CHAPTER X

ELECTRICAL CLOCKS

THE designs and devices connected with the evolution of electrical horology are so very numerous that it is intended to deal in this chapter with the principles underlying only those mechanisms which have latterly come into greatest prominence both scientifically and commercially. It cannot be disputed that electricity as applied to clockwork now forms one of the most important branches of horological science, and still offers scope for development along lines of simplicity in mechanical construction.

Experimental work on the subject dates back to the commencement of the Victorian era, though, strangely enough, present attainments can really only be said to be due to the advancement made during the last forty to fifty years. During the 'forties several devices concerned with the application of electricity to timepieces were patented by Alexander Bain, who will always be remembered as one of the pioneers. It seems probable, however, that this scientist, and others who devoted themselves to the question of maintaining the motion of a pendulum by electrical means, had at heart the solution of the problem of perpetual motion quite as much as the advancement of horology. The very system adopted by Bain for obtaining electrical energy seems to point to this. He generated the necessary current by means of a zinc and copper plate buried in moist earth. If, therefore, this conjecture is at all accurate it may reasonably account for the long period of sterility in the advancement of electrical horology.

One of Bain's clocks may still be seen (and usually working) in the Science Museum at South Kensington. The pendulum of this clock carries a coil in place of the bob, which moves in the field between two fixed magnets with North poles adjacent. One of these attracts the coil and the other repels, and the pendulum is arranged to receive impulse only when passing to the right. This is effected by means of a " make and break " which consists of a slide moved to and fro by a pin half-way down the pendulum rod. The ends of the slide turn down at right angles and pass along grooves cut diametrically across two gold and agate pieces, one at each end. When the points rest on the sections of gold, contact is made; but when the points are on the agate, the circuit is interrupted. Should the pendulum receive more impulse than desirable, so that the amplitude of the arc becomes excessive, then the slide is carried farther towards the left and off the gold piece, with the result that no contact is made and the pendulum receives no impulse on the following beat. The clock itself is of a usual type, but has no weight or other motive power, since the pendulum receives impulse independently. The escapement, therefore, is formed in such a way as to be driven by the pendulum and the order of the going is thus reversed. Reference is made later to a clock introduced by C. Bentley which follows very closely the principle first devised by Bain.

Generally speaking, it may be preferable to think of electrical clocks as comprising two main groups, namely, Primaries and Secondaries; or Time Transmitters and Time Recorders. The clocks in each group, however, may differ considerably in principle and application.

PRIMARIES OR TIME TRANSMITTERS

The primary group includes the mechanisms which actually measure periods of time, not necessarily recording, whilst those of the secondary group are mechanisms electrically synchronised periodically at short or long intervals by the primary, that is to say, they are simply governed by the behaviour of the primary; what the one dictates the other records.

Again those of the primary group may be either: (1) a clock which is electrically wound at regular intervals; (2) a mechanism in which the pendulum receives impulse by electro-magnetic means; or (3) a super-mechanical clock, such as a regulator, provided with an attachment for distributing signals or closing a circuit at specific intervals by means of electrical contacts.

The greatest possible accuracy of timekeeping is, of course, expected of these machines, especially if, for the control or synchronisation of a system of clocks, they are employed as standard "Master" timepieces.

Electrically-wound Primaries. Of the three categories just mentioned, the first has probably been developed to greater advantage than the other two, chiefly on account of the fact that by such means it is possible to ensure a maximum amount of freedom to the pendulum. The most usual way of applying this principle is to reset a weighted arm or rewind a flat spring by means of the attraction, at a given moment, of an armature to an electro-magnet. Rewinding a weight or spring by automatically running an electric motor is, however, another method which may be adopted.

The idea of providing impulse for the pendulum by releasing a gravity lever was patented as far back as 1849 by Charles Shepherd, and it is interesting to record that such a clock of his construction was for many years in use at the Royal Observatory, Greenwich.

It was not, however, until 1895 that electrical horology commenced to advance commercially. In that year and in 1897 the "Synchronome" Co. (then Bowell and Hope-Jones) patented their earliest forms of gravity impulse transmitter. Numerous developments on similar lines came along in the decade which followed, notably, the Standard Time Co.'s transmitters and the "Pulsynetic," whilst in the "Lowne" primary a propulsion spring impulse was adopted. The recently introduced "Princeps" primary is somewhat different in principle from those just mentioned, but in this instance also impulse is provided by a spring. All these systems, excepting the "Princeps," employ a count wheel, which is operated with the swing of the pendulum and determines the equal intervals necessary for applying impulse. Generally these intervals are of 30 seconds' duration. The chief feature to notice is, however, that by employing a mechanically liberated impulse of constant force and period the pendulum is rendered free of any disturbing influence due to fluctuation of either voltage or supply of electric current.

The "Synchronome" Primary. Fig. 42 illustrates diagrammatically the system patented by the Synchronome Co. The pendulum rod, *P*, carries a projection, *M*, the extremity of which forms an impulse plane for the roller, *R*, pivoted on the bell-crank lever, *L*. Extending from the projection, *M*, a light pawl with a hooked end passes over the ratchet-shaped teeth of the count wheel, *W*, as the pendulum swings to the left, but gathers up a tooth on its return. The wheel has 15 teeth and is advanced one tooth with every double beat, back action being checked by the jumper, *J*, so that a complete rotation is made every half minute. A finger, *F*, rotates with the wheel and once in every revolution disengages the catch, *C*, thus releasing the lever, *L*. The roller, *R*, drops on the pendulum projection, *M*, and in descending the inclined plane a gravity impulse is provided just as the pendulum is crossing the line of centres. At the end of its fall, the lever, *L*, makes contact with the armature, *A*, which, being thus attracted to the electro-magnet, *E*, throws back the lever, *L*, over the catch, *C*. Contact is broken and the armature falls away, leaving the lever, with its impulse roller, locked in position.

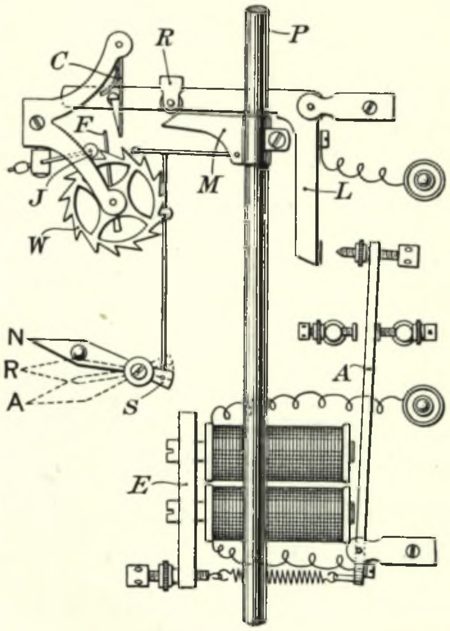

FIG. 42.—Illustrating the "Synchronome" design of electrical primary.

Simultaneously with the making of contact for resetting the gravity impulse lever, the same contact is used for closing another circuit, so that a system of secondary clocks may be synchronised. Should these require alteration or adjustment for time, the operation of correcting them is carried out from the primary or master clock by means of the control lever, *S*. This is capable of being moved by hand from its normal position, **N**, as shown, to two other positions, raising at the same time the pawl extending from the projection, *M*. At position, **R**, the pawl is raised free of the count wheel and progress of the secondaries is retarded for 2, 4, 6, 8, 10 seconds and so on as required. At position **A**, however, the pawl is raised so high that with every alternate beat the catch, *C*, is disengaged and the impulse unlocked, with the result that contact is made every 2 seconds instead of every 30 seconds, and half-minute advances of the secondaries are made in rapid succession. Provision is also made in this system for giving warning of failing current supply by sounding a bell or lighting a lamp. If the supply becomes too weak to reset the gravity impulse lever, the magnet is assisted by the pendulum itself raising the impulse roller during the swing to the left and closing an auxiliary circuit.

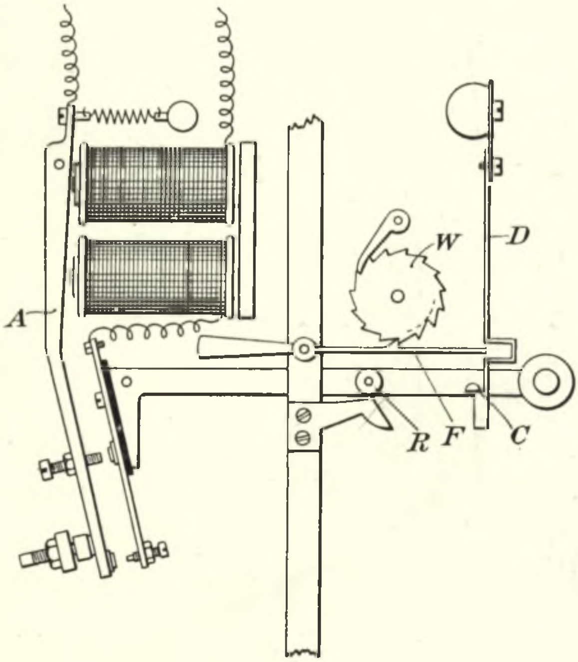

FIG. 43.—Illustrating the "Pulsynetic" primary.

The "Pulsynetic" Primary. The "Pulsynetic" (formerly known as the Parsons and Ball) system shown in Fig. 43 is very similar to the one just described. In this case, however, it will be seen that the count wheel is pushed instead of pulled whilst the pendulum is proceeding to the right. One of the ratchet teeth on the count wheel, *W*, is cut deeper than the rest and when the arm, *F*, drops into it, the detent, *D*, which normally is missed on account of the recess, becomes deflected and releases the catch, *C*, to allow the gravity arm and impulse roller, *R*, to fall until reset by making contact with the armature lever, *A*.

The "Standard Time Co.'s Primary." Fig. 44 illustrates the type of primary introduced into the Standard

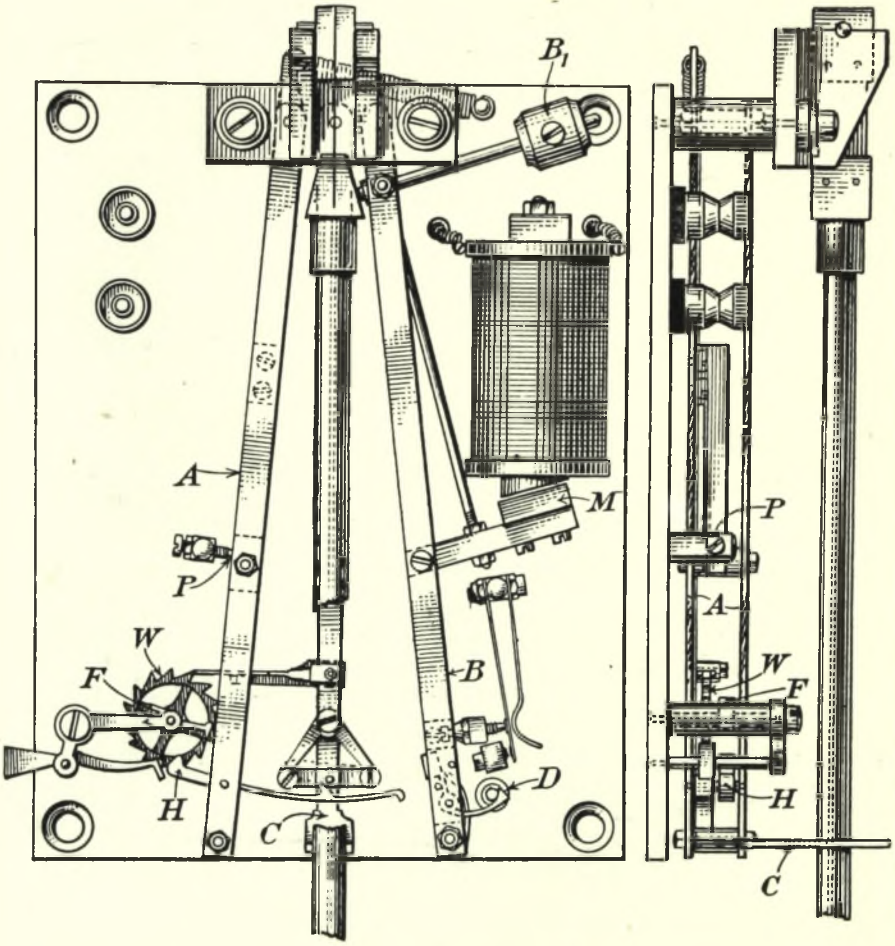

FIG. 44.—Illustrating the Standard Time Co.'s primary.

Time Co.'s system. Here the pendulum receives its impulse through a crutch, *C*, after the principle of those used in mechanical clocks. The crutch is pivoted near the suspension, and on either side there are also two long pivoted levers, *A* and *B*. The lever, *B*, with its weighted end, B_1, is actually the gravity arm providing impulse through the crutch to the pendulum, but it is held back by a catch and trigger, *D*, until at a given instant determined by the count wheel, *W*, it is released. The count wheel is propelled at alternate beats by a pawl mounted on the crutch. The lever, *A*, in its normal position makes contact at *P*, and near the bottom a light horizontal lever, *H*, is pivoted, the short end of which is bent at right angles towards the count wheel, *W*, whilst the long end projects towards the crutch. On the completion of each rotation, a finger, *F*, travelling round with the count wheel depresses the tail of the lever, *H*. A hook on the front part of the lever, *H*, is by this means raised into the path of a pin, projecting from the crutch, *C*. As the pendulum swinging to the right crosses the line of centres the pin on the crutch is lifted over the hook on the lever, *H*, and the pendulum thus carries with it the entire lever, *A*, which breaks contact at *P*. A projecting portion of the lever, *H*, beyond the hook finally releases the trigger and catch, *D*, causing the gravity arm, *B*, to exert its impulse on the return swing to the left. Just after the crutch has again crossed the line of centres, the lever, *A*, makes contact at *P*, the electro-magnet is energised and the gravity arm, *B*, is reset through the armature, *M*. As the crutch continues to the left the hook drops off the pin, leaving the tail again in the path of the count wheel finger.

The "Lowne" Primary. The three systems just described are all gravity impulse clocks, but the Lowne primary, shown in Fig. 45, furnishes an example of a spring impulse clock and, as in the last case, a crutch is employed as the medium for delivering the impulse. A count wheel, *W*, is again used and advanced by a pawl on the crutch, *C*, during the swing of the pendulum to the left. Two spring contacts, P_1 and P_2, are attached to the crutch at right angles, so that the points have a slightly circular movement up and down. Frictional contact is, however, actually made on their motion being arrested by the end of a finger rotating with the count wheel. This occurs with every half revolution of the count wheel when the pendulum is travelling to the left and, as soon as the circuit is closed, the armature, *A*, is attracted, contact at P_3 is broken and, at the same time, the pin on the pivoted lever, *L*, rides over

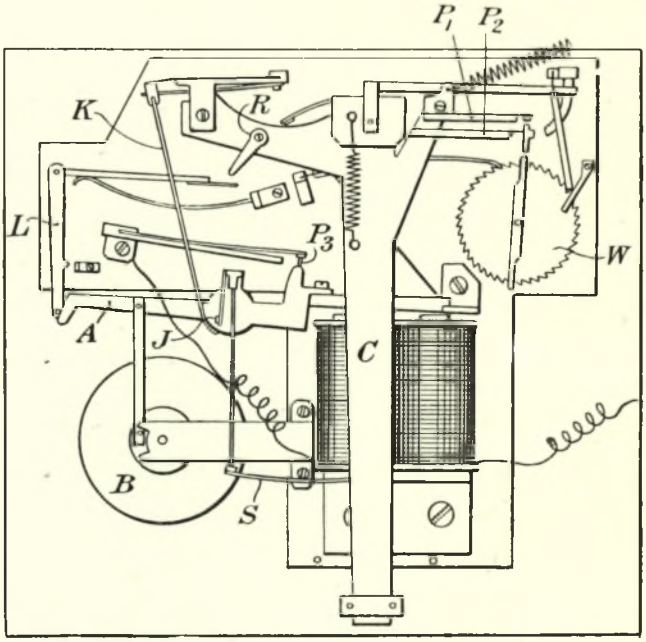

FIG. 45.—Illustrating the "Lowne" primary.

the tail of the armature, *A*. The armature is thus locked, the impulse lever, *K*, is set into the catch, *J*, and the impulse spring, *S*, compressed. As the crutch completes its return vibration, the projection, *R*, depresses the lever, *L*, which in turn releases the armature, *A*. The impulse spring, *S*, then raises the armature and with it the impulse rod, *K*, as well as the crutch through which the actual impulse is transmitted to the pendulum. The adjustable disc, *B*, provides a means of controlling and regulating the speed of the armature.

The "Princeps" Primary. One of the latest introductions into the field of electrical horology is the "Princeps" clock, the pendulum of which also receives spring impulses. A noticeable deviation from the usual custom in the construction of these clocks is that impulse is given with alternate beats and no count wheel is employed. The electrical part of the mechanism consists of a polarised electro-magnet arrangement known as the reverser, which is shown diagrammatically in Fig. 46. An armature in the

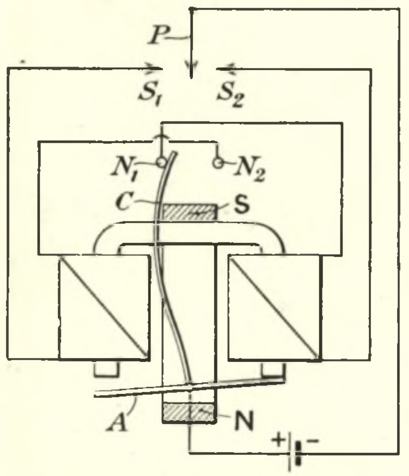

FIG. 46.—Showing the Reverser in the "Princeps" primary.

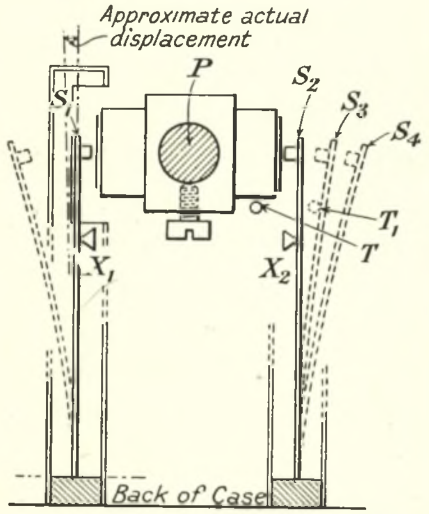

FIG. 47.—Illustrating the "Princeps" method of giving impulse.

form of a rocker arm, *A*, is attracted first to one solenoid and then to the other, according to the direction of the flow of current, this being dictated by the movement of the pendulum, *P*, between two contact springs, S_1, S_2. With the change over of the armature, *A*, the contact arm, *C*, also passes between the points, N_1, N_2, and by this means closes a secondary circuit for synchronising purposes. Fig. 47 shows diagrammatically the pendulum viewed from above and the method whereby impulse is given. The pendulum, *P*, vibrates between the two contact springs,

S_1, S_2, each of which is protected by a glass tube and provided with a stop, X_1, X_2. On one side there is an auxiliary stop, T, which is removed to the position T_1, with the attraction of the rocker, A (Fig. 46), to one of the solenoids. As the pendulum swings to the right, instead of meeting the contact spring, S_2, at rest on the stop, X_2, it has to proceed to the position shown at S_3, the spring having been already advanced by the motion of the stop from T to T_1. The pendulum then makes contact, the stop, T_1, retires because the rocker, A (Fig. 46), has changed over and the spring is carried on by the pendulum to the end of the beat at S_4. On the return to the left, the spring, acting against the pendulum, remains in contact right up to the stop, X_2, and the difference between the total lift and total descent constitutes the impulse which is represented in the figure by the separation between S_3 and S_2.

Motor-wound Clocks. In addition to the varieties of electrically-wound clocks already described there are also many instances where an ordinary mechanical clock is provided with an electrical winding gear for raising the weight or coiling the mainspring. The winding gear simply consists of an electric motor which is started at regular intervals by means of contact switches in the clock mechanism itself. In the case of a weight clock, the length of fall available for the weight would determine the suitable period between the successive re-windings. The method employed in spring clocks wound in a similar manner may more conveniently take the form of a worm drive on the shaft of the motor gearing into a wheel mounted on the barrel arbor. In both types, care has to be taken to ensure that the motor is switched off in time to prevent overwinding, so that everything really depends on the design of a suitable device for starting the motor and bringing it to rest when its work has been performed.

Steuart's Continuous-motion Clock. The latest development in motor-wound clocks is the ingenious mechanism known as the Steuart continuous-motion clock, the principle of which is illustrated in Fig. 48. Behind the pendulum two gravity arms, *A*, *B*, are pivoted on the line of centres and at the bending line of the suspension spring. The arm, *B*, carries the disc, *W*, mounted just below the centre, which acts as the gravity-weight, keeping

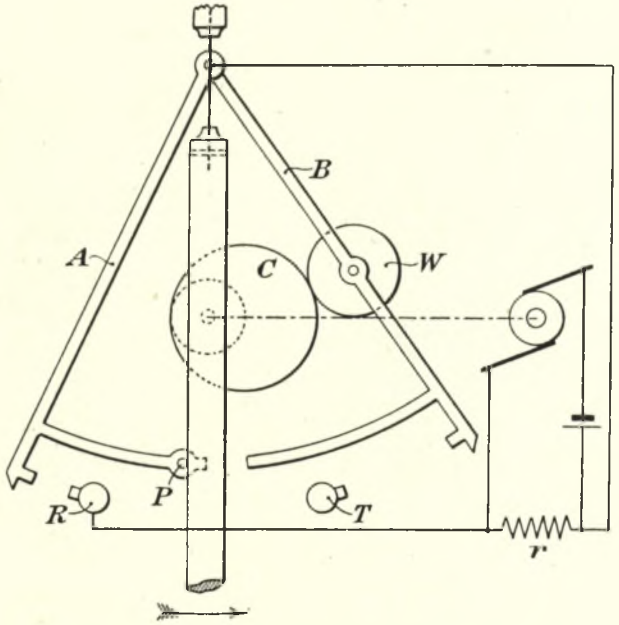

FIG. 48.—Steuart's continuous motion clock.

the disc, *W*, in contact with the eccentric cam, *C*. The latter rotates on the arbor of a wheel pivoted behind the pendulum, on the line of centres, and is driven by a pinion on the shaft of an electric motor. The motor is in continuous motion, though the supply of current is intermittent. Impulse is given to the pendulum whilst swinging to the right through contact with a pin, *P*, which projects from the gravity arm, *A*. When the extremity of the gravity arm, *A*, reaches the adjustable stop and contact, *R*, the direct current through the motor which maintains the rotation of the cam, *C*, is short-circuited through the resistance, *r*. As the pendulum proceeds still farther to the right, the cam, *C*, gradually presents its shortest radius to the wheel, *W*, and so lowers the arm, *B*, until its extremity reaches the stop, *T*. In doing this the arm, *B*, also raises the impulse arm, *A*, to its set position, breaking contact at *R* in the process. When the pendulum has arrived back at the extreme left, the cam, *C*, has already commenced to move the arm, *B*, away to the right, preceding the pendulum and leaving the arm, *A*, free to supply impulse to the pendulum as before. Between the periods of contact the motor is kept running partly by kinetic energy, but also by a reduced current passing through the resistance, *r*, which serves at the same time to eliminate sparking at the contacts.

Although the motion of the motor is not perfectly regular, the fluctuations of speed are very small and do not prevent sub-divisions of a second being accurately observed. Whenever the necessity for measured continuous motion arises, as, for example, in the rotation of drums for chart recording or for driving astronomical telescopes, this mechanism may be utilised to advantage.

Before passing to other types of electrical clocks there are certain features of contrast in connection with the foregoing systems which must not be left unnoticed, notably in the manner in which the respective pendulums receive impulse. Considering the systems individually, it will be observed that the "Synchronome," "Pulsynetic," "Standard Time" and "Lowne" all employ a count wheel which has to be operated by the pendulum, and impulse is given intermittently, generally at half-minute intervals. In the case of the first two, the pendulum receives impulse near the line of centres, where, aided by gravity, it has achieved its maximum velocity; whilst, in the other two instances, impulse is given at the commencement of the beat, ceasing soon after crossing the line of centres. The "Steuart" clock is similar in this respect, but differs in three other important aspects—the impulse is continued farther across the line of centres, delivered as frequently as at alternate beats, or even every beat, and the pendulum is entirely relieved of the work of unlocking. The "Princeps," however, stands in contrast to the rest, first, inasmuch as impulse is delivered only during a short period before the pendulum reaches the line of centres, and, secondly, that the pendulum has to raise side contact springs at every beat. The friction introduced by these contact springs suggests a similarity to the unlocking friction of a mechanical escapement, but whereas the latter presents point contact, the springs of the former are affected by frictional resistance. This condition may, however, be regarded as constant, particularly as it occurs with each vibration.

As emphasised in Chapter III, on Pendulums, the ideal for which one strives in order to ensure vibrations as nearly perfect as possible, is to remove every particle of obstruction or interference with the beat. The series of mechanisms just described, with the exception of the motor-wound ordinary clocks, do approach very closely that free pendulum ideal, provided that the essential feature of good workmanship is maintained.

Electro-magnetic Impulse Clocks. Clocks of the primary group following the second category, namely, those in which the pendulum receives impulse through an electro-magnetic agency, are by no means uncommon. Bain's clocks, one of which was described in the early part of this chapter, were of this type. An objectionable feature is that the pendulum is open to the effect of any disturbing influence due to fluctuation in the electric current, with consequent variations of arc. Excepting in the case of the "Bentley" clock, where this difficulty is overcome, these fluctuations are most detrimental in instances where the greatest precision is essential. Nevertheless, clocks of this class have been constructed in large numbers, though not often as "Master" timepieces.

The Bentley Clock. Following very closely upon the principle of the Bain clock, inasmuch as it is maintained by a voltaic current through zinc and retort carbon plates buried in the earth, the Bentley clock was introduced in

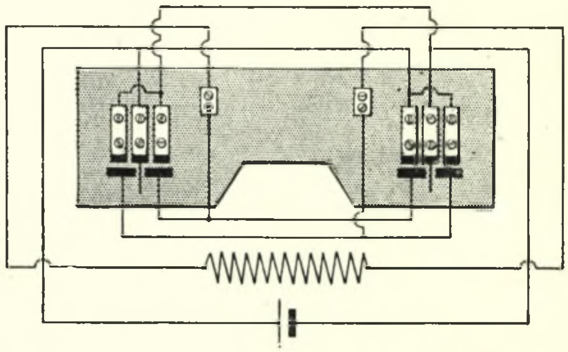

FIG. 49.—The "Bentley" clock. Showing the arrangement of the contacts across which the "make and break" carriage travels as determined by the arc described by the pendulum.

1912. Instead of Bain's "make and break" slide, a bar is used with a little wheel at each end. The pendulum carries a coil above the bob and there are two fixed magnets with adjacent north poles intercepting the field of the coil as before. The chief feature is, however, that the arc of vibration is more closely under control than in Bain's clock. The wheels at the extremities of the bar or carriage travel upon groups of contacts (Fig. 49), which are so arranged that the direction of the current is reversed as soon as a certain arc has been completed; if, however, the arc becomes excessive and overruns the point, the carriage wheels reach contacts which maintain the original direction of the current and retard the downward acceleration due to gravity. This clock, therefore, is rather an exception to the rule of its kind, because by means of the contact device the arcs are kept as near constant as possible.

Hipp Trailer. In this category of electro-magnetic impulse clocks the principle which has been developed and improvised upon to a very considerable extent was originated by Dr. Hipp about the year 1850. This system, one application of which is shown in Fig. 50, has the advantage of being comparatively economical in current consumption and extremely simple in construction. At the foot of the pendulum, below the rating nut, a soft iron bar forming an armature is attached. Under this, fixed to the case and slightly to one side of the line of centres, is an electro-magnet. Half-way down the pendulum rod a small pivoted flap is arranged to trail with the vibrations to and fro over a notched block which projects above the upper arm of a pair of contact levers screwed to a bracket on the back of the case. As the pendulum vibrates, the flap, or trailer, passes over the block so long as the arc permits. When the energy of the pendulum weakens and the arc falls off, the trailer fails to pass the notches in the block, with the result that the lever is depressed, contact made and the circuit through the magnet closed. The armature on the pendulum is at once attracted, the vibrations re-energised and the trailer again passes the block.

Impulse is thus given on the downward vibration, the intensity depending entirely on the force of the current. The vibrations will be vigorous at first, the maximum arcs wide and the intervals between the impulses great, but as the supply of current degenerates the arcs will narrow down and impulse will be sought more frequently.

Féry Principle. Another system, on rather different lines, was developed by Ch. Féry, utilising the effect of

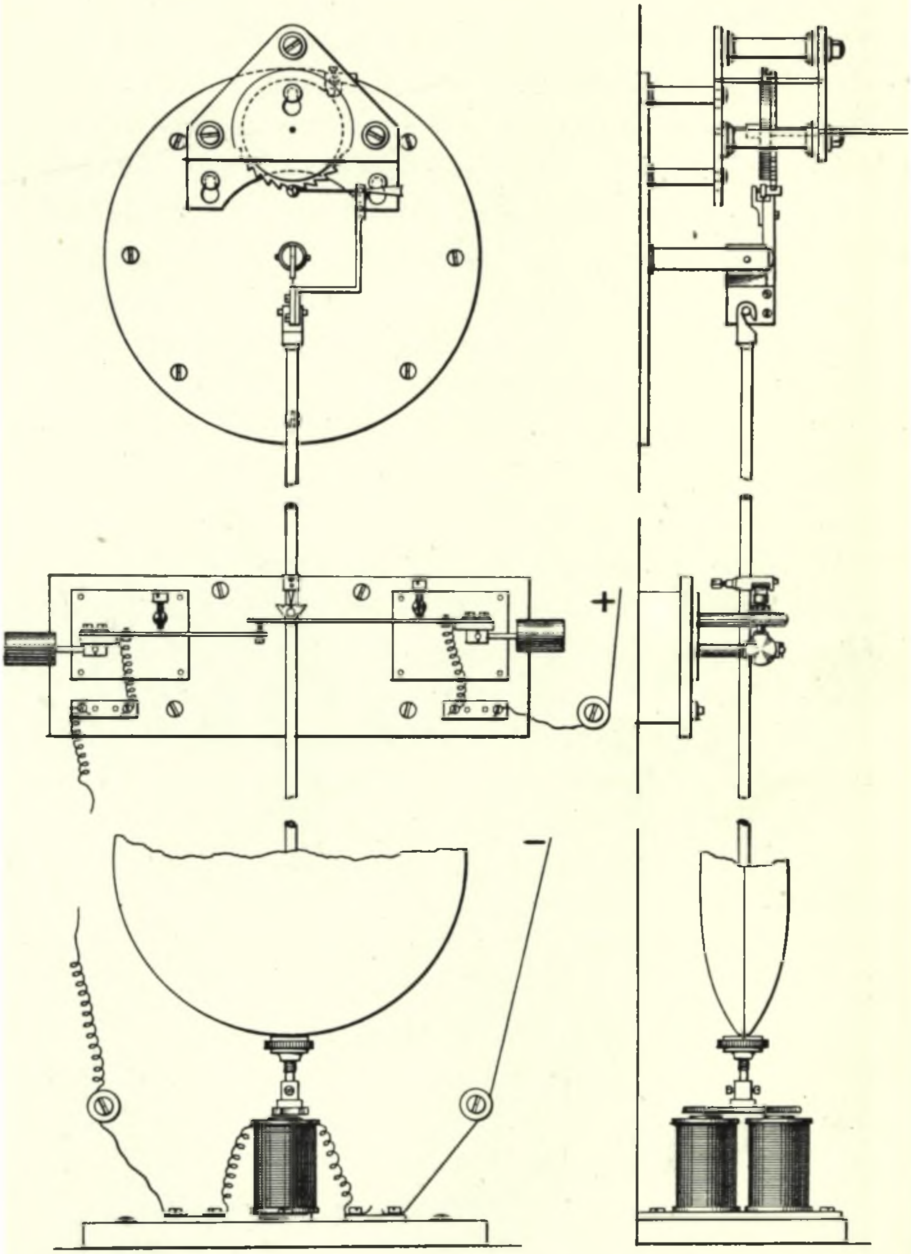

FIG. 50.—Showing an application of the "Hipp trailer" principle; from a model constructed by Mr. W. Beckmann.

Foucault currents. The eminent French physicist, Jean Foucault (1819–68), discovered that if a metallic mass lay in a magnetic field of varying intensity, electrical currents were induced in that mass. In Féry's application of this phenomenon, two pendulums are used, having the same time of vibration, and suspended in line with each other. At the bottom of one, P_2 (Fig. 51), is a copper ring, C, to admit the extremity of an arm of a horse-shoe magnet,

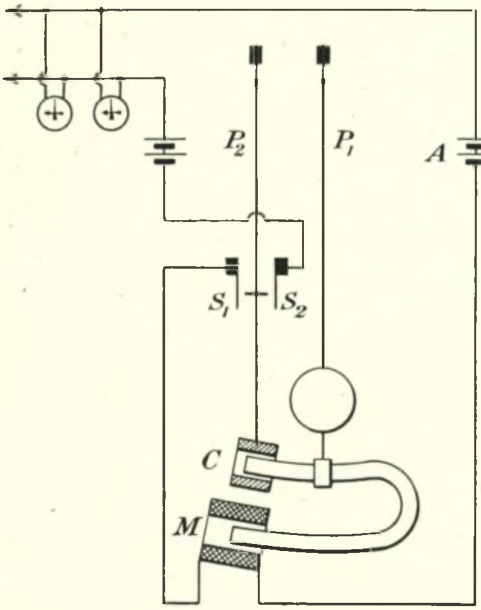

FIG. 51.—Illustrating the Féry principle of impelling a pendulum.

which is attached horizontally below the bob of the second pendulum, P_1, as shown. The other arm of the horse-shoe magnet passes in and out of a solenoid, M, as the pendulum, P_1, vibrates. During the vibration of the pendulum, P_2, contact is made alternately with the springs, S_1, S_2. Contact with S_2 closes the circuit through the secondaries, whilst contact with S_1 closes the current from the battery, A, through the solenoid, M, which attracts the one arm of the magnet, the other entering the copper ring on the pendulum,

P_2. Foucault currents are thereby induced and react on the arm attracted to the solenoid. Thus, by successive reactions, the pendulum P_1 maintains the vibrations of the pendulum P_2, and this alternately closing the different circuits, the one energising the solenoid, *M*, the other distributing signals or impulses to the secondaries, keeps the system in continuous operation.

Moulin-Favre-Bulle Clock. Although not used as a transmitter, an interesting example of an electro-magnetic impulse clock which has recently come into commercial

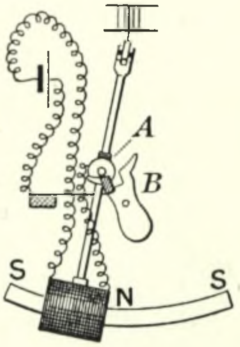

FIG. 52.—The Moulin-Favre-Bulle clock. Showing the system of electro-magnetic impulse.

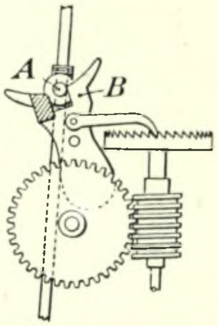

FIG. 53.—Illustrating the counting mechanism of the Moulin-Favre-Bulle clock.

prominence, principally as a domestic timepiece, is known as the "Bulle." The bob of the pendulum (Fig. 52) takes the form of a hollow coil through which is passed a curved permanent magnet, magnetised so that at both extremities there is South polarity whilst the North is concentrated about the centre. The coil travels along this magnet as the pendulum vibrates, and at the same time a pin, *A*, on the upper part of the rod oscillates with each beat a pivoted contact-piece, *B*, a combination closely resembling the ruby pin and forked part of the lever of a watch lever escapement. One of the forks is insulated so that contact is made only on alternate vibrations. The arrangement of closing the circuit through the coil, combined with the effect of the bar magnet with its central north pole, serves a dual purpose. Not only does it provide the impulse necessary, but the external supply of current from a battery, to excite the coil, is automatically diminished by reason of the electro-motive force generated in the coil by the motion of the latter with regard to the magnet. Thus the clock is maintained on a very low current consumption, whilst the vibrations have the advantage of receiving impulse regularly, which renders them more isochronous. Fig. 53 shows the way in which the contact-piece propels a horizontal count wheel at alternate beats in order to advance the hands.

Mechanical Primaries Transmitting Electrically. In this third category of primaries which simply consist of mechanical precision clocks it is the mode of electrical transmission which here comes under review. The attachment varies according to the purpose for which the signals may be required, but generally the given instant for distributing the signal is denoted by a count wheel mounted on the escape pinion arbor. The wheel is cut with V-shaped teeth placed at requisite intervals, so that, as the wheel rotates, the teeth intercept a contact arm. A regulator may be arranged in this way to send out remote sound signals in seconds with, perhaps, a gap at the 60th or at the 59th and 1st, or in numerous other ways for the benefit of an observer. In some instances, the contact may occur only at the 60th second and be used to synchronise automatically a distant secondary clock. The contact device itself may consist of light spring arms attached to an insulated bracket or, better still, the arms may be pivoted and delicately counterpoised by small adjustable gravity weights.

"**Magneta**" **Primary.** There is, however, another form of mechanical primary embodied in the "Magneta Time System" which possesses certain unique features in the method of controlling secondary clocks and signal transmission generally. Some of these primaries are weight-driven and some spring-driven, but in either case the motive power, besides keeping the clock going, is used to rotate an iron cylinder within a coil of wire, at one-minute intervals, through a quarter of a turn at a time. The motion of the iron cylinder thus generates an alternating magneto-electric current through the coil sufficient to actuate a large number of dials or other signalling devices which may be included in the circuit. An important point to notice is that the circuit is always closed, so that faulty or corroded contacts are completely eliminated, as well as the need for batteries which would both require periodic attention.

SECONDARIES OR TIME RECORDERS

As stated earlier in this chapter, the secondary group embraces mechanisms which are constructed to record, by periodical adjustment, the performance of a primary. Some of these mechanisms may, in certain instances, take the form of a time-measuring instrument, either mechanical or electrical, which is synchronised at specific intervals by the primary. Perhaps the most important example of a secondary is, however, a simple dial mechanism, forming a unit in what may be a large system of recording time-pieces all controlled by one primary. Sound signals, as electric bells, or even wireless time signals, as well as rotating drums and charts, may all be secondaries, but a description of these is hardly necessary here.

For indoor systems, the methods of constructing dial-work secondaries vary but little, though for turret clocks, where large hands are exposed to the elements, difficulties arise which demand a more robust mechanism.

"Synchronome" Secondary. Fig. 54 illustrates the Synchronome system for ordinary requirements and embodies the principle upon which most indoor dial secondaries are founded. It is a simple device consisting of the usual type of clock motion work, but the centre arbor, on

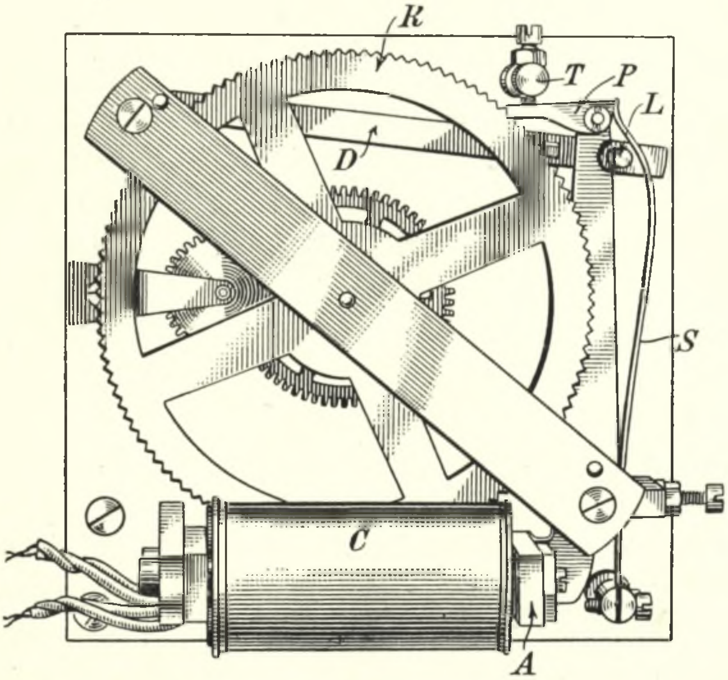

FIG. 54.—"Synchronome" secondary or dial mechanism.

which the minute hand is mounted, carries a large ratchet wheel of 120 teeth, *R*. This wheel is thus advanced at half-minute intervals, relying on the primary clock to excite the coil, *C*, when necessary and attract the pivoted armature, *A*, on which is mounted at its opposite extremity a propulsion click, *P*. Every time the circuit with the primary clock is broken the armature, *A*, falls away from the coil, aided by the spring, *S*, and the propulsion click, *P*, advances one tooth of the ratchet. The stop, *T*, controls the advance of the wheel and locks it to prevent any extraneous movement of the hands. The gravity lever or detent, *D*, which carries a pallet to drop into the wheel teeth, obviates the possibility of the wheel turning backwards when the propulsion click, *P*, is withdrawn to advance the next tooth. When the armature is attracted the propulsion click lever is brought sharply up to the stop, *L*, and the recess in the lever at that point embracing the stop temporarily locks the detent, *D*.

"Silectock" Secondary. A form of secondary clock possessing interesting features, principally that it operates quite silently, is the "Silectock." There is the usual motion work, but the centre arbor carries a wheel driven by a pinion, mounted on the arbor of which is a double-stepped snail, the steps being spaced equidistantly. The snail forms an armature free to revolve between four pole pieces—two opposite ones being the poles of a permanent horseshoe magnet and the other two those of an electro-magnet. Whilst at rest, the permanent magnet fixes the projecting portion of the snail-armature, but when the circuit is closed by the primary and the electro-magnet is excited, greater attraction is set up and the permanent magnet is overcome. After the armature has thus advanced one-quarter of a turn the circuit is broken, and the next quarter of a turn is taken up and completed by the permanent magnet, which again comes into evidence. So that at every contact made by the primary the snail-armature actually advances half a turn, the intervals shown on the dial depending upon the gearing of the centre arbor.

"Princeps" Secondary. A simple form of dial mechanism is the "Princeps," shown diagrammatically in Fig. 55. A wheel, W_1, of 60 teeth is mounted on the centre arbor of an ordinary motion work and gearing with it is an idle wheel, W_2. Projecting from the armature, *A*, is a pallet, *P*, which is normally held by means of the spring, *S*, in a space between two teeth of the wheel, W_1. When the electro-magnet, *M*, is energised and the armature attracted, the pallet crosses over to the other wheel and advances it half a tooth. In returning, after the circuit is broken, under the influence of the spring, *S*, the pallet, *P*, enters and advances the succeeding tooth of the wheel, W_1, which has already moved forward with the wheel W_2. In this

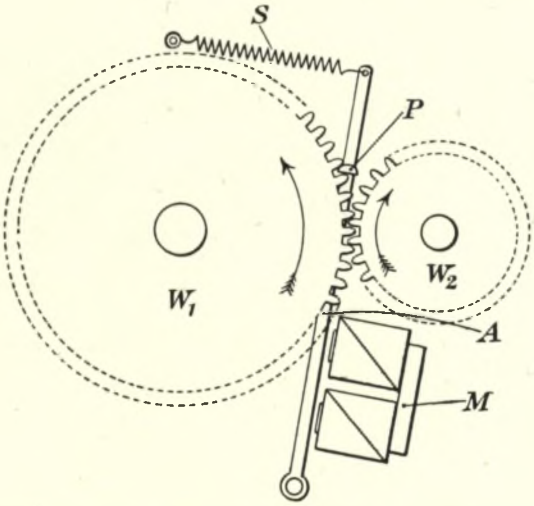

FIG. 55.—Diagrammatic representation of the "Princeps" secondary.

way, one complete tooth of the wheel W_1 is advanced with every signal from the primary.

In connection with multiple secondary working it may be of interest to refer here to a relay device introduced into the "Princeps" system. As explained on p. 115, an important feature of the "Princeps" primary is the polarised electro-magnet switch mechanism known as the "reverser." This reverser is again used in conjunction with a relay, the object of the latter being to keep the current supply to the primary distinct from that required for the secondaries.

In this case, there is a dial mechanism, similar to that described above, which is wired direct to the primary, but mounted on the centre arbor of this secondary is a snail, *S*, shown in Fig. 56. Two spring contacts, C_1, C_2, are normally held open with their outer springs, P_1, P_2, resting equidistantly apart on the edge of the snail. The contacts are connected to the respective solenoids of the reverser, *R*, in series with which is included the relay, *L*. With every half revolution of the snail, therefore, contact is made at C_1 and C_2, the current flows through the relay and the rocker

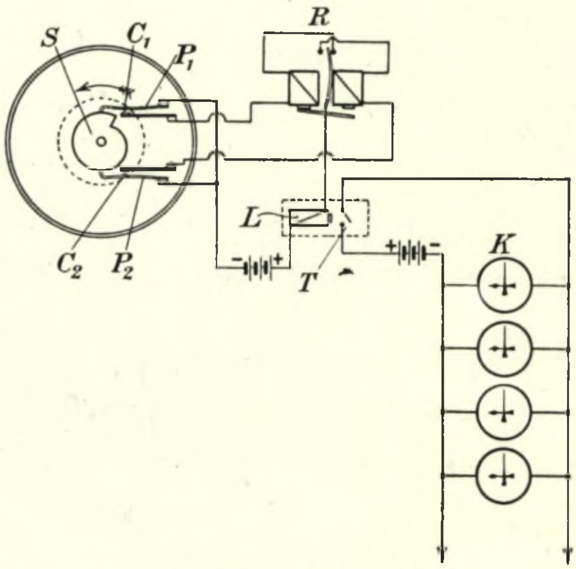

FIG. 56.—Relay device for working multiple secondaries ("Princeps" system).

armature of the reverser changes over, breaking the circuit in the process. The remaining secondaries, *K*, of the system are simply connected in parallel with the relay contacts, *T*, current being supplied from an independent battery.

Synchronising. Electrical attachments for the purpose of synchronising the hands of mechanical clocks were devised far back in the commercial history of electrical clocks. They have, however, been to a large extent superseded by the direct connection now formed between primaries and secondaries of the types just described. There are, nevertheless, two synchronising systems which demand attention, one originated by Dr. Hipp and the other by Messrs. Barraud and Lund. The latter is a simple device consisting of an electro-magnet which is excited hourly or at certain hours by a primary. Connected with the armature, which is attracted on these occasions, are two pivoted bell-crank levers from the extremities of which projects a pin, each coming through the dial on either side of zero. As the minute hand of the mechanical clock approaches the hour it enters the space between the pins. Directly the signal is received from the primary, the bell-crank levers close like a pair of scissors and, gripping the minute hand, reset it to the hour exactly. Any slight inaccuracy, either fast or slow, is thus immediately corrected.

Dr. Hipp's system is very similar, except that an inverted V-forked gravity lever, which descends sharply on a pin at the appropriate moment, is used instead of the bell-crank levers acting direct on the minute hand.

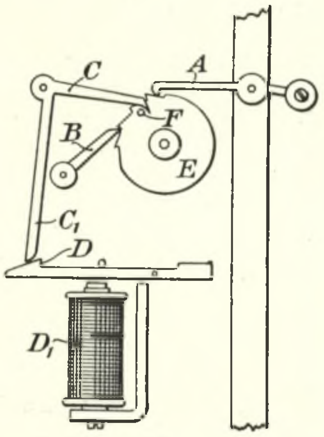

FIG. 57.—" Pulsynetic " waiting-train system for synchronising turret clocks.

What must be regarded, perhaps, as a more important development of synchronising is the system as applied to turret clocks, instituted for the purpose of overcoming troubles due to the exposure of large hands to inclement weather.

Fig. 57 illustrates the " Pulsynetic " system of synchronising for this purpose. The movement, which is described as a " waiting-train," is in reality a pendulum maintained on the " Hipp-trailer " principle (p. 121) which is rated to drive the motion work slightly in advance of the predetermined signals of the primary. Assuming that these occur every half minute, the " waiting-train " covers the distance in about 27 seconds. The pendulum, in vibrating, pulls over a count wheel, *E*, carrying the pin, *F*, which at the end of each revolution of the wheel raises the bell-crank lever, *C*, C_1, over the notched armature, *D*, and into the path of the pawl, *A*, so that the wheel is subsequently prevented from advancing. At the precise instant of the half minute, the notched armature, *D*, is attracted at the signal from the primary to the coil, D_1, thereby releasing the lever, *C*, C_1, and liberating the pawl, *A*, to recommence advancing the count wheel through which the motion work is driven. The click, *B*, prevents back-action.

Many are the devices which may form part of a secondary circuit, but they are too numerous to be detailed here. Factory time recorders, idle-machine recorders, warning signals of different descriptions all come under this category, and the ever increasing present day demand for such instruments enhances enormously the importance of what, at the commencement of this chapter, it was desired to emphasise—namely, that electrical clocks were now to be regarded as having assumed a most prominent and prospective branch of the science of horology.