficient energy to continue its path.

In Fig. 65, E represents an electro-magnet set with its poles uppermost. Situated to the right of the magnet E is a permanent magnet M centrally pivoted, and carrying at its outer end the contact T for engaging the fixed contact R.

Arranged to travel in a circuit or path above the poles of the magnets ME is the "magnetic ball" B. When the ball assumes the position shown, it attracts the poles of the permanent magnet M, causing T to become depressed and thus complete the circuit at T and R.

Current now flowing excites the magnet E, causing the ball B to be attracted from the poles of the permanent magnet M, but at the same time endowing it with sufficient energy to continue its journey around the track.

When the ball again comes within the vicinity of the magnet M the contacts T and R are again closed, the ball receiving a fresh impulse. In a modification of this invention

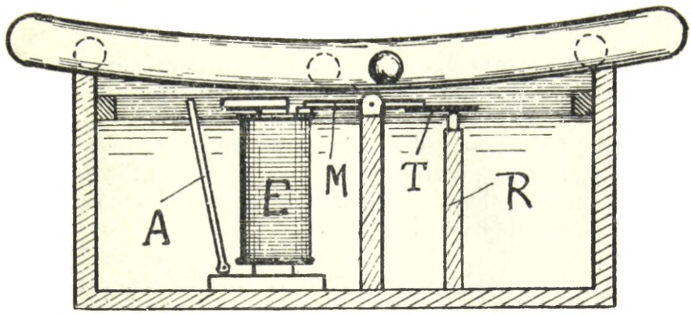


FIG. 64.—Boult's Electric Clock Controller.

matters are arranged slightly different. The ball B is enclosed by a curved glass tube in which exists a partial vacuum. By mounting the tube over the poles of the magnets the

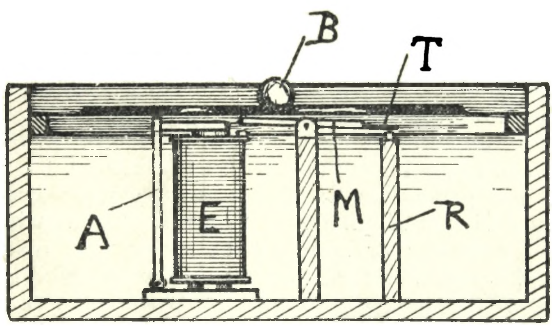


FIG. 65.—Boult's Electric Clock Controller.

ball oscillates freely from end to end of the tube (Fig. 64). To close the contacts necessary for the transmission of the controlling current to the secondary clocks a pivoted armature A with contact points may be introduced, the armature being attracted each time the electro-magnet E is energised, thereby affecting the closing of the contact points. A small spring returns the magnet M to its normal position, so as to open the circuit at T and R.

The "Magneta" Electric Time System.

Wheatstone was acquainted with the principles involved in the generation and utilisation of magneto-electro currents for the electrical transmission of time signals.

To the "Magneta" Time Co., however, must be given the credit of developing and also for the invention of the ingenious mechanism, by which it has become possible to operate any number of secondary or impulse dials from a central or master clock.

The "Magneta" system requires no batteries nor any outside source of current, and consequently there are no contact points to give trouble sooner or later. The master clock is the central point of each installation, and by it the whole system of secondary clocks is actuated and synchronised, and the highest time-keeping qualities are secured by the simplicity of construction of the various parts of the system.

In construction, the master clock is peculiarly massive and of good design, and the mechanism may be relied upon to be operating with the same precision at the end of a quarter of a century as when first erected. The master clock, which is either hand or electrically wound at regular intervals, generates the electric impulses for operating the mechanism of the dials, and are constantly equal in strength and duration.

For the generation of the magneto-electric currents a specially designed alternator or "inductor" is attached to a weighted regulator or spring-driven clock, and once every minute the movement of the "regulator" causes the iron cylinder of the inductor to turn a quarter of a revolution. This movement causes an alternating current to be generated in a coil of wire forming part of the "inductor."

The movement of the hands of the secondary clocks is simultaneous with movement produced on the iron cylinder of the "inductor."

It will at once be evident that since the source of current is the master clock itself, the electrical circuit must be a closed one.

Fig. 66 represents diagrammatically the "Magneta" system. The small arm A is connected to the mechanism of the weight or spring driven regulator C, and through the medium of the light rod R it causes the arm B to rotate the cylinder E of the "inductor" J through 90°. For the production of the magnetic field necessary for the generation of electro impulses the

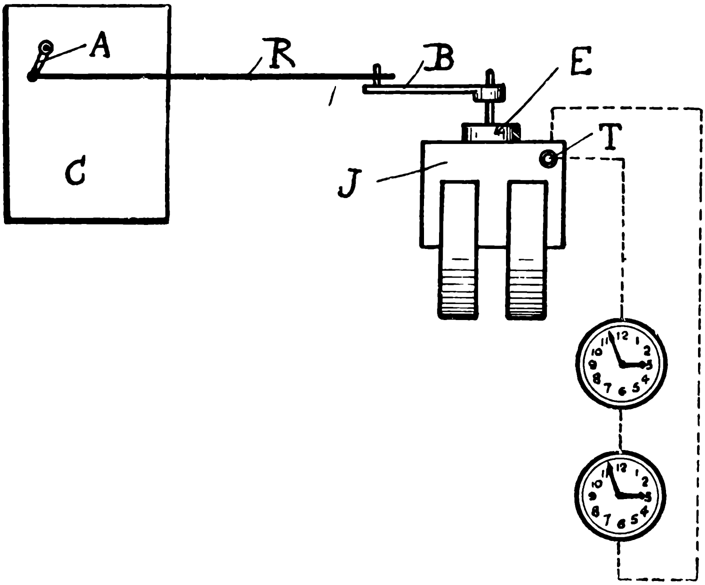


FIG. 66.—The "Magneta" Electric Clock System.

permanent magnets P are used. The secondary clock circuits are connected to the terminals T, one being situated on either side of the "inductor."

For marine purposes the "Magneta" Co. have devised a special form of master clock which actuates any number of secondary clocks. By a simple device attached to the master clock the time shown by all the clocks on board the vessel can be corrected simultaneously, thus doing away with the necessity for an officer going his rounds for the daily winding and setting of each individual clock. The "Orsova," "Olympic," "Britannic," "Mauretania," and "Alsatian" are a few of the many ships equipped with this electric time system.

Among many other functions that the "Magneta" may perform is the ringing of a system of electric bells, or even "time stamps" may be automatically actuated. Existing turret clocks may be synchronised by a "Magneta" master clock, or if necessary, the standard secondary clock movement may be substituted for the mechanical clock movement. The system has been adopted by over 170 of the leading hotels throughout Europe. At the Imperial Hotel, London, there are in daily use 400 clocks actuated from one master clock.

It might be interesting to place on record that the general survey of electric clocks throughout Europe (drawn up for the Rt. Hon. Sir J. G. Ward, P.C., K.C.M.G., Postmaster-General, Wellington), which was laid on the table of the House as a parliamentary paper, recommended "Magneta" for Government use as being the most perfect apparatus.

We append also the Report of the late Sir William H. Preece, K.C.B., F.R.S. :—

"All systems of Time Distribution by Electricity, with which I have had any practical experience, have been dependent on batteries, on intermittent currents, and on the maintenance of clean mechanical contacts. Batteries, however, become exhausted and contact points get dirty. Hence much personal supervision and expert aid are necessary to obtain correct working and secure true time.

"The 'Magneta' System removes these two weak points. The battery is replaced by an alternator, and the circuit is never broken. There are no sparks and no contact points to get dirty. The alternator is worked by the mechanical energy of the falling weight of a Master Clock. Every minute this weight falls the fraction of an inch, and by doing so turns the armature of the alternator in a strong magnetic field and generates an electric current, which throbs through the whole circuit and propels simultaneously every minute hand of every secondary clock in the circuit to the next minute. There is no difficulty in doing this through fifty miles of line and working 500 clocks. Synchronous time is thus provided if the propelling action in each clock is maintained in working order. This is a mere mechanical action which differs little from that in existing use and is much simpler.

"The system is trustworthy. There is little to maintain and nothing to renew. Occasional lubrication is of course desirable, as it is in common clocks; but the secondary clocks require no winding, setting, or repairs. I have formed a very high opinion of its practical merits."

The "Pulsynetic" Marine Transmitter.

A system of marine "Pulsynetic" impulse clock consists of a master clock of special construction, provided with an

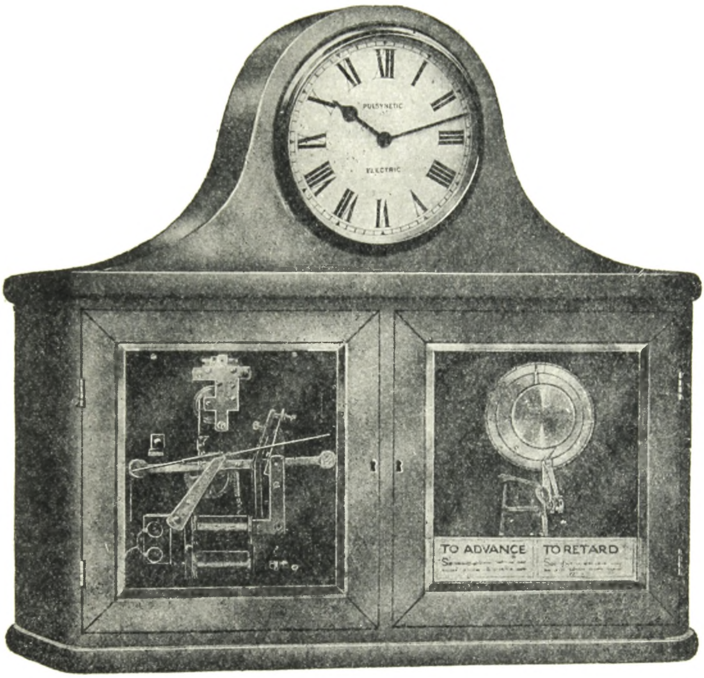


FIG. 67.—The "Pulsynetic" Marine Transmitter.

automatic "advance" and automatic "retard" mechanism, and an unlimited number of secondary impulse clocks connected in "series" with a battery. If desired, a special form of warning bell for giving timely warning when the battery requires attention may be installed.

The transmitter consists of a strong and reliable half-minute impulse mechanism mounted within a cabinet, and provided with a silvered "pilot" dial to show the time indicated by the ship's "Pulsynetic" clocks. The special feature of the transmitter is the automatic "advance" mechanism which is provided, in addition to the usual "retard" mechanism also operated automatically.

For advancing the clocks when sailing eastward, the same automatic self-controlling contact which operates the clocks when working normally is employed. This contact is controlled by a "fly" action, which allows it to contact in comparatively quick succession — approximately once per second instead of the usual half-minute. The automatic action does away with the possibility of error due to imperfect contact which might occur under the old push-button advance system, and so put the secondary clocks out of step.

The automatic setting functions as follows: To advance the ship's time, say thirty-five minutes, the pointer of the "setting dial" is turned to the figure 35. The "advance" lever is then depressed, and seventy contacts are automatically made by the transmitter (one for each half-minute), and the clocks are thus set to time.

To "retard" the clocks it is only necessary to set the pointer to the desired number of minutes and press the "retard" lever, and the ship's clocks remain "held" until the desired number of minutes have elapsed. At this point the ship's clocks are then automatically restarted.

Chronoscopes.

When it is desired to measure very small intervals of time it is customary to use an instrument called the chronoscope. This instrument is very ingenious, but at the same time sufficiently accurate to determine the velocity at which a projectile leaves the barrel of a gun. Professor Wheatstone's arrangement consisted of two screens placed a known distance apart but situated in the path of the projectile. Each screen has its surface covered with an insulated wire in such a manner that the network of wire on each screen forms a separate circuit, and, of course, is in electrical connection with the instrument.

Supposing the wire on each screen to be severed by the projectile, then the successive cessation of the independent currents may be recorded electrically on a chart or card moving at a known velocity. Unfortunately, however, since the time elapsing between the passage of the projectile through each screen must be measured by reference to some uniform movement, it has been found in practice rather a difficult problem to produce a continuous movement.

In the Navez pendulum chronoscope a bold attempt was made to remove many of the defects that former instruments possessed, but nevertheless, this instrument was not entirely free of the evils to which chronoscopes are subjected. It was the idea of this inventor to compare the velocity of the projectile directly to that of the pendulum.

Although Navez's chronoscope has been extensively used its results are not strictly accurate for the following reasons :—

The "bob" of the pendulum encounters the resistance of the air during its oscillation, and it is almost impossible to calculate the amount of error arising from this interference. Since it is necessary to employ a contact breaker, there is naturally just the chance that the circuits are not interrupted at the same instant; also, as three electro-magnets are required for the instrument to function, it is feasible that the magnetic state of either may vary from one observation to another. This would naturally yield inaccurate results.

Again, since friction is the means adopted to operate the index, the latter may be effected by the force being too small or too great, causing the index in the first case to lag behind the pendulum, and in the second case to accelerate the index.

It has been suggested that the Navez pendulum chronoscope might have been rendered more serviceable by the introduction of direct observation, and recording same by the aid of an electric spark from an induction coil, or even noting the swing of a magnetic needle.

To describe the instrument briefly, it consisted of a special form of "contact breaker" for interrupting the two circuits at exactly the same instant; also a mechanism for restoring the contact at a given instant, after a second circuit had been broken.

The pendulum was of rather novel design, equipped with two electro-magnets and other accessories.

The chronoscope was exhibited at the International

Exhibition of 1862, and was briefly described in the Juror's Report, thus:—

"The pendulum is fitted with two electro-magnets; one used to hold it at one extremity of its oscillation by attracting a little piece of soft iron let in the 'bob'; the other to stop a very light aluminium index centred on the axis of the pendulum, and carried round with it by the light friction of a spring, until a current passes round this second electro-magnet, which then stops the index by attracting an iron collar fitted to its hollow axis, but allows the pendulum to continue its oscillations freely. A vernier on the end of the index allows the exact arc described in passing from the first to the second position of rest to be accurately read on a fixed graduated limb.

"Thus the interruption of the current through one circuit starts the pendulum and index simultaneously, and the establishment of a current in a second circuit stops the index, showing the arc traversed in the interval. It will readily be understood that the velocity of the pendulum in falling through various arcs can be determined by direct experiment.

"The speed of the projectile in this as in other chronoscopes is measured by the time elapsing between the successive fractures of two wires; but in the present case the measurement is indirect.

"The nearest wire screen forms part of a circuit which includes the electro-magnet used to restrain the pendulum; but the farther wire screen is not directly connected with either of the pendulum electro-magnets, but it is connected with the electro-magnet of the contact breaker.

"This electro-magnet carries an armature, which drops off when the circuit is broken, and falls on to a spring furnished with a contact point, adjusted close to some mercury in a little cup. The fall of the armature makes contact between the mercury and the spring, and by so doing completes a circuit through the second electro-magnet of the pendulum, and stops the index. Thus, when a ball passes through the two wire screens in succession, it first breaks the first circuit and starts the pendulum; it next breaks the second circuit and stops the index. The arc can then be measured, which corresponds to the time elapsing between the moment when the pendulum started and that when the index stopped. But this period of time depends on many elements:—

"1. The time required by the first electro-magnet to lose its magnetism.

"2. The time required by the electro-magnet of the contact breaker to lose its magnetism.

"3. The time occupied by the fall of the armature.

"4. The time required by the second pendulum electro-magnet to acquire sufficient force to stop the index.

"5. The time of flight between the two screens.

"The contact breaker is used to eliminate, by a separate observation, the first four of these elements, leaving the fifth, which is alone required. This is simply and easily effected by establishing all the circuits as before, and breaking the two wire screen circuits simultaneously. All the events will occur in the same sequence as before, except the rupture of the two circuits; and as all the other circumstances remain similar, they will occupy in the aggregate exactly the same time as they must have done in the previous experiment, and the index will be arrested after it has traversed an arc B measuring their duration; if then A be the arc traversed in the former experiment, the difference A-B will measure the time of flight between the screens in the first observation.

"This measurement is required to be reduced into seconds by calculations of an obvious character."

M. Harday, of Paris, introduced a recording chronoscope, an electric spark created by the secondary winding of an induction coil being the medium by which this was accomplished.

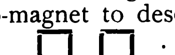
This instrument which is highly suitable for the measurement of same intervals of time, consists of a fairly large brass cylinder which is fixed and has wound around its circumference a band of specially prepared paper. A rotating axial arm, driven by clockwork and carrying a platinum point, outlines a circle as near as possible to the cylindrical surface of the paper.

To produce, as far as possible, a continuous movement of the clockwork, a novel pendulum arrangement driven from the axial arm is introduced. Another adjunct is an induction spark coil, the primary winding of which is connected with the necessary cells to the target or screen, while one of the wires leading from the secondary or high tension circuit is electrically connected to the rotating axial arm, the other terminal of the secondary winding being connected to the brass cylinder.

Under working conditions the primary circuit is closed and whenever this circuit is broken by the passage of the projectile, a spark passes between the ends of the secondary circuit, resulting in a hole being punched through the paper. So by this simple device the event is registered. If desired, a series of records may be obtained from a number of targets by installing a system of electro-magnets, the armatures of which cause the primary circuits of the targets to be restored.

When it is desired to record the time at which any scientific event takes place, such as the passage of a star, etc., an instrument known as a "chronograph" may be used.

M. Krille, of Denmark, produced an elegant apparatus consisting of a clockwork driven cylinder, the latter being controlled by a special pendulum governor, thus producing a fairly uniform speed. Stretched around the circumference of the cylinder was a piece of blackened paper. Bearing lightly on this paper were two fine points attached to the ends of two levers, the latter being fixed to a piece of mechanism which moves slowly in a direction parallel to the axis of the rotating cylinder. The two motions will cause the points of the levers to draw either helical or continuous lines on the blackened paper. Further, the two levers were each actuated by an electro-magnet which produced a slight translatory movement of the points along the blackened paper.

Now, the first electro-magnet received an impulse from a standard clock, causing the point of that lever, actuated by the electro-magnet to describe a broken line, but equally divided thus . The observer controlled the current to the second electro-magnet through the intervention of a key switch, and at the instant that the phenomena takes place, the closing of the key switch causes the electro-magnet to actuate the second lever, and its point then traces a wavy line on the blackened paper. From its position on the cylinder relatively to the first but broken line, it is possible to ascertain the instant at which the phenomena was observed.

A modification of the Krille chronograph was effected by a Swiss firm, who caused a strip of paper to move at a continuous rate by a weight-driven clockwork controlled by a fly governor. The paper in its course passed beneath two self-inking rollers, each roller being attached to an armature lever, and which in turn was controlled by an electro-magnet. One of the electro-magnets was placed in circuit with a standard clock, and on the reception of an impulse transmitted at regular intervals of one second, the roller of that armature lever will naturally describe a wavy line at each impulse.

Under normal conditions the two rollers will describe parallel lines on the paper, but since the circuit of the second electro-magnet is under the control of the observer whenever a record is made, the second roller will also describe a wavy line.

By comparing the second line with the first, it is an easy matter to determine the time at which the event took place; in fact, intervals of time less than one-tenth of a second may be measured.

The "Bulle" Electric Clock.

The "Bulle" clock is quite a new entry into the field of electrical horology, and is the production of MM. Marcel Moulin, Professor of Chronometry, Faculty of Sciences, Besançon, and Favre-Bulle, the inventor, who is a well-known horologist.

The essential mechanism of the clock consists of a pendulum which is virtually a coil of insulated wire; through the coil an electric current is established and interrupted at regular intervals by an ingenious contact device.

During its vibration the pendulum moves over a curved permanent magnet,* and the magnetic reaction set up between the permanent magnet and the electro-magnetic pendulum coil is the source of power by which the pendulum is kept vibrating.

Unlike obsolete and existing types of electro-magnetically maintained pendulum clocks, the pendulum of the "Bulle" clock on receiving a starting impulse, has both the properties of a dynamo and a motor, consequently very little current is drawn from the battery at each discharge.

* The curved permanent magnet is specially magnetised so that the central portion of the bar possesses North-seeking magnetism, while the two ends exhibit South-seeking polarity.

Another feature is the propelling electrical force generated by the vibrating coil and magnet, tending also to reduce the amount of current drawn from the battery. In fact, by adopting this novel form of propulsion, the inventors claim that

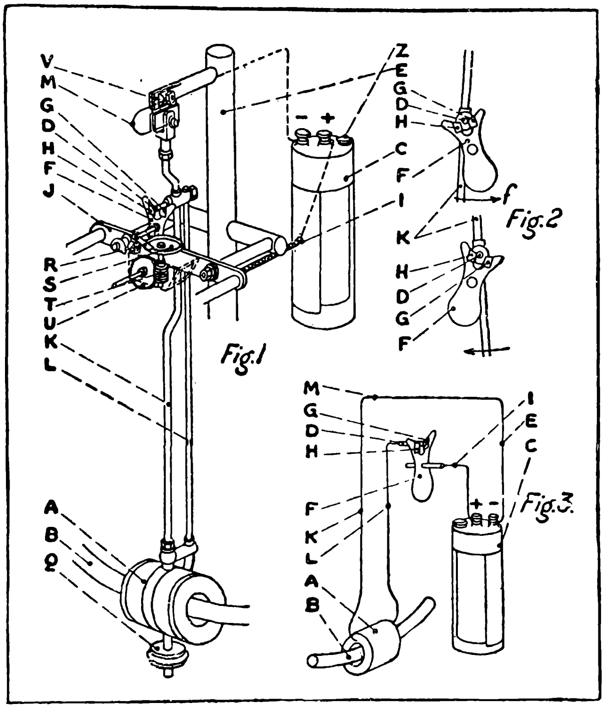


FIG. 68.—General Arrangement and Wiring Diagram of the "Bulle" Clock.

it is an easy matter for one battery to operate the clock for ten years.

The absence of complicated mechanism, and the highly efficient electro-magnetic principle on which the clock functions, will doubtless merit its extensive use.

By kind permission of Messrs The British Horo-Electric

Ltd., we reproduce here a description of the "Bulle" clock, which forms the substance of an interesting booklet issued by the above firm. If the illustration of the clock is now examined it will be observed that—

"Fig. 1 shows the essential parts.

"The pendulum coil A moves over a special magnet B. An intermittent current provided by the battery C runs through the coil A at suitable intervals assuring the pendulous movement.

"The current passes into the coil A by means of an automatic electric contact formed by the conducting pin D, fixed on the pendulum, acting alternatively on the conductive metal G and on the insulating fibre H of the pivoting fork F (see Fig. 2).

"The electric circuit comprising coil A and battery C, occurs for a short period on each swing of the pendulum in the direction *f*, when the pin D and the conductive metal G come into contact.

"The positive pole + of the battery is connected to the plate of the mechanism J by the conductor I. This plate I is fixed on the framework E, but insulated from it.

"The pivoting fork F and the conductive metal G are therefore connected with the positive pole + of the battery.

"The negative pole − is connected to the framework E.

"The rod of the pendulum K carries the current to the coil A, and then the rod L takes the current up to the pin D, which is insulated from the pendulum rod K. The rod K is connected to the framework E by a flexible wire M. Thus one of the ends of the coil is continually connected to the negative pole − of the battery, while the other end is only connected to the positive pole + of the battery when the pin D touches the conducting metal G, which completes the circuit, and maintains the swing of the pendulum.

"The electric circuit is shown diagrammatically on Fig. 3.

"The pivoting fork F controls the mechanism actuating the hands by means of a pawl R, which pushes the ratchet wheel S forward one tooth every second, the wheel transmitting its movement to the hands by means of a worm screw T and a central wheel U."

CHAPTER IX

LATER DEVELOPMENTS IN ELECTRIC CLOCKS

The Princeps Electrical Clocks.

The year 1924 marks an important era in the history of electrical clocks; as well as being the year of the British Empire Exhibition, visitors to the Exhibition had the opportunity of examining the construction and operation of the Princeps electrical clock system.

This system of electrical clocks is quite a new departure as far as the application of electricity to time-keeping is concerned, involving entirely new principles possessing many desirable advantages.

Many of the difficulties that led to failure in the older types of electrical clocks have been surmounted, and the great ingenuity displayed, coupled with the novel nature of the simple mechanisms used, renders the system highly reliable for all requirements of time-keeping and transmission.

Major C. E. Prince, O.B.E., M.I.E.E., the inventor of the system, by following up an original line of thought, applied an entirely new principle for maintaining the swing of the pendulum, so that it might be relieved of as much interference as possible.

Interference must inadvertently take place when the pendulum is either mechanically connected to a clock movement, or is caused to release some mechanism from which it will receive an impulse to maintain its vibration.

In the Princeps master clock the vibration of the pendulum is sustained by the impulses imparted to the rod by one of the side contact springs. The springs are lightly mounted one on either side of the pendulum rod, so that as the latter vibrates the springs are alternately slightly deflected to one side. Suitable contacts are mounted on either side of the rod, the latter forming part of the electrical circuit.

The left-hand contact spring normally rests against a fixed stop until engaged and displaced by the pendulum rod, being arrested by the stop on the return of the pendulum.

The second contact spring situated on the right of the pendulum rod is identical to the first spring. However, instead of always coming to rest against a fixed stop near the zero position of the pendulum's swing, it may be arrested earlier by a movable stop, so that it remains in a bent or deflected condition until picked up by the pendulum and further deflected by being carried to the right.

During the period of engagement of the pendulum rod and the contact spring the current has been allowed to pass through a "reverser," which is in effect a polarised electro-magnet with a spring blade attached to the centrally pivoted armature. The upper portion of the spring blade contacts alternately with suitably disposed contact points.

Since the reverser is situated near the suspension head of the pendulum, a projection or tail-piece on the centrally pivoted armature of the reverser serves as the movable stop for the spring.

Reconsidering now the contacting of the right spring and the pendulum rod, the current passing through the reverser instantaneously throws the armature over, the spring blade breaking the circuit just established by the contacting of the spring and pendulum; but, however, simultaneously the blade re-establishes contact with a second contact point included in the second circuit. By the withdrawal of the movable stop by the movement of the armature, the spring contact is now free to follow up and impart an impulse to the pendulum until arrested by a fixed stop situated near the zero position of the pendulum's swing.

The pendulum passing the zero position picks up and deflects the left-hand spring contact; again the circuit is closed and the current flows through the reverser.

Excitation of the reverser coil throws the armature over, the spring blade suddenly breaking the circuit, renewing contact with the second contact point in circuit with the right-hand pendulum spring.

It will be evident that the movable stop integral with the armature has again slightly deflected the spring to the right of the pendulum prior to imparting an impulse to the pendulum when it is picked up by the latter. Thus it will be seen that the spring in returning through a greater distance than it is carried by the pendulum, supplies the energy for driving the pendulum. This, then, is a brief outline of the ingenious principle by which the pendulum is kept vibrating.

The current operating the reverser also pulsates through the external clock circuit, the duration of contact being about .05 second; this naturally results in the current consumption being extremely low.

Another noteworthy feature is the breaking of the circuit by the reverser at its contact points and not between the pendulum and side springs.

The dials working in conjunction with the master clock are called "slave clocks," and contain extremely simple step-by-step movements.

The orthodox ratchet and pawl propelling mechanism has been abandoned and recourse made to the use of toothed wheels A and B (Fig. 69) propelled by a specially shaped pallet C fixed at the end of an arm D. The latter is attracted by an electro-magnet E and returned on the waning of the electrical impulses by a spring F. By the attraction of the arm the pallet drives the small wheel B half a tooth; the latter, however, since it gears into the larger wheel A, will cause the wheel to move sufficiently forward for the pallet to engage it on its return.

The strong spring F now briskly returns the arm and the wheel is driven forward: so by two combined movements the larger wheel A moves forward one tooth. Mounted on the arbor of the wheel A is the seconds hand, the movement of the arbor being transmitted to the hands of the clock by suitable gearing.

Normally the slave clocks are operated at intervals of one second, but if desired, by the introduction of a relay G (Fig. 70) and an auxiliary reverser H into the clock circuit, impulses are sent out to the clocks at half-minute intervals. To actuate the reverser it is of course essential to provide two sets of spring contacts for the express purpose of controlling the current to throw the reverser armature over at the precise instant. The spring contacts I are operated from a "snail" J carried on the centre arbor of the master dial, so that the "snail" J makes one complete revolution in a minute.

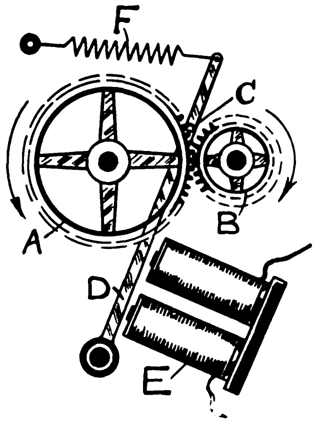


FIG. 69.—Princeps "Slave" Clock.

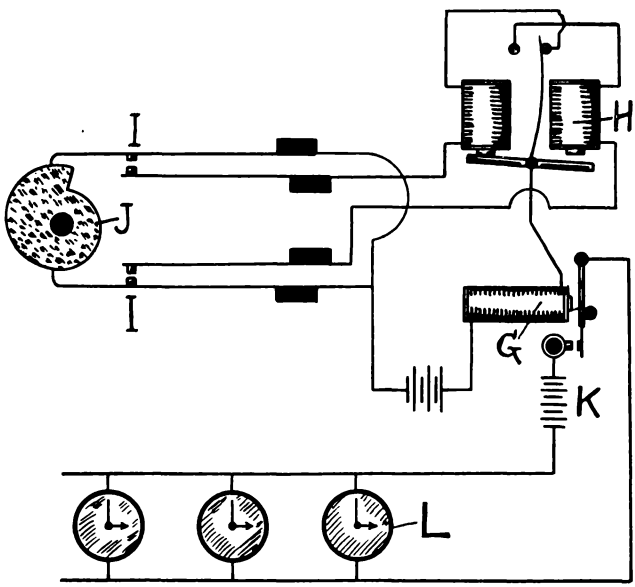


FIG. 70.—Relay and Reverser for Transmitting Impulses at Half-minute Intervals to "Slave" Clocks.

The spring contacts being disposed 180° apart, it is evident that on the " snail " making one revolution, each pair of contacts will be closed once for a certain period.

When either of the contacts close the circuit the instantaneous action of the reverser transmits a momentary current through the relay. The latter in turn on becoming energised closes for an instant the clock circuit, in which is included an auxiliary battery K for supplying the requisite current for the propulsion of the hands of the slave clocks L which are arranged in " parallel," consequently the windings of the clocks will be of high resistance. The Princeps Company use a combination of " series " and " parallel " connections when they consider it good practice.

The " cottage system " of Princeps clocks (Fig. 71) is a modification of the larger system, and consists of a special type of master clock in which no relaying mechanism is necessary.

The clock is very compact and contains its own dry battery for maintaining the oscillation of the half-seconds pendulum, as well as for the driving of the slave clocks.

Advantage is taken of the flowing of the momentary currents through two distinct circuits to drive the slave clocks. The circuits are completed at every alternate swing of the pendulum, so that by the inclusion of a balanced number of slave clocks in the circuits, each set of clocks will receive an impulse alternately; hence the slave clocks are propelled at one second intervals.

The Princeps Company have also incorporated the reverser scheme for the dual purpose of maintaining the swing of the pendulum, and for propelling the mechanism of solo clocks.

Turret clocks are also capable of being driven and operated by this new and revolutionary principle.

Interesting Data.

Voltage required - -	4 to 4½ volts.
Current per clock - -	50 milliamperes.
Duration of contact - -	.05 second per impulse.
Master clock - - -	21 ampere hours per annum.
Half-minute slave clock systems	About 1 ampere hour per annum per clock.
Seconds impulse slave clocks	About 30 ampere hours per annum per clock.

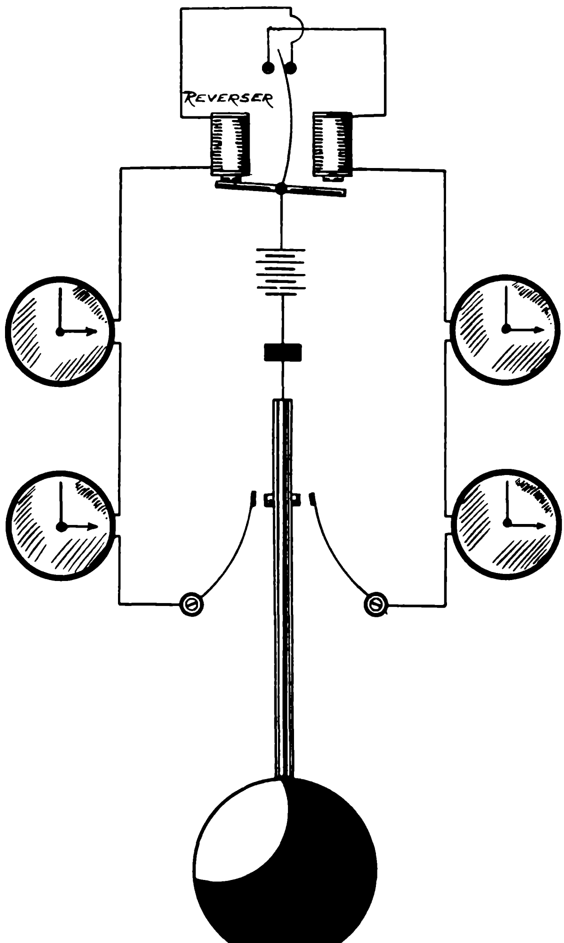


FIG. 71.—The "Princeps" Cottage System of Electric Clocks.

The Shortt (Synchronome) Free Pendulum Clocks.

To meet the requirements of the authorities of Greenwich Observatory the Synchronome Company devised the arrangement of electric clocks depicted in Fig. 72, and which consists of a " free " pendulum A impulsed by a gravity arm G normally retained in the reset position by the pivoted catch C.

The upper end of C is provided with an armature D attracted by the electro-magnet E, the latter being placed in circuit with a resetting magnet F of a standard controlled synchronome transmitter shown on the right of Fig. 72. Obviously when the pendulum H, through the intervention of the count-wheel I, releases the gravity arm J, the same current passing through F must pulsate through the smaller electro-magnet E, causing the attraction of D to effect the release of the gravity arm G, in consequence of which the " free " pendulum A is impulsed.

From an inspection of the wiring system it will be perceived that an electro-magnetic device K (" synchroniser ") is included in the circuit of the resetting magnet L.

The magnet of the synchroniser pulls down an armature R, the end of which is suitably shaped to engage a steel spring M attached to the pendulum H. Should the pendulum portion M of the device be within striking distance of the end of the armature R, the pendulum's swing is accelerated.

An impulse dial is under the control of each pendulum, and observations over a long period have revealed the astounding fact that the relative rates of the clocks (O) seldom vary more than $\frac{1}{100}$ of a second per day.

To reduce the barometric error and air resistance to the swing of the " free " pendulum the latter is housed in a copper cylinder in which the pressure is as low as 3 cms. of mercury.

" Pulsynetic " Process Timing Impulse Clocks.

In many industrial processes it is essential that an audible, and occasionally a visual, warning be given when the specified number of minutes or hours have elapsed. Provided the process does not exceed fifty-nine minutes, a standard dial

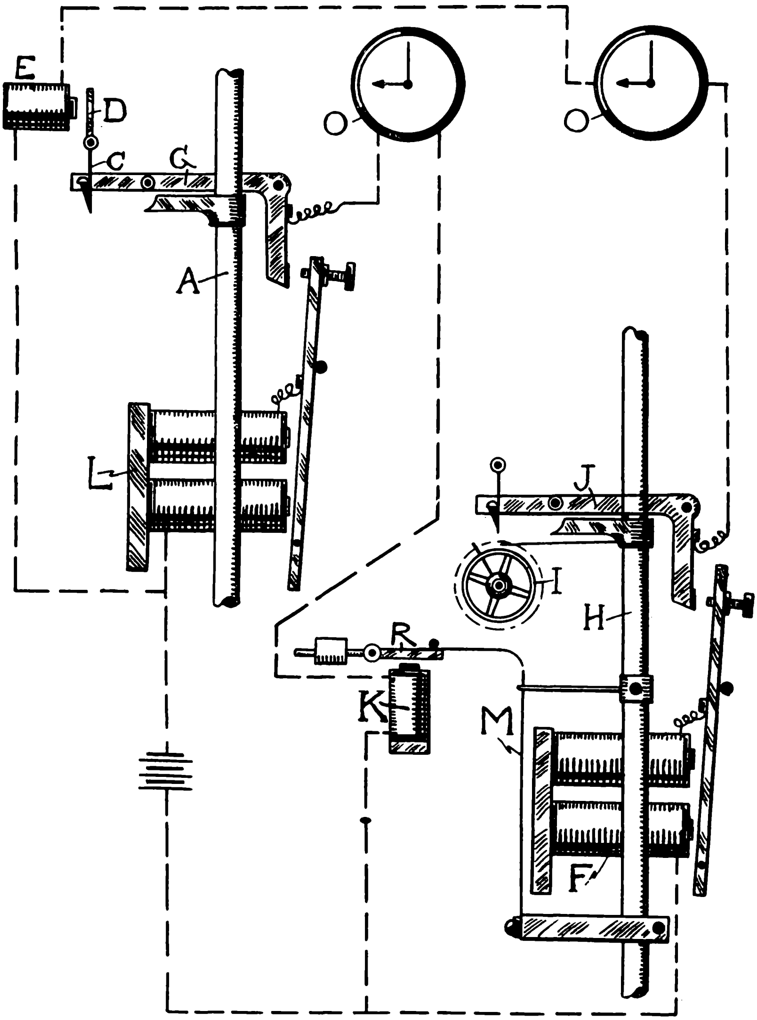


FIG. 72.—The "Shortt" Free Pendulum Clocks.

face is used, but when the process takes several hours it becomes necessary to fit a special dial face (see Fig. 73).

At the commencement of the process an adjustable hand is set to the desired number of minutes, then when a moving hand (previously zeroised) reaches the adjustable hand, warning is given by a lamp, bell, or some other device to indicate the time has elapsed. To reset the clock it is only necessary to press a button on the case, when the hand flies back to zero for restarting of the process.

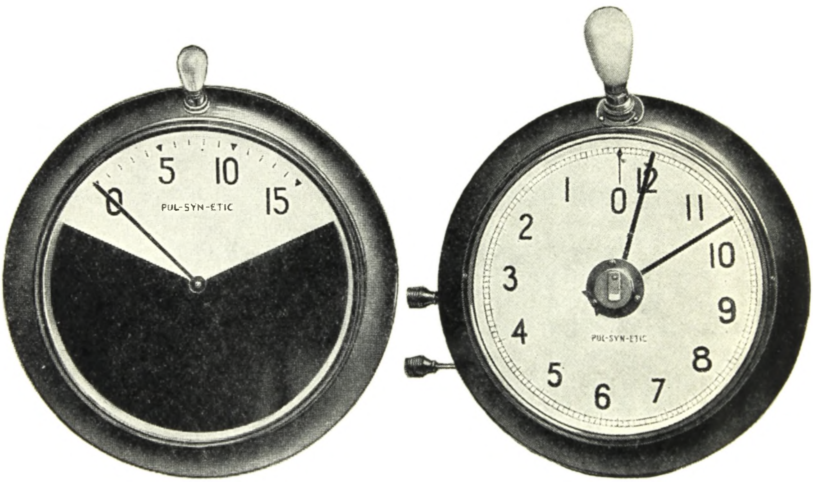


FIG. 73.—Alternative Types of Process Timer.

A second button may be provided which merely cancels the warning device and does not restart the timing clock, thereby allowing for the necessary preparatory work being done before the process commences. When the process lasts less than a minute, the dial is fitted with a seconds hand which is driven from a special seconds contact on the "Pulsynetic" transmitter.

Messrs Gent, the inventors, find that, since "process" timing varies so differently with various industries, most of the apparatus has to be made up specially to suit the particular industry.

"Pulsynetic" Automatic Ship's Progress and Position Indicator.

The indicator (Fig. 74) takes the form of a large coloured relief map of the recognised route that the vessel is in the

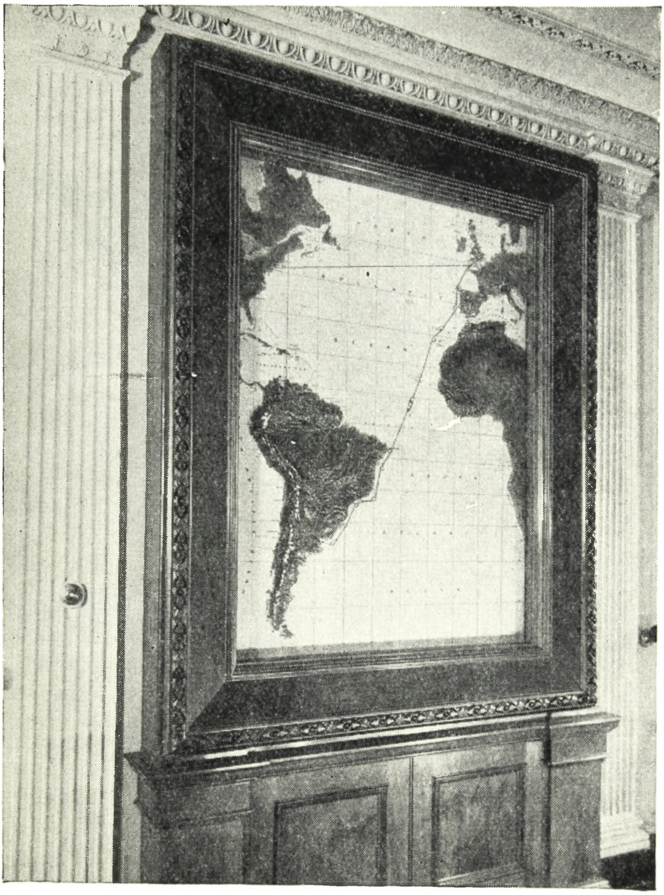


FIG. 74.—"Pulsynetic" Automatic Ship's Progress and Position Indicator.

habit of taking; in the particular example portrayed both hemispheres are covered by a ship sailing from England to Buenos Aires, touching at the various ports *en route*.

The mechanism consists of a model ship moved along the route by an ingenious electric clockwork receiving impulses from the " time " system of the ship.

Further, the rate of travel of the model is arranged proportionate to the actual speed of the vessel, hence its position on the ocean at any time may be seen, and the vessel's progress noted each day. Lighting effects are provided in the form

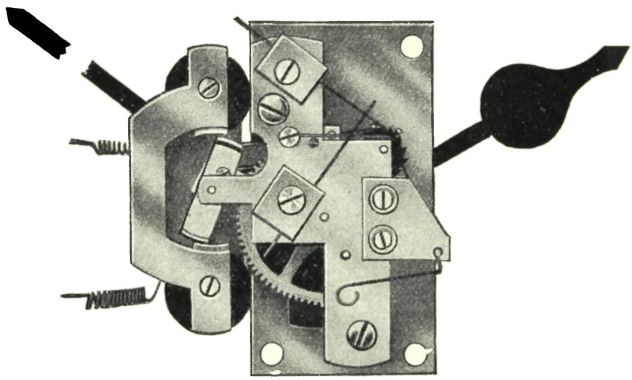


FIG. 75.—" Pulsynetic " Inaudible Movement for Bedroom, Cabin, Hospital, Library, or Lounge.

of rising and falling coloured lights—these tend to give " life " to the relief map; the lights simulate sunrise and sunset effect on the model ship and across the hills, at the same time casting shadows in the valleys. On the commencement of the return voyage a switch automatically reverses the model ship, which then indicates the return journey.

Naturally the progress indicator is only suitable for vessels sailing over a regular route.

The indicator is a handsome instrument, and is usually fixed in the main entrance to the first saloon, the operating mechanism being housed in a cupboard or cabinet beneath the map.

CHAPTER X

ELECTRIC TURRET CLOCKS

IN driving the hands of the mammoth Royal Liver Clock at Liverpool by the highly ingenious "waiting-train" mechanism described in Chapter VII., it was demonstrated that turret clocks of any size could be driven by electrical agency. To this end the originators of the "waiting-train" movement have further improved it, and found scope for its application in some of the largest and most notable turret clocks to be found at home and abroad. Limitations of space, however, will only permit of particulars of a few being in this section of the work.

The Royal Liver Clock, Liverpool (1911).

Four 25-ft. illuminated faces.

Height of tower, 220 ft.

Hands, 14 ft. long; 3 ft. wide in the centre.

Since the east dial is in a separate tower at the east wing of the building, it was necessary to employ four "waiting-train" movements, all connected together electrically. No less than 16 tons of iron and opal glass were used in the construction of the dials; the total weight of the clockwork is nearly 3 tons.

The Singer Clock, Clydebank, Glasgow.

This clock is now the largest electrically operated in the world. The tower was built in 1884, and then housed a very heavy mechanically driven clock for driving the eight enormous hands; this mechanism has now been replaced by one modern "waiting-train," which ensures its absolute accuracy as a timekeeper.

Fig. 77 shows the "waiting-train" movement designed for the Singer clock, the current maintaining the motor pendulum being supplied from a battery of twenty-one small accumulators. A standard time transmitter governs the colossal clock; the former also controls the small clocks and workmen's recorders throughout the very large works of the Singer Company.

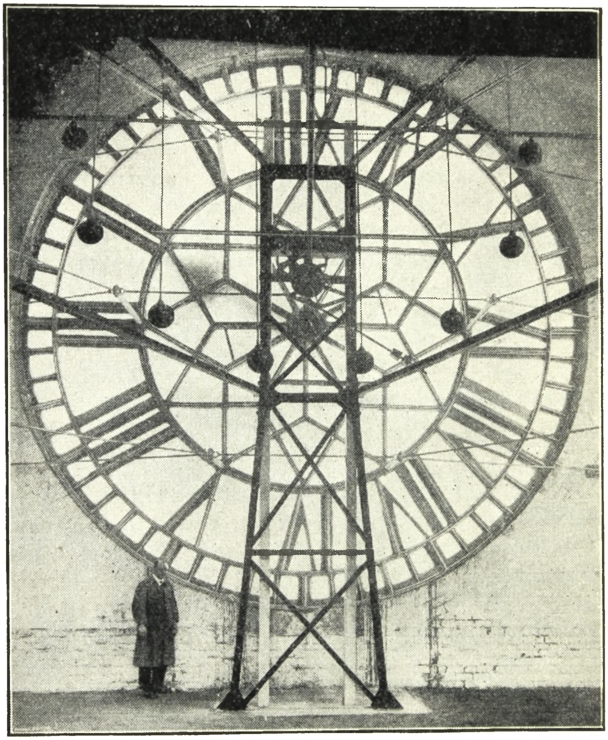


FIG. 76.—Singer Clock, Clydebank.

The following are a few particulars of the clock :—

Four 26-ft. illuminated dials; illuminated by eight reflectors.

Height of tower, 240 ft.

Length of hour hands, 9 ft. 6 in.

Length of minute hands, 15 ft. 7 in.

Size of chapters, 4 ft. 3 in.

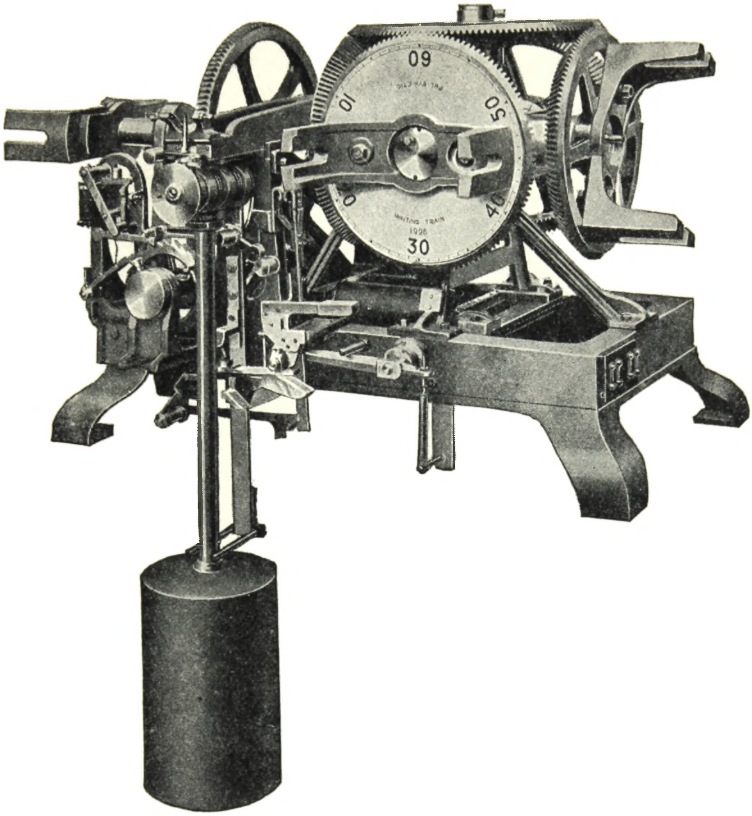


FIG. 77.—Large " Waiting-Train " Movement as used in the Singer Clock.

Some Memorial Turret Clocks.

1. The Leicestershire " waiting-train " turret clock has exposed hands, the four dials being 5 ft. in diameter, and are automatically illuminated.

The clock is operated by a battery of Leclanche cells, whilst the striking mechanism, which counts the hours on a 5-cwt. bell, is driven by alternating current from supply mains. The timekeeping is dependent upon a transmitter in the base of the tower.

2. The Shanghai Memorial has four 7-ft. faces. Chiming and striking is carried out on five bells having a combined weight of 1½ tons, whilst alternating current supplies power for the "going-train" as well as for striking and chiming. A battery of Leclanche cells with a Sentinel switch comes in automatically if the supply current fails.

3. *A Chiming Memorial Clock.*—Mention may also be made of another "waiting-train" movement driving the hands of four 7-ft. faces illuminated by lamps switched on automatically, the power for operating the striking and chiming gear as well as lighting being supplied from the power mains. The striking and chiming gears operate on bells having a total weight of 22½ cwt., the hours being counted out by the striking gear on a bell of 10 cwt., whilst the quarters are sounded on four properly proportioned bells after the order at Westminster.

Clock with Carillon.

At a Midland Institute a "waiting-train" movement is installed together with striking and chiming gear, all operated from A.C. mains at 200 volts.

A carillon of thirteen tubular bells is fixed in the tower, the striking gear counts the hours on tube "E" Flat, while the chimes are Westminster, operated on selected tubes.

A keyboard in the basement enables the tunes on the carillon to be played on festive seasons.

The time circuit is operated by Leclanche cells operating on a standard time transmitter; the cells also drive the clock during the period of failure of the A.C. from the mains.

The "Synclock" Turret Movement.

Since all modern generating stations are equipped with an "Everett Edgcumbe" master frequency meter to govern the frequency of the alternating current supplied to the service mains, the use of synchronous motors for driving the hands of turret clocks has been rendered possible.

The " Synclock " tower movements comprise a special self-starting synchronous motor mounted directly behind

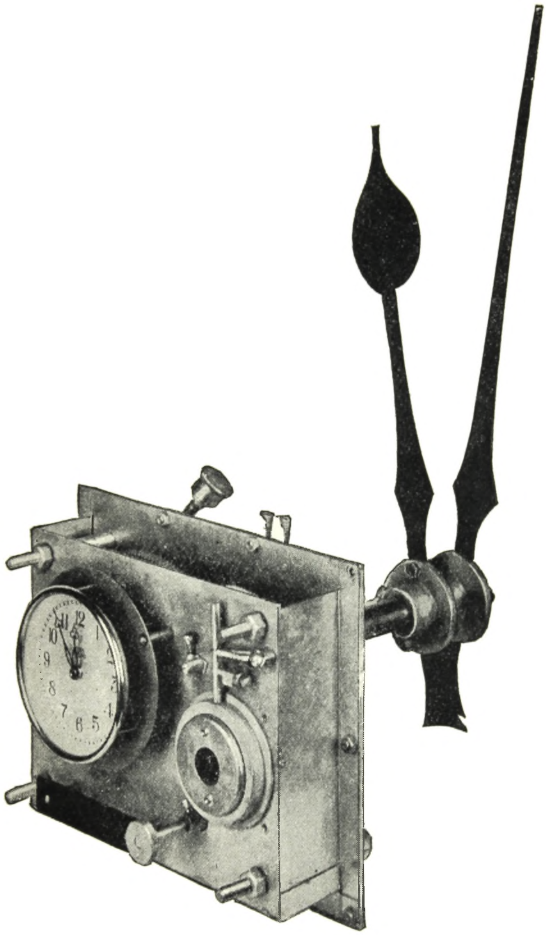


FIG. 78.—Tower " Synclock " Movement, with Hands.

the centre of the dial and connected direct to the service mains. The movement is of substantial design and very powerful, the motor and gearing being housed between heavy steel plates carrying the necessary bearings, and which also support the shaft sleeve for the hour and minute hands. This novel arrangement dispenses with tedious alignment and adjustment of the minute-hand shaft and hour-hand sleeve, since these are integral parts of the movement. To facilitate setting of the clock hands a small direct-reading "Synclock" dial with manual setting knob is provided on the back of the movement.

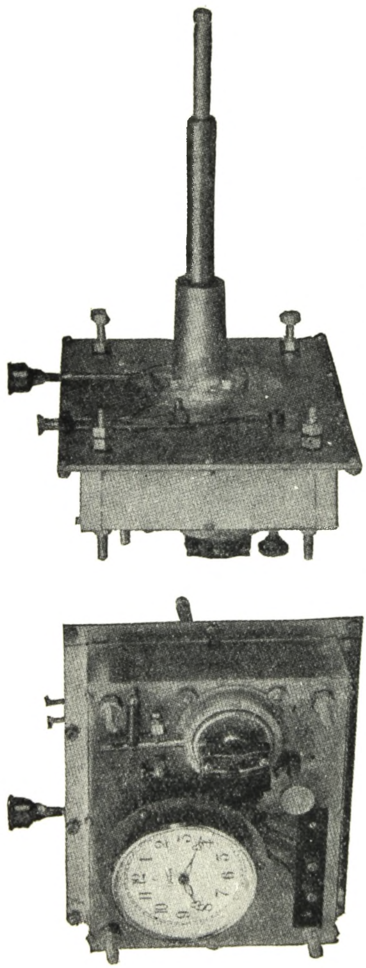


FIG. 79.—Tower "Synclock" Movement, with Inside Sub-Dial for Manual Resetting.

Since the "Synclock" is simple, compact, and accessible, its original installation and subsequent change or adjustment can be made with the minimum of effort, attention, and cost. Furthermore, the movement is mounted close to and directly behind the centre of the dial, the remaining space being available for other purposes; this is very important where accommodation has to be provided for lift control equipment, water tanks, ventilating machinery, and other gear.

Existing public clocks may be converted to "Synclock" drive: the existing hour and minute hands, together with certain of the gearing, can be utilised, the "Synclock" motor being mounted in a suitable position in the gearing.

The "Synclock" imposes no limitations on either size, design, or position of the clock face.

It is interesting to record that the Town Clock, Hampstead, is operated by a "Synclock" movement.

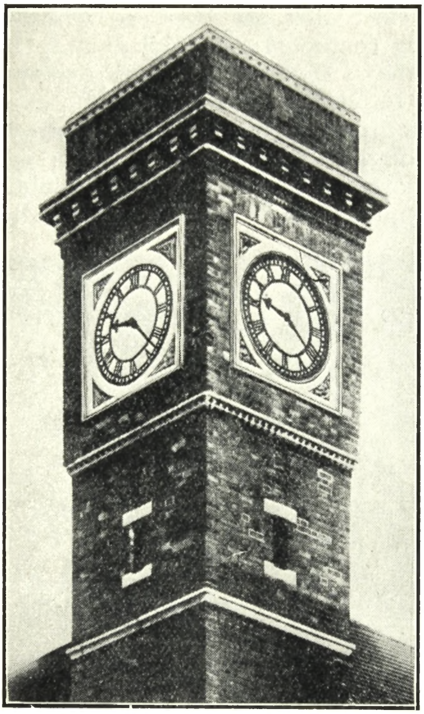


FIG. 80.—Hampstead Town Clock Converted to "Synclock" Drive.

The "Duflex" Pendulum Control.

An elaboration of the "Reflex" pendulum control already considered in Chapter V. has resulted in an extension of its use to deal with heavy pendulums of existing mechanical turret clocks.

The system compels the pendulum to keep its own accurate time, since should the pendulum depart from this by gaining or losing, the " Duflex " device immediately corrects the pendulum. The scheme possesses the further advantage that if the circuit in which the " Duflex " is placed is interrupted or destroyed, the turret clock continues to run under its own power and pendulum. This state of affairs may exist after the overhead wires in which the " Duflex " is connected are carried away by snow, etc. Apparently the " Duflex " mechanism may be fitted to any existing turret clock irrespective of the weight of the pendulum, and can be relied upon to correct faulty rates of the pendulum.

Fig. 81 shows the mechanism fitted to an existing turret-clock pendulum. It is interesting to record that the public

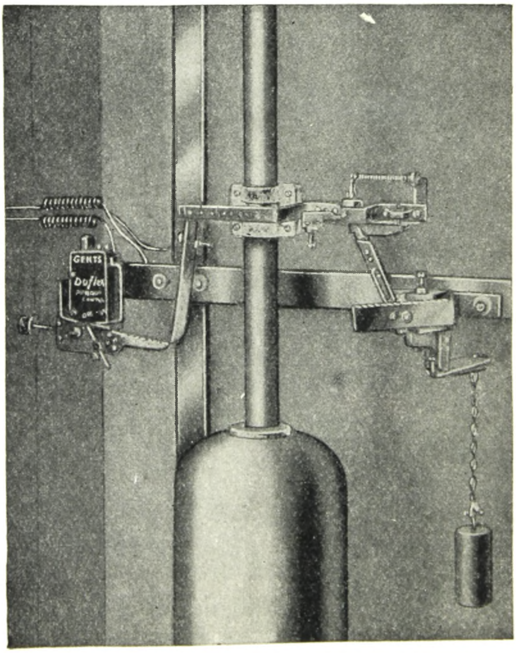


FIG. 81.—" Duflex " Control Fitted to Existing Turret Clock Pendulum.

clocks of Chesterfield, England, are equipped with the "Duflex" control governed by half-minute correcting impulses transmitted from a standard "Pulsynetic" transmitter situated in the Corporation Offices.

All the public clocks are connected up with overhead telephone wires, consequently they must all indicate the same time. Incidentally, Chesterfield was the first city to introduce universal accurate time for the convenience of its inhabitants.

Electro-Motor Tolling Gear.

The "Pulsynetic" mechanism for tolling large and small bells consists of an electro-motor driving a cross-shaft through the intervention of worm gearing.

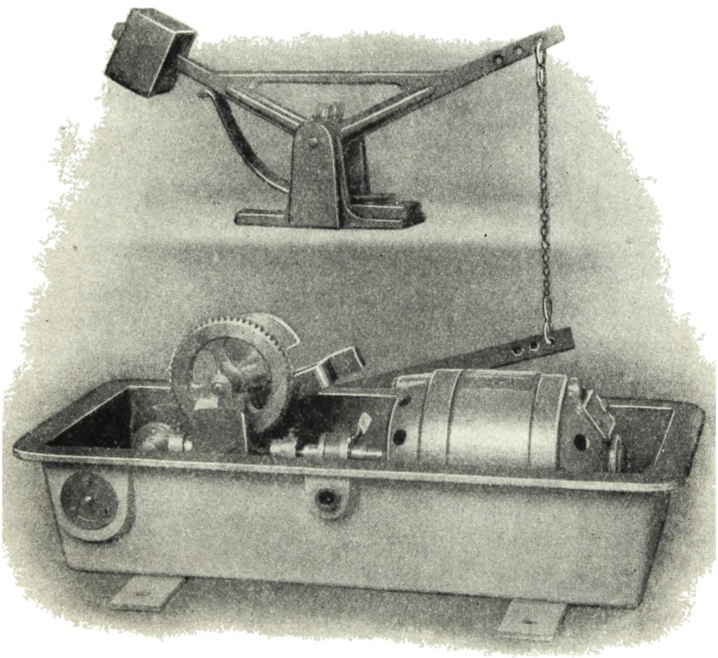


FIG. 82.—"Pulsynetic" Electro-Motor Tolling Gear.

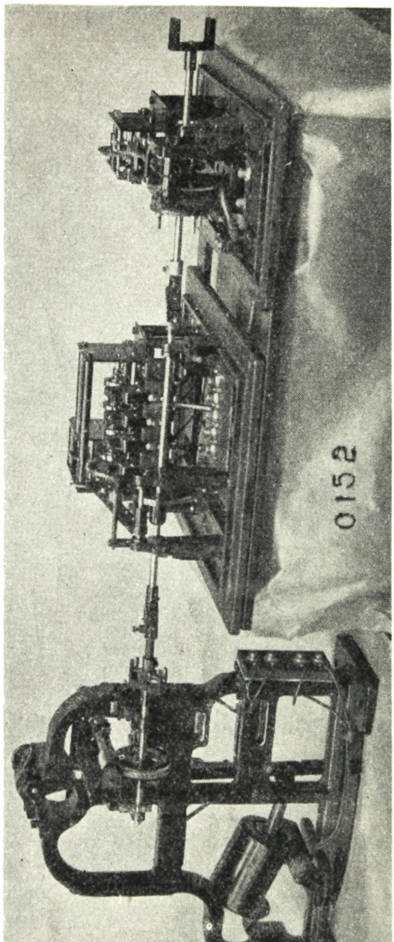


Fig. 85.—"Pulsynetic" "Waiting-Train" Movement operating Chiming Gear.

CHAPTER XI

MAINS OR SYNCHRONOUS ELECTRIC CLOCKS

ALTHOUGH with few exceptions the electric clocks enumerated in the preceding chapters may be operated by either primary or storage batteries, yet direct current from the lighting mains may be used after being first reduced to the voltage of the clock circuit.

The great activity in electrical circles to develop the National Grid System for the distribution of alternating current at a standard frequency through existing systems of various electricity undertakings, has resulted in the introduction of an entirely new type of electrically driven timepiece.

The introduction of the latter has only been rendered possible on account of the frequency of the supply current being very carefully time-controlled by an " Everett Edgcumbe " master frequency meter installed in the power station.

The uniformity of the frequency of the electric impulses renders them particularly suitable for the operation of a small " asynchronous " or induction motor.

It is beyond the scope of this work to enter into a discussion of the theory or construction of asynchronous motors; the miniature electric motors are designed to run at speeds varying between 100-200 revs. per min., and are connected to the hands of the clock through reduction gearing.

Strictly speaking, two types of electric motors are used for operating clocks directly connected to the mains, and are known respectively as " synchronous " and " sub-synchronous " motors, the latter being a non-self-starting type.

Each has peculiar advantages, and consequently their advocates, many manufacturers of mains electric clocks, favour the non-starting motor. Timepieces of this type, however, require to be given an initial start by hand when the hands have been set; a special device is provided for the purpose.

The " Synclock " Time System.

" Synclock " dials require no local master clock, they are plugged in the service mains of any electric supply system where the frequency is controlled by an " Everett Edgcumbe " master frequency meter.

The hands of the " Synclock " are driven by a very small " Warren " motor; the latter is a silent, self-starting, synchronous electric motor.

The Warren motor is supplied in several sizes, and the system can be readily applied to the driving of clocks employed for the following purposes where synchronous time-keeping is essential:—

Electric time switches for water heating, street lighting, shop-window lighting, etc.
Change-over switches for electric metering or other purposes.
Driving charts in graphic recording instruments.
Factory time-checking clocks.

The makers state that the power taken by one " Synclock " is about one-twentieth of that consumed by a single 40-watt lamp at 1d. per unit, the cost being less than 1½d. per month.

Description of Warren Motor.

The smaller (type B) measures approximately 2½ in. square, and consumes some 4 watts or less at 110 volts 50 cycles; the larger (type C) motor consumes about 6 watts.

These motors are capable of starting under load, and attain a synchronous speed in a fraction of a second, and continue to run at synchronous speed so long as they are connected to the service mains. The motors are extremely simple in construction, they possess few parts, and require no attention.

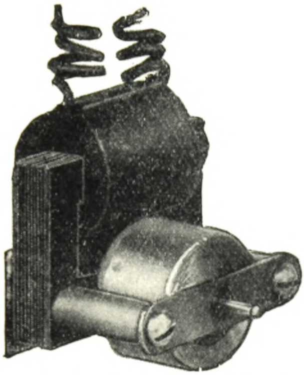


FIG. 86.—" Synclock " Type B Motor.

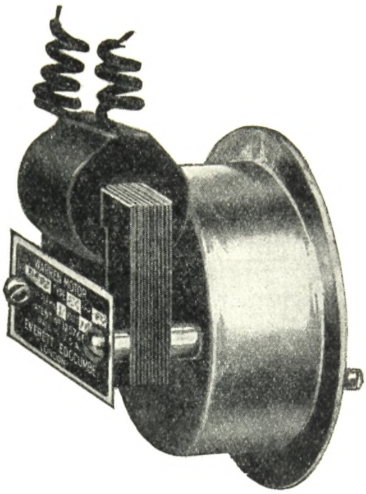


FIG. 87.—" Synclock " Type C Motor.

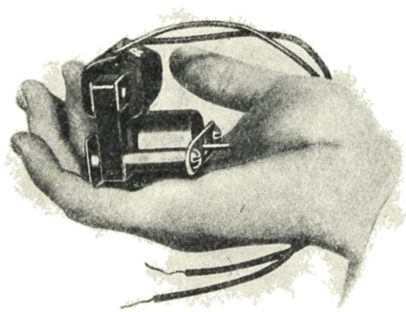


FIG. 88.—Showing Small Size of " Synclock " Motor.

Referring to Fig. 89, the electro-magnet A, with its winding B, is provided with shading rings C, and produces a rotating magnetic field in which the iron armature D is situated, causing the latter to rotate in absolute synchronism due to hysteretic lag. The shaft carrying the disc is geared down, so that the terminal shaft revolves either once a minute or once a second in type B, and once a minute in type C. All the gearing and moving parts are placed in a dust-tight housing containing oil, in which the working parts are immersed.

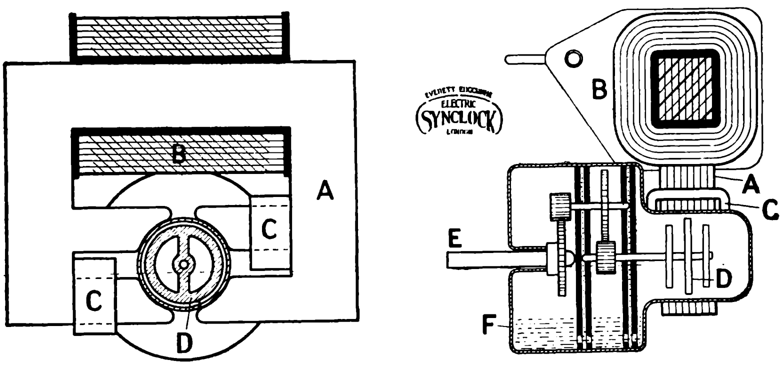


FIG. 89.—Section of B Type " Synclock " Motor.

The motors are supplied for use on 50 or 25 cycles per second at either 100-125 or 200-250 volts as standard; the motors, however, can be furnished specially for other frequencies or voltages. Changes of voltage as great as 25 per cent. does not affect their synchronous operation; but a motor designed for one frequency will not operate as efficiently on another frequency, because of the necessary difference in the field properties.

The motor has been successfully applied to the following uses :—

The timing of photographic exposures.
X-ray tube dosage.
Automatic time limit relay operation.
The operation of maximum demand indicators.

The driving of oscillographs and stroboscopes.
The stirring of oil baths.
The intermittent lighting of neon tubes.

The Dorchester Hotel, London, has a large installation of " Synclocks," and which over a considerable period have maintained a wonderfully good time-rate.

The " Smith " Synchronous Electric Clock.

We propose to conclude this section of our work with a few particulars of the "Smith" synchronous motor, as fitted to their well-known mains electric clock.

Motor.—The motor is not self-starting; the setting to time and starting up are performed by a simultaneous operation by a single lever. The motor runs at the comparatively low speed of 200 revs. per min. when connected to a supply having a frequency of 50 cycles; the speed of the motor is entirely independent of variation in the voltage of the service mains, which may be occasioned by heavy power, lighting, or heating loads.

Construction.—Essentially the motor consists of two parts: (*a*) the " Stator," and (*b*) the " Rotor."

The " stator " is clamped in a substantial " Bakelite " housing, and consists of two pressed steel cups enclosing the energising coil, the latter being wound on a cellulose acetate moulding which effectively protects the winding from mechanical damage.

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.

Specially ground and polished bearings are employed, which ensure silent and smooth running. It is interesting to note that these are self-lubricating and, therefore, do not require either oiling or cleaning.

Current Cost and Consumption.—The current taken by the motor is practically negligible, and is about 0.007-0.008 of an ampere at 200-250 volts. This is considerably less than the current required to move the ordinary electricity meter. The power consumed is about 1 watt, that is, one-sixtieth of the power consumed by a lamp used to illuminate a medium-sized room. Allowing 6d. per unit (which is equivalent to 1,000 watts per hour), the cost of the clock, assuming it does operate the meter, would be 6d. for 1,000 hours, or under 4½d. per month of thirty-one days.

General.—No attention whatever is required, the absence of delicate moving parts, springs, etc., ensure a robust and reliable mechanism. The clock is also independent of temperature variations and weather changes.

The " Synclock " Master Frequency Meter.

In the past it was only necessary to maintain the frequency of A.C. within the " Board of Trade " limits of 2½ per cent. above or below the declared value; to-day, however, this has proved to be inadequate. There must ever be small temporary variations in frequency which the operator is unable to counteract; fortunately, however, he is able to maintain a truly accurate mean or average frequency at all times, which actually is what is required.

In practice this is effected by a " Synclock " master frequency meter, a highly ingenious instrument capable of yielding an accuracy equivalent to one-thousandth of 1 per cent.

A variety of these meters are manufactured by Messrs Everett Edgcumbe & Co. Ltd., Hendon, London.

These instruments measure the mean or average frequency in contradistinction to the instantaneous value of the frequency indicated by the ordinary indicating frequency meter.

The average frequency is more easily controlled than the instantaneous value, due to the fact that a comparatively small speed adjustment is cumulative in its effect.

If in two stations the readings of the frequency-indicating instruments differ by a quarter of 1 per cent., an attempt to correct the frequency by either of these instruments will result in an altogether fictitious sharing of the load between the two stations. On the other hand, if " Synclock " frequency meters are installed at each station, the attendants will observe at once whether the supposed high or low frequency is temporary or permanent. If the former, it is probably best left to correct itself.

Obviously, under normal conditions the average or mean frequency will remain constant over a considerable period due to the flywheel effects of the turbo-generators, etc., connected to a large system; this is further assisted by the accurate speed-regulating characteristics of the governors once equilibrium has been obtained. Only changes in the average or mean frequency, which is the important factor, will affect the position of the pointer of the " Synclock " master frequency meter.

Principle of Operation.—Now since frequency is a function of time, it can only be measured accurately by a direct reference to a time standard. The " Synclock " frequency meters consist of a standard pendulum clock with an excellent going rate, combined with a " Synclock " synchronous motor connected to the system, the frequency of which is to be governed.

As long as the pendulum clock and the motor keep in step the frequency is correct; this is usually indicated by the pointer and a red line on a disc.

Any departure from normal frequency is clearly indicated, and the turbine governor control is adjusted accordingly; simultaneously, the exact amount by which the mean frequency is high or low can be determined at a glance.

It follows, therefore, that if the pendulum clock keeps time within one second in twenty-four hours, the error in the average frequency will be less than one-thousandth of 1 per cent.; with any other form of frequency meter this accuracy is seldom obtained.

The " Synclock " Model II. Master Frequency Meter.

This particular model is supplied either for floor or wall mounting. The indicating device takes the form of a disc with a radial red line and a black pointer rotating independently on a central dial of 8 in. diameter.

The black pointer is electrically controlled by the pendulum and keeps accurate time, the pointer making one revolution in three minutes. The disc is, of course, driven by a " Synclock " motor so geared that when the frequency

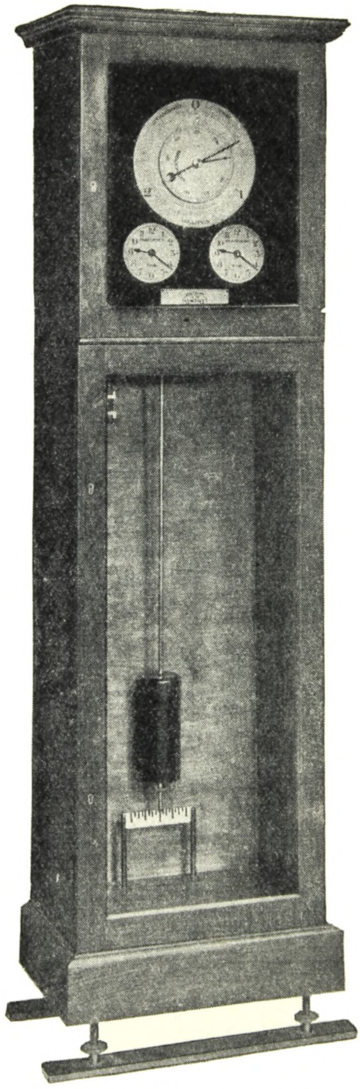


FIG. 90.—Master Frequency Meter, Model II., with Three Dials and Pendulum for Floor Mounting.

is correct the red line will rotate at exactly the same speed as the black pointer. Obviously, the red line and the pointer revolve together provided the frequency remains accurate, but should a change in frequency take place, the red line gains or loses on the black pointer, the exact difference being readable on the graduated disc. If the red line and pointer are now made to coincide by altering the governor setting, the average frequency will at once be corrected.

To briefly describe the ingenious mechanism of the meter, the disc and pointer are driven by a standard " Synclock " motor, the disc being rigidly attached to the motor spindle, whilst the pointer is attached to a sleeve driven through a friction clutch. A star wheel is mounted on the sleeve, and into the depressions of the former a roller is forced by an electro-magnetically operated tapper bar, the electro-magnet being energised by impulses transmitted from a standard " Invar " pendulum at thirty-seconds intervals. When the frequency is correct, the roller will find the apex of one of the depressions exactly opposite; should the frequency be high or low, then the roller falls on the slope of the depression, the force of the blow moves the star wheel, bringing the apex to the correct position by causing the clutch to slip. It will be appreciated that accurate standard time-keeping is ensured by a direct check from the impulse " Invar " pendulum, the disc and pointer moving steadily forward instead of moving in a jerky manner, as when responding to the beats of an escapement-controlled pendulum, or, alternatively, an impulse-operated clock.

Referring to Figs. 90 and 91, the two small dials are driven from the mechanism controlling the disc and pointer, the " frequency time " dial being on the left, and for convenience the " standard time " dial is placed on the right. As a standby a second " Synclock " motor is provided, and in the unlikely event of failure of the driving motor may be instantly put in commission. Since many patented features are incorporated in this model, notably the concentric mounting of the " frequency time " disc and the " standard time " pointer with its steady progression, the meter is, therefore, recommended for the larger power stations, especially those which are or will be connected to the National Grid System.

The distinctive advantages of the " Synclock " master frequency meter may be summarised thus :—

1. The pointer moving concentrically with a red line on a disc, giving a direct comparison between " standard time " and " frequency time."

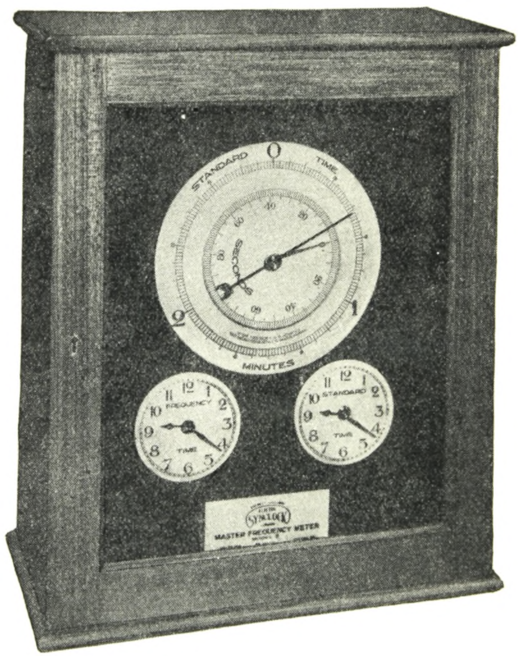


FIG. 91.—" Synclock " Master Frequency Meter with Concentric Disc and Pointer, also Two Dials, but without Pendulum.

2. A " standard time " pointer moving forward evenly instead of in half-second "beats," enabling any difference to be read more easily.

3. A standard Invar " free " pendulum capable of accurate regulation, its function being only to regulate and not to drive the pointer.

4. The dials may be installed separately and at any distance from the standard pendulum, and any number of

dials may be operated by the same master pendulum. This is of great importance where space is limited, for example in the control room, or if there is excessive vibration.

5. The dials may be operated from any existing impulse standard clock giving half-minute impulses.

6. The impulses from the " Synclock " master frequency meter may be used for controlling maximum demand meters or similar devices.

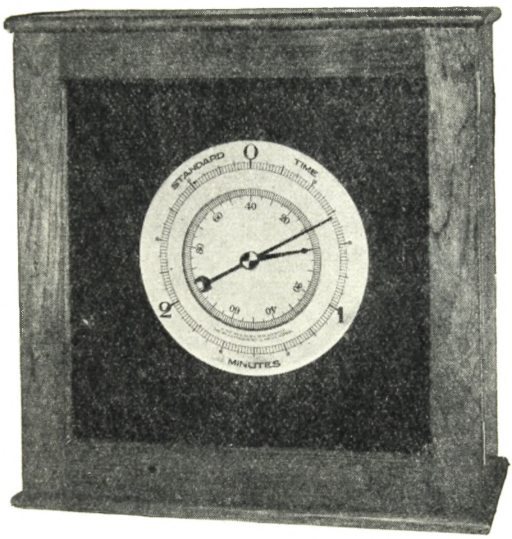


FIG. 92.—" Synclock " Model V. Frequency Meter, with Concentric Disc and Pointer only, but without Pendulum.

7. The complete electrical mechanism of the clock is operated at low voltage, derived through a self-contained transformer connected direct to the lighting mains, no batteries being employed.

Messrs Everett Edgcumbe are frequently called upon to design special master frequency meters. To cite one instance (London Power Co.), it was desired to install a master frequency meter to control the frequency of the whole system from the control room at Westminster. Further, it was desired to give an exact replica of the readings of the master frequency meter at each of their five large generating stations, and ultimately at Battersea. The problem was solved by installing at the control room a master frequency meter arranged to send out current impulses each second, the impulses being conducted by pilot wires to each of the generating stations, where they were caused to operate the sub-master frequency meters.

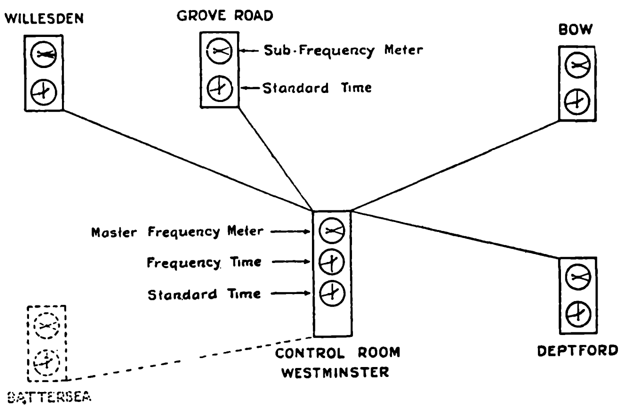


FIG. 93.—Lay-Out of London Power Co.'s Frequency Control System.

Operating Electric Clocks from Service Mains.

Now that the Grid System of A.C. mains has become available throughout the country, Messrs Gent Ltd., of Leicester, have introduced special arrangements for operating their electric clock systems direct from the mains.

Although A.C. from the mains can be employed to operate "Pulsynetic" clocks direct by using a transformer and rectifier, they suggest, however, that the clocks should be supplied with current through the intervention of an accumulator.

When either A.C. or D.C. is the source from which current is drawn, an accumulator is desirable but not essential, in any case an accumulator trickle charger is to be recommended.

Experience has shown that when the mains current goes off for even a few seconds the transmitters may sometimes stop; this failure may be obviated by the use of an accumulator.

When the system of clocks is connected direct to A.C. mains through a transformer to produce the correct voltage for the clock circuit, it will be necessary to employ a Westinghouse all-metal rectifier so that direct current is supplied to the transmitter. The scheme is open to the objection that should the mains supply fail for half a minute the clocks must lose an impulse and result in possible stoppage of the transmitter, hence the suggested use of an accumulator.

Connecting an accumulator and a trickle charger across the leads from the rectifier ensures that the accumulator is kept fully charged, but the latter immediately discharges through the clock circuit should the A.C. fail.

Assuming that D.C. from the mains is employed to operate the "Pulsynetic" electric clocks, the latter may be operated direct or through accumulators. Considering the first case, it will be necessary to reduce the current on the clock circuit to about $\frac{1}{4}$ amp. by the use of carbon filament lamps. It should be realised that the D.C. mains voltage comes directly on the clock circuit, consequently the makers advise the use of incombustible impulse clock cases; it should also be remembered that shocks may be obtained from the circuit. The method or arrangement of wiring has the drawback that should the current fail for a few seconds, or half a minute, the clocks will be affected and the transmitter may cease to operate.

In the second method of utilising mains current to protect the clocks from high voltages and current fluctuation two batteries of accumulators are recommended, one of which is charged through a trickle charger ready to be switched into circuit. With this arrangement one is always in use and the second is kept charged as a standby.

"Pulsynetic" clocks aboard ship are generally driven from the ship's dynamos by the D.C. that is always available on board. Frequently the voltage has to be reduced to suit the clock system by means of a potentiometer; the latter is specially designed with an adjustable slide which can be locked after being set to correct position when connecting up. When the vessel is in dry dock and the current is cut off, the clocks may, of course, be run from a battery of accumulators when installed, the accumulators being kept fully charged by a trickle charger from the ship's mains.

It is customary when " Pulsynetic " systems are operated by Leclanche cells to allow three cells for the transmitter, and then to add one cell for every three clocks in the circuit; the "warning bell" is reckoned as one clock. Two or three extra cells are added to overcome line resistance plus one-third of the total to provide a working margin. The current flowing through the circuit is 0.22 amp., the working limits being 0.17-0.27 amp.

Line wires are of either 18 or 20 S.W.G. electric bell wire thoroughly insulated, but 18 S.W.G. 300 or 600 megohm electric lighting wire is to be preferred.

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