# MODERN ELECTRIC CLOCKS

PHILPOTT

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PRINCIPLES, CONSTRUCTION, INSTALLATION, AND MAINTENANCE

BY

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# PREFACE

PRESENT-DAY literature on the subject of Electric Clocks mostly falls into two classes—one dealing with the subject from an historical viewpoint, and the other written for the amateur constructor of such clocks.

In the present work the writer has aimed at giving an outline of the principles, construction, and installation of typical modern electric clock systems.

It is, of course, impossible to deal with every system and make of clock, not only for want of space but for the fact that these are being added to daily.

The writer would here like to acknowledge his indebtedness to the many firms and individuals who have placed information and illustrations at his disposal in compiling this work.

S. F. PHILPOTT

BANBURY, 1932.

# MODERN ELECTRIC CLOCKS

## CHAPTER I

### INTRODUCTORY

THE subject of electric clocks is a very wide one, for they are to-day found in every sphere of life—in industry, commerce, at sea, and in the home, each application having its own special requirements and problems.

Electric clocks are generally conceded to be superior to the mechanical variety, and with the general growth of electrification, together with the development of a greater appreciation of correct time since the advent of broadcasting, are likely to supplant them altogether.

In the following chapters it is proposed to describe the principles, working, and installation of the modern electric clock.

**The Measurement of Time**

Time, like other quantities, such as weight or length, is measured by comparison with a standard. The setting of a unit of weight or length is a fairly simple procedure, involving the manufacture of a master which can be retained for reference.

The unit of time, on the other hand, is not a concrete object, consequently any permanent standard is out of the question, and the best that can be accomplished is to measure it against the movement of some body in steady motion.

The only practical object which can be taken for such a standard is the rotation of the earth upon its axis. The determination of its speed is not, however, a simple procedure, and in practice time is thus determined by astronomers and time indicators or clocks are made to indicate the actual time of day.

It is important to note that there is no connection between the speed of the earth and the rate of the clocks, and thus the essential feature of a clock is that its hands must always take exactly the same time to cover a given distance on its dial. In practice, of course, the accuracy of clocks varies with their construction. The clock at the Houses of Parliament, for instance, keeps correct time within a second a day. Clocks used in observatories keep even more accurate time than this, showing a variation of only a few seconds a year. The vagaries of the time-keeping of cheap clocks is well known.

For everyday purposes the standard of time in England is the Greenwich mean solar day, which is divided into twenty-four hours. Each hour is further divided into sixty minutes, and each minute into sixty seconds.

For astronomical purposes another unit called the Siderial day is used. A description of this and of the methods of measuring and distributing accurate time will be given in a later chapter.

The earliest form of clock was the CLEPSYDRA or water clock, which was known in 200 B.C., and has been used in various forms ever since. It consists of a vessel containing water which is arranged to drip out slowly. The vessel is filled daily, and the drop in the level of the water indicates the passage of time, the instrument being graduated in hours.

The Egyptians divided the period between sunrise and sunset into twelve equal hours, so that provision was made for the rate of flow of the water to be adjusted as the length of the day increased or decreased.

Another ancient form of time recorder is the sand glass—the use of which is still preserved for such domestic purposes as timing the boiling of eggs.

The familiar sundial provides a link in the evolution of time recording devices. It indicates solar time by means of the shadow of a "style" thrown across a suitably engraved dial.

Its obvious limitation is that it is of no use if the sun is not shining. The process of accurately setting and marking the dial is somewhat complicated, and a dial constructed for one particular place is useless for a locality in a different latitude.

In the time of Alfred the Great, candles were used to indicate the passage of time. The candles were of wax, 12 in. in length, and graduated in inches. They burnt for four hours each.

The origin and early development of the mechanical clock is wrapped in obscurity. The earliest records of such clocks in this country date back to the thirteenth century, but from the details of construction available, it is evident that development had been going on long before this time.

The earliest electric clock was that of Alexander Bain, who took out a patent in 1840, and its development has proceeded steadily since that date, both in this country and abroad. Generally, the modern electric clock is a high-class instrument, combining beauty of construction and design, wonderful accuracy of time-keeping, and reasonable price.

It will be seen in later chapters that development has proceeded along several distinct lines, according as to the way in which electricity has been applied to the clock.

For instance, apart from the purely electric clock, i.e. driven entirely by electricity, mechanical clocks may be wound by electrical means, or the time-keeping of existing clocks can be controlled by electrical impulses from another master clock or Greenwich Observatory.

Before proceeding to a description of electric clock systems, it will be necessary to consider briefly the principles of electricity and magnetism, and of clock construction.

# CHAPTER II

## PRINCIPLES OF ELECTRICITY

THE study of electric clock installations demands a wide, even though it be superficial, knowledge of two subjects, not normally connected, viz. that of the science of time and timekeeping, and that of electricity.

The latter demands considerable attention, because not only are we concerned in this volume with the principles of no less than five different systems of electric clocks, and several makes of each type, but also with their installation, maintenance, and repair.

Thus the following brief survey of electrical and magnetic principles should be read with care. All are closely related to the main subject.

A natural starting point for a chapter devoted to elementary principles is to define electricity, and here we are immediately up against a difficulty, for although its properties are well known, and it can be controlled and made to perform innumerable services for the community, no one has yet been able to discover what electricity really is. Many theories have been advanced, but the problem still remains to be solved.

For most practical purposes, electricity may be considered as a fluid permeating all substances, which can be made to flow when an electrical pressure is applied to the ends of what is generally called the circuit.

A simple electric circuit is shown in Fig. 1. Here $A$ is a generator of electricity, and may be a battery or dynamo, $C_1$ and $C_2$ are switches, $D_1$ and $D_2$ are clocks or other apparatus to be operated by current derived from the battery.

$B$ is a meter to measure the current flow (usually called an ammeter), and $V_1$, $V_2$, and $V_3$ are instruments (known as voltmeters) to measure the electrical pressure across the points to which they are connected.

All the components are connected together by wire and, with the exception of the voltmeters $V_1$, $V_2$, $V_3$, are said to be in series because, assuming the switches to be closed, the current flows from the battery first through $B$, thence through $C_1$, $D_1$, $D_2$, $C_2$, and back to the battery.

The opposite of a series circuit is called a "parallel" circuit, as shown in Fig. 2.

Here $A$ is the battery and $C$ the switch as before, but the clocks $D$ are connected in such a manner that the current from the battery flows partly through one clock and partly through

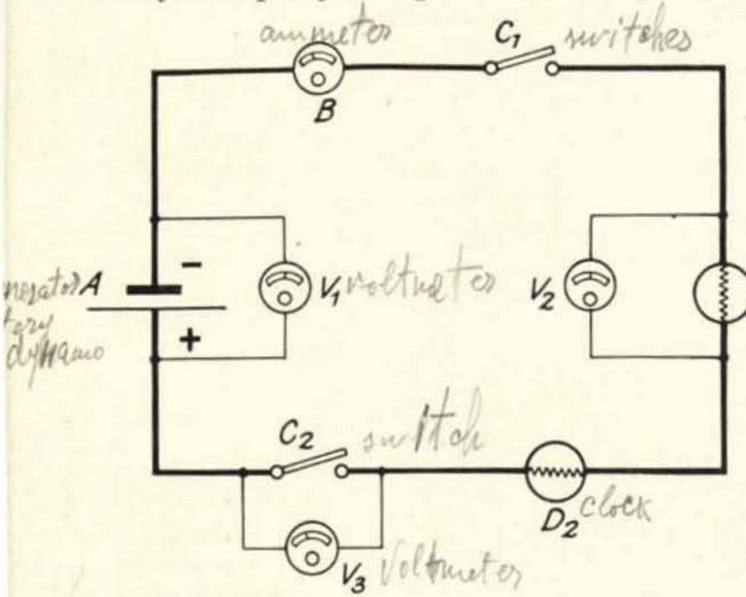



FIG. 1. SIMPLE ELECTRIC CIRCUIT (SERIES)

the other. If the one clock is disconnected, the other is not affected.

Circuits may, and often are, a combination of series and parallel.

Fig. 3 shows such a circuit. Here $A$ is a master clock, $B$ the battery, $C$, $D$, $E$, $F$, each a group of several clocks in series. In this case the current from the battery splits into four parts so far as the secondary clocks are concerned, but all the current flows through the master clock.

It may be mentioned here that materials differ considerably in their powers of conducting electricity, and can generally be split into two groups, viz. conductors and non-conductors.

All the metals are conductors of electricity as also is carbon and certain acid and alkaline solutions. Practically all other materials are non-conductors. Very bad conductors of electricity are called insulators.

Tables I and II give a list of the principal conductors and insulators met with in practice.

The conductors are classified in order of their conductivity, e.g. silver being the best known conductor is placed at the head of the list.

This practice cannot be followed with insulators because other properties enter into the selection of an insulator for a particular purpose.

TABLE I

CONDUCTORS OF ELECTRICITY

| | |
|---|---|
| Silver | 100 |
| Copper | 94 |
| Gold | 72 |
| Aluminium | 55 |
| Zinc | 25·5 |
| Iron | 16·2 |
| Tin | 11·2 |
| Lead | 7·2 |
| Mercury | 1·56 |
| Carbon | ·019 |

Conductivity at 0° C. Silver taken as 100.

TABLE II

SOME COMMON INSULATORS

| | |
|---|---|
| "Bakelite" | Micanite |
| Cotton | Paper (compressed) |
| Ebonite | Paraffin wax |
| Empire cloth | Porcelain |
| Glass | Press-Spahn |
| Leatheroid | Shellac |
| Marble | Silk |
| Mica | Slate |

Having outlined the principles of the simple electric circuit, it is necessary to consider its properties in more detail.

To do this, let us first of all look at the hydraulic circuit shown in Fig. 4. In this diagram $A$ is a centrifugal pump, $P_1$, $P_2$, $P_3$ are pressure gauges, $FM$ is a meter to register the rate of flow of the water, say, in gallons per minute. $R$ is a coil of piping or any consuming device, and all connected together by piping shown. $T_1$ and $T_2$ are taps.

The pipes are supposed to be full of water, the taps off, and the pump stationary.

Now if the pump is started up, it creates a pressure which is indicated, in pounds per square inch, by the pressure gauge $P_1$. If tap $T_1$ be turned on the meter $P_2$ will indicate the same pressure as $P_1$, but water will not flow through the pipes because of tap $T_2$ being "off." When this is turned on the path to the pump is open and a flow of water takes place. The

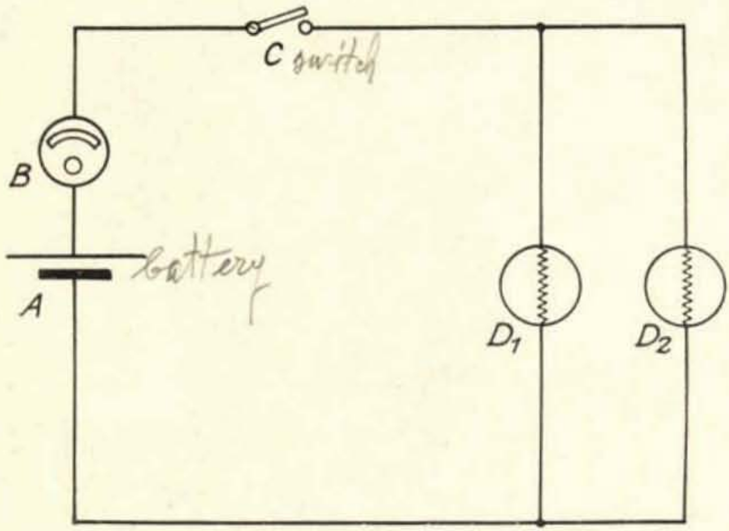



FIG. 2. SIMPLE PARALLEL CIRCUIT

rate of flow in gallons per minute is, of course, the same throughout the circuit.

Several things are to be noticed. The pressure at $P$ has dropped a little, and the pressure indicated by $P_2$ is very small indeed, and that of $P_3$ nil.

The flow meter indicates the rate of flow of the water, this depending on several factors as follows: (1) The pressure developed by the pump. If this is doubled, twice the former amount of water is forced through the pipes. (2) The length of the piping. If this is increased it is evident that more pressure must be exerted to get the water through, or, the pressure remaining the same, the flow will be less. (3) The sectional area of the pipe. If the pipes shown are replaced by some of larger diameter it is obvious that they will be able to carry more water than the smaller, and it will consequently require less pressure to get the same amount of water through. (4) The flow of water is also influenced by the internal condition

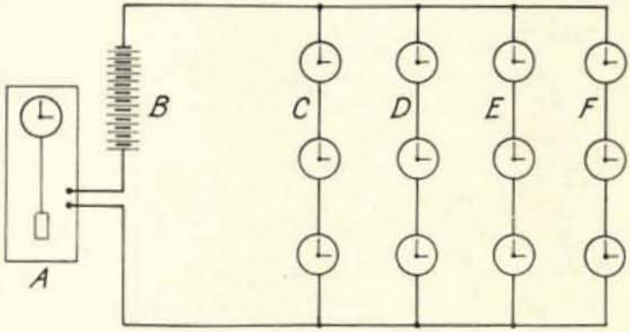



FIG. 3. SERIES-PARALLEL CIRCUIT

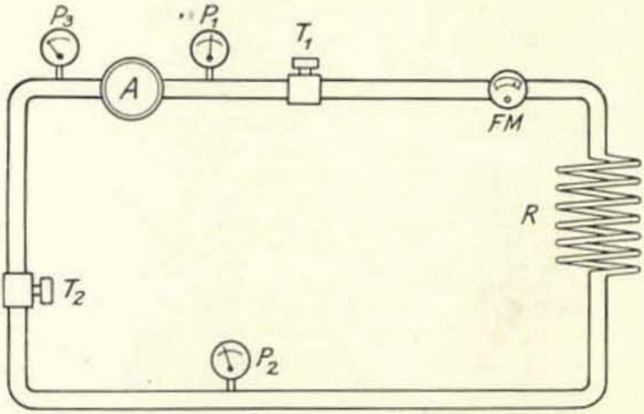



FIG. 4. SIMPLE HYDRAULIC CIRCUIT

of the pipes. For example, water will flow through a pipe which has a smooth bore more easily than through one which has in some way been roughened.

It is thus seen that with a given pump pressure the flow of water is controlled by three factors, namely, length, diameter, and internal condition of the piping.

The conditions prevailing in the electric circuit conform fairly closely to the hydraulic circuit as given above, but the analogy must not be taken as being an exact one.

Electrical pressure is measured in "volts." The pressure obtained from a battery is 1 to 2 volts per cell, depending on the type. Country house lighting plants usually work on 25, 50, or 100 volts, 50 being the most common. The pressure of commercial electricity ranges from 100 to 250 in this country—220 and 230 volts being the most general.

The rate of flow of electricity, corresponding to the gallons per minute in our hydraulic analogy is known as the "ampere," named after an illustrious pioneer in electrical science.

Opposition to the flow of current, termed resistance, is measured in "ohms."

Now referring back to Fig. 1 the voltage across the battery terminals, sometimes called the electro-motive force or simply E.M.F., is measured by voltmeter $V_1$. On closing switch $C_1$ the full pressure is also indicated by $V_3$. It should be noted that there is no pressure drop in the circuit until the current flows by closing switch $C_2$.

When the current flows, the voltage of the battery or generator falls a little, the ampere-meter indicates the amount of current, and a drop of pressure occurs over each clock $D_1$ and $D_2$.

Similar to the water circuit, the amount of current can be increased by increasing the battery pressure or by reducing the resistance of the circuit so that it may be said that the current produced is directly proportional to the pressure (or electro-motive force) and inversely proportional to the resistance of the circuit.

It would be very convenient if it were possible in the above expression to write "is equal to" instead of "proportional to," and the electrical units mentioned above have been chosen with this object so that we come to the fundamental formula of all electrical engineering, known as Ohms Law, thus—

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms.}}.$$

Thus by simple conversion we get—

$$\text{Volts} = \text{amperes} \times \text{ohms and}$$

$$\text{Ohms} = \frac{\text{volts}}{\text{amperes}}.$$

This law is so important that a few examples of its use will be given.

*Example* 1. The resistance of an electric clock is 12 ohms, and to it is connected a battery having an E.M.F. of 4 volts.

Calculate the current flowing in the circuit.

By Ohms Law, current $= \frac{\text{volts}}{\text{ohms}}$.

Substituting figures.

$$\text{The current } I = \tfrac{4}{12} = \tfrac{1}{3} \text{ ampere.}$$

*Example* 2. The current in a time circuit is $\frac{1}{2}$ ampere, and

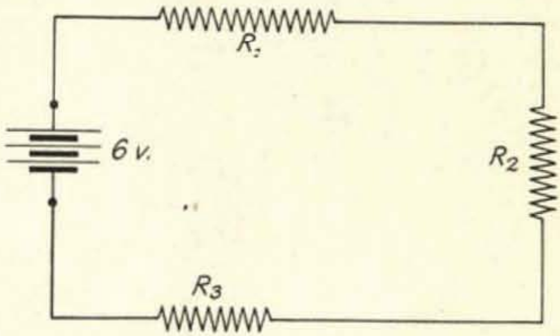



FIG. 5. CALCULATION OF RESISTANCES IN SERIES

the resistance of the wiring apart from the clocks themselves is 2 ohms. Find the voltage lost in the circuit wires.

$$\text{Volts} = \text{current} \times \text{resistance}$$
$$\text{Volts} = \cdot 5 \times 2 = 1 \text{ volt.}$$

The resistance of a conductor is directly proportional to its length, and inversely proportional to its area.

In other words, a long piece of wire offers more resistance to the passage of a current than a short length, and current will flow more readily through a large diameter wire than a small wire.

The actual volt drop in a cable can be calculated by Ohms Law as Example (2) above.

The resistance of a wire also depends on the material, and as shown in Table I metals vary in their conductivity. The resistance of one centimetre cube of the metal is known as the "specific resistance."

Knowing the specific resistance of a conductor, the actual resistance can be calculated from the formula.

$$\text{Resistance (ohms)} = \frac{\text{length (cm.)} \times \text{sp. res.}}{\text{area (sq. cm.)}}$$

Before passing to a more practical aspect of the subject it is necessary to consider the question of resistances in series and parallel.

If two or more resistances are joined in series, as Fig. 5, the resultant resistance will equal the sum of the separate resistances, or generally—

$$R_T = R_1 + R_2 + R_3$$

The volt drop across each will be in proportion to its resistance, thus if the coils in the figure had resistance of 3, 5, and 4 ohms, and a six volt battery were applied as shown, the volt drops would be 1·5, 2·5, and 2 volts respectively.

The current flowing would be, by Ohms Law—

$$I = \frac{E}{R}$$

$$= \frac{6}{12} = \cdot 5 \text{ amperes.}$$

The calculation of the resistance of two or more circuits in parallel is not quite so simple.

The rule is, add together the reciprocals of the resistances, and the reciprocal of the answer gives the resultant resistance,

or $$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

In the circuit shown in Fig. 6 the reciprocal of the resistances $A$, $B$, and $C$ are $\frac{1}{4}$, $\frac{1}{2}$, and 1 respectively, which added together give $1\frac{3}{4}$ or $\frac{7}{4}$. The resultant resistance is, therefore, $\frac{4}{7}$ ohm.

A term met with frequently in electrical work is the watt. This is the unit of electrical power. 746 watts are equivalent to one horse-power.

1,000 watts are called a kilowatt. In direct current circuits the power being developed or used in watts is the product of the volts and amperes, or watts = volts × amperes.

In the case of alternating current circuits it is necessary to multiply further by what is known as the power factor.

The Board of Trade unit by which electricity is sold by supply undertakings represents one kilowatt hour.

That is, a B.O.T. unit is used when 1,000 watts of electricity are used for 1 hour, or 1 watt for 1,000 hours, or any other combination of hours and watts giving a product of 1,000.

The power consumed by electric clocks when such are

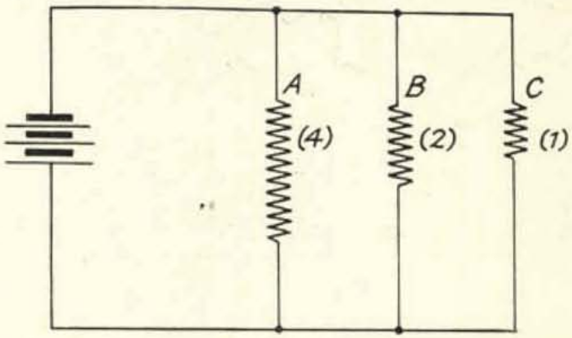



Fig. 6. Calculation of Resistances in Parallel

operated from the supply mains is usually very small indeed, often so small, in fact, that it is insufficient to work the supply company's meter when no other device is consuming current.

## Batteries

So far as electric clocks are concerned there are two principal sources of current supply, viz. batteries and the public supply mains. The first method will now be considered.

There are two types of battery—the primary battery, and the secondary battery or accumulator.

Primary batteries produce current by chemical action. Secondary batteries, as is well known, have to be first charged with electricity by some outside source.

The simplest type of primary battery is that shown in Fig. 7. *A* is a plate of copper, *B* a plate of zinc, *C* a dilute solution of sulphuric acid, all contained in the earthenware jar *D*.

When the plates are connected together by a wire, current will flow from the copper to the zinc in the external circuit and from the zinc to the copper inside the cell. The copper plate is termed the positive, the zinc the negative electrode.

The simple cell has several disadvantages, and numerous modifications have been devised. The principal ones met with

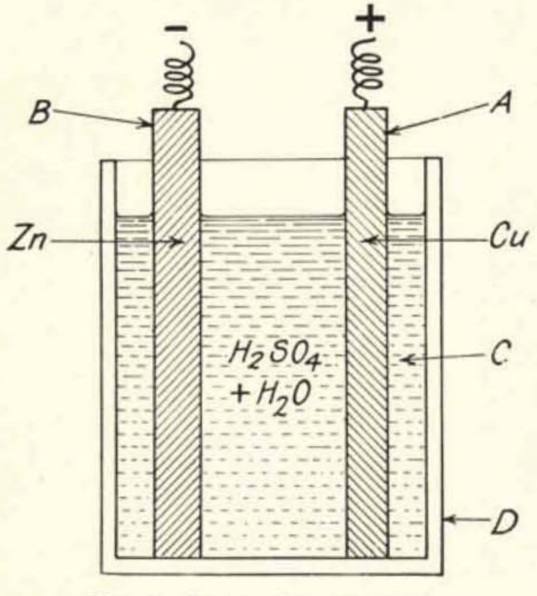



FIG. 7. SIMPLE PRIMARY CELL

in electric clock practice are the Daniell, the Leclanché, and the dry cell. The first two are named after their inventors. The dry cell is really a modified type of Leclanché cell.

It may be mentioned here that the terms cell and battery are often used indiscriminately to mean the same thing. A battery is the name given to a number of cells connected together.

A sectional view of the so-called gravity type Daniell cell is shown in Fig. 8.

It consists of an outer glass or stoneware jar *A* from the top of which is suspended a heavy zinc element *B*.

In the bottom of the jar is a spiral of copper strip *C*, to which a length of insulated cable *D* is soldered.

The copper is covered with a layer of crystals of copper sulphate (*E*), and the jar filled to just above the level of the zinc with a solution of zinc sulphate *F*.

As in the simple cell, the copper plate constitutes the positive and the zinc the negative. The E.M.F. produced is 1 volt.

The Leclanché type of cell is probably the best known and most widely used of all where small currents are required

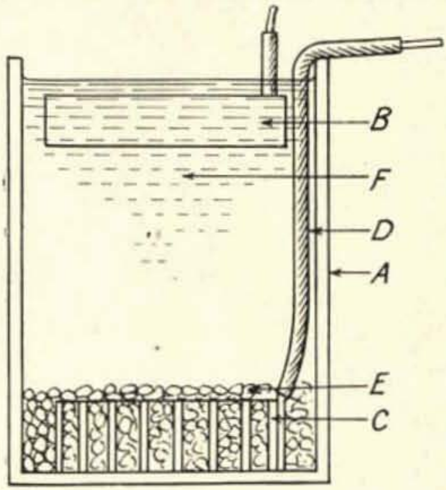



FIG. 8. GRAVITY TYPE DANIELL CELL

intermittently, and is admirably suited to the operation of electric clocks, bells, alarms, etc.

It consists of an outer glass jar *A*, Fig. 9, containing a solution of ammonium chloride—popularly known as sal-ammoniac—in water (*B*) and a rod of zinc *C*.

An inner "pot" of porous earthenware *D*, contains the carbon plate *E*, which is tightly packed with a mixture of carbon powder and manganese dioxide *F*. The top of the porous jar is sealed with bitumen *G*, one or two small holes, *H*, being left to allow for the escape of gases generated in the pot.

The carbon is the positive plate, and the E.M.F. generated is 1·5 volts.

*Dry cells* are only dry in the sense that they do not spill. The chemical action and the chemicals used are substantially the same as that of the ordinary Leclanché cell. The container is usually made of zinc, this being the negative pole. The "solution" is in the form of a paste, and a linen bag replaces the earthenware jar to contain the carbon rod. The voltage per cell is 1·5.

It should be noted that the electro-motive force obtainable

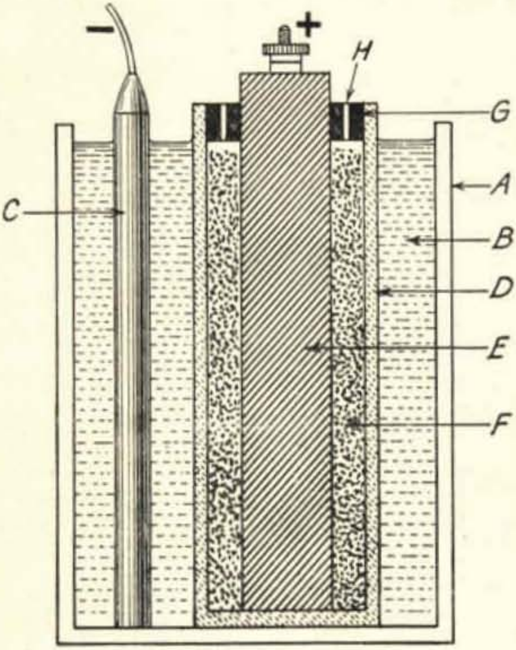



FIG. 9. LECLANCHÉ CELL

from a primary or secondary battery is independent of the size. A simple cell made up in a thimble will show the same voltage as one made up in a large tank.

The amount of electricity that can be taken from a cell is, however, proportional to its size.

The larger cell has also the advantage that the volt drop in the cell itself due to the passage of the current is less. In other words, the voltage of the cell when giving current is more nearly equal to that shown when not discharging.

The open circuit volt reading is known as the electro-motive force of the battery, and the terminal voltage when delivering current is known as the potential difference (P.D.) The P.D.

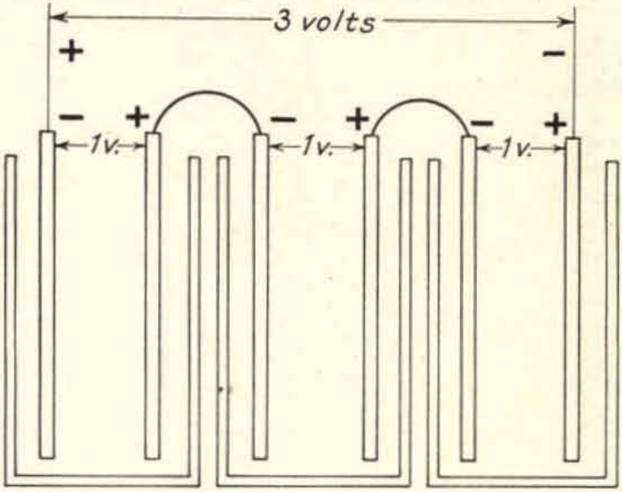



FIG. 10. CELLS CONNECTED IN SERIES

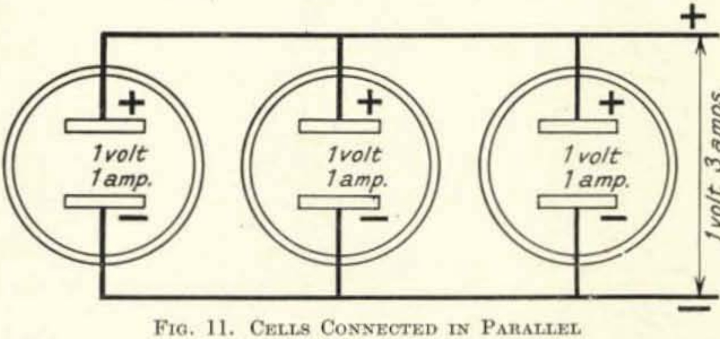



FIG. 11. CELLS CONNECTED IN PARALLEL

reading plus voltage lost inside the cell itself is equal to the E.M.F.

The voltage of all forms of primary and secondary cell is very small. To increase the voltage cells can be connected in *series*, as in Fig. 10. It will be seen that the positive plate of one cell is connected to the negative of the next, and the voltage across the outer plates of the battery equals the sum of the individual voltages.

Cells can also be connected in parallel, as in Fig. 11. All the positives are connected together, and all the negatives likewise.

Here the terminal voltage remains the same as that of a single cell, but the capacity of the battery is increased in proportion to the number of cells connected.

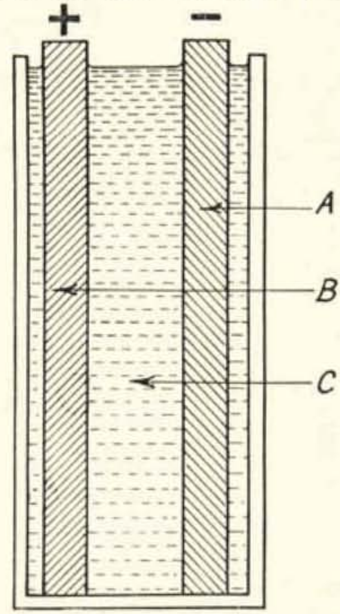


FIG. 12. SIMPLE SECONDARY CELL OR ACCUMULATOR

**Accumulators**

A simple secondary battery or accumulator is shown in Fig. 12.

*A* is a lead plate having a number of interstices filled with a paste of lead monoxide (litharge) surrounded by sulphuric acid, this being subsequently reduced to spongy lead during the first charge. *B* is a similar plate, the paste in this instance being red lead and sulphuric acid, changing to lead peroxide. *A* is the negative plate and *B* the positive. *C* is a dilute solution of sulphuric acid in water having a specific gravity of about 1·200.

During charging the chemical composition of the plates is altered but returns to its original form during discharge.

The E.M.F. of each cell is 2·4 volts when fully charged, dropping quickly to 2 volts. This value is maintained until the end of the discharge, when the voltage drops to 1·8. The last figure is an important one to remember, as to discharge an accumulator below this value will result in permanent damage being done.

Accumulators are preferable in many ways to primary batteries. Heavier currents can be taken than from a corresponding size of primary cell, and maintenance is less. The characteristics and charging of accumulators will be fully dealt with in a later chapter.

### Magnetic Effect of the Current

One of the most important effects of the electric current is that of electro-magnetism, and every electric clock employs

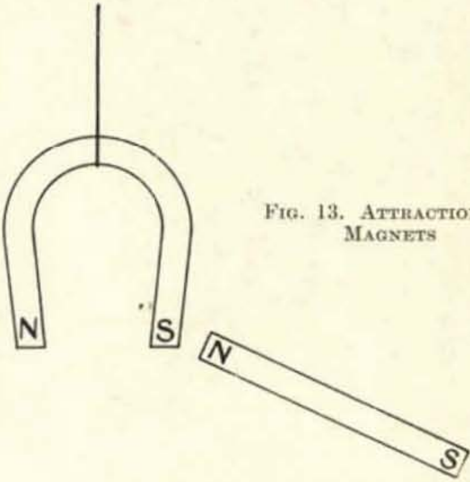



FIG. 13. ATTRACTION OF MAGNETS

this principle in one way or another; in fact, there are few electrical devices that do not.

Our power stations depend upon it, for it is by electro-magnetism that all commercial electric current is generated.

No doubt all readers are familiar with the simple magnet—a bar or horseshoe of hardened steel which has the power of attracting pieces of iron or steel to it. This is generally known as a permanent magnet to distinguish from the temporary magnets which may be produced by electrical means, and which will be discussed later.

If a permanent magnet be suspended on a piece of fine cord attached to its centre so that it is free to swing round, it will settle in a definite direction—the one end pointing to the earth's North Pole, and the other to the south.

The ends of the magnet are called the poles, and the one which points north is called the north pole.

Every magnet, however large or small, has these two poles. It is impossible to make a magnet with one pole only.

Now, considering the suspended magnet shown in Fig. 13, if the north pole of the bar magnet be brought in close proximity to the south pole of the horseshoe magnet, violent attraction between the two takes place.

If, on the other hand, the north pole of the bar magnet be presented to the north pole of the other, the latter will immediately swing away.

Thus we come to a fundamental law of magnetism, viz. unlike magnetic poles attract, like poles repel one another.

It is very important that this be clearly understood.

A type of magnet which is rarely met with in general practice, but is used in certain electric clocks, is the consequent pole type, Fig. 14, so called because it is magnetized in two

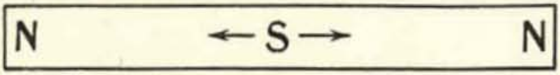



FIG. 14. CONSEQUENT POLE BAR MAGNET

halves with similar poles of each section in the centre. Thus the effect is produced of a magnet having similar poles at both ends.

Iron and steel are the only commercial magnetic materials. All others are non-magnetic.

## Electro-magnets

If a coil of insulated wire be wound round a bar of iron or steel, and an electric current passed through the coil, the bar will become magnetized and have exactly similar properties to the permanent magnet described above. If the direction of the current through the coil be reversed, the polarity of the magnet will be reversed also.

If the iron is hard it will remain a magnet when the current is switched off. If the iron is very soft practically all trace of magnetism will disappear. This is the condition usually required in practice, and cores of electro-magnets are in consequence generally made of annealed Swedish iron.

Now if the iron core be removed altogether from the coil and a compass needle (which in effect is a pivoted bar magnet) is brought near, it will be found that all the magnetic effects will still be exhibited so long as the current remains on. They will, however, not be so strong as when the core is in position.

Such a coil, without a core, is termed a solenoid.

If a piece of iron is introduced into the end of a solenoid, it will be immediately drawn into the centre. Solenoids are used to a considerable extent in electric clocks.

The amount of magnetism produced by a given coil depends

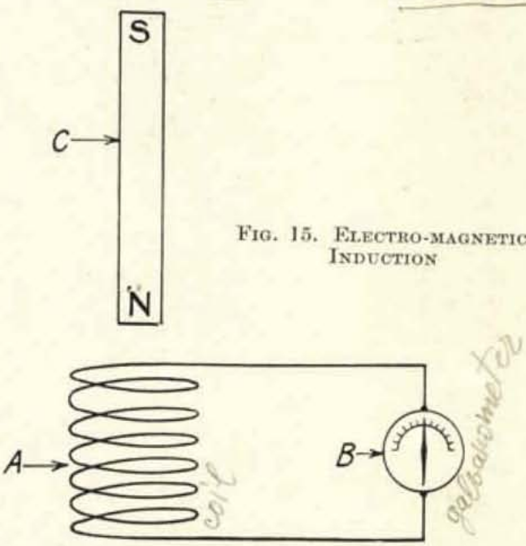



FIG. 15. ELECTRO-MAGNETIC INDUCTION

on the product of the current, and the number of turns of wire—or the "ampere turns."

Thus to produce a given magnetic effect, one may use either a small current and a large number of turns or *vice versa*, dependent on circumstances.

Another important magnetic effect is that illustrated in Fig. 15.

Here *A* is a coil of wire, the ends of which are connected to a galvanometer *B*—an instrument for indicating the presence and direction of an electric current.

*C* is a permanent magnet.

If the one pole of the magnet be thrust into the centre of the coil of wire, the needle of the galvanometer will be seen to deflect momentarily. When the magnet is removed from the coil, the galvo. will again be deflected, but this time in the opposite direction.

This is due to the lines of magnetic force which radiate from the poles of the magnet cutting through the turns of the coil. Whenever a conductor cuts through, or is cut by a magnetic field, an electro-motive force is produced within it.

The voltage produced depends on the strength of the magnet, the number of turns in the coil, and the rate of cutting.

This is the basic principle of all electrical generators or dynamos.

Actually the coil in our simple illustration is replaced by

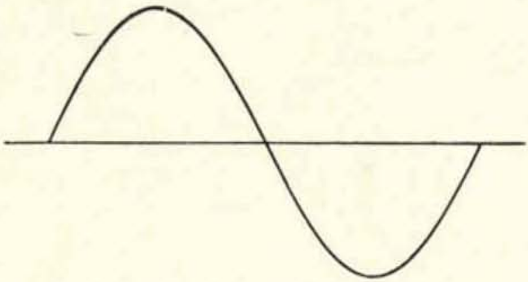


FIG. 16. WAVE FORM OF ALTERNATING CURRENT

a number of coils mounted on an "armature" which rotates in a magnetic field, and the current as generated alternates in direction and is thus called alternating current.

Many generators are, however, fitted with commutators, which cause the current to flow in the same direction all the time. This is known as direct current. Current produced by primary batteries is, of course, direct current.

Direct and alternating current supplies have their respective advantages and disadvantages.

Alternating current has been adopted as the standard supply in this country, and existing direct current supplies are changed over to alternating.

In dealing with alternating current, the term frequency or periodicity is frequently met with. This represents the number of reversals per second, and ranges from 25 to 100 in this country, 50 being the most used. A graphical illustration of an alternating current cycle is shown in Fig. 16. It will be seen that the current starts at zero, gradually builds up to a maximum in one direction, dies down to zero, reverses, builds up to a maximum in the other direction, and again goes to zero—whence the cycle is repeated.

The reversals of the current are so quick as not to be normally perceptible when one looks at an electric lamp, for instance, but as will be described in detail later, these rapid reversals have been made use of in an important form of electric clock.

# CHAPTER III

## TYPES OF CLOCK

THE subject of time and time measurement is a large and complex one, and only broad principles will be touched upon in this chapter. Some knowledge of mechanical clock principles is a necessary prelude to the understanding of the working and maintenance of the electric clocks to be described later.

It will be found that certain classes of electric clocks are to all intents and purposes mechanical clocks, and the electrical portion is only subsidiary—being used, for example, to wind the clock, or periodically to correct the time shown—while other electric clocks have nothing in common with mechanical clocks except perhaps the dial and hands.

A clock may conveniently be regarded as comprising three separate units, viz. (1) the hands which indicate the time on the dial, (2) the driving mechanism which keeps the hands in motion, (3) the controlling unit which regulates the speed at which the hands are driven and is responsible for the accuracy of time-keeping of the clock.

The driving power of mechanical clocks in common use is of two forms: the falling weight, and the uncoiling of a previously wound spring.

The principal control methods are the pendulum and the balance wheel, both used in conjunction with an "escapement." The best mechanical clocks are weight driven and pendulum controlled, but these require to be permanently and strongly fixed to work well.

Domestic clocks are frequently spring driven and pendulum controlled, while portable clocks, watches, and chronometers are invariably spring driven, and controlled by a balance wheel escapement.

The various units will now be considered in a little more detail.

### Dial and Hands

These call for little comment. The system of using two hands, and graduating the dial into twelve hours is universal and familiar to everyone.

**Weight Driving**

The motive power of all the early clocks was a weight of iron or lead, a method which had the advantage of simplicity and constant pull. The weight is suspended on a rope, gut

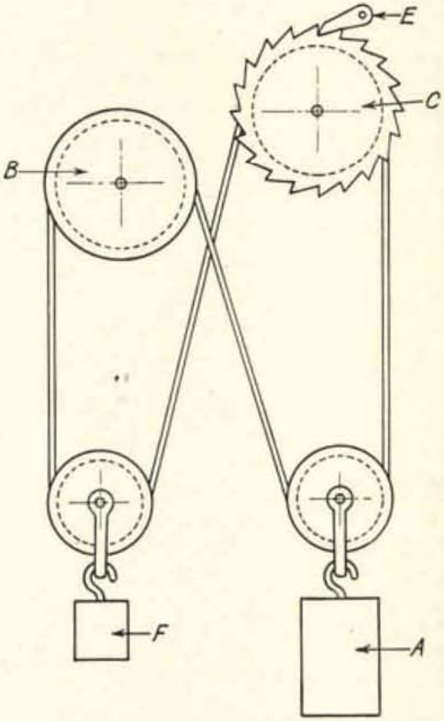



FIG. 17. HUYGENS ENDLESS CHAIN DRIVE FOR MECHANICAL CLOCKS

line, or chain, the upper end of which is wrapped round a barrel. A ratchet is provided to enable the clock to be wound, and the rate of fall of the weight is governed by the escapement.

A modification of the simple weight system is the Huygens endless chain, introduced about 1670, and extensively used in 30-hour long case or grandfather clocks.

Fig. 17 represents this arrangement.

*A* is the driving weight supported by an endless cord passing over the pulley *B*, from which the clock is driven, and also over the pulley *C* which is provided with ratchet teeth as shown. In a timepiece this pulley merely rotates on a stud. In a striking clock the striking train is driven from a gear attached to the ratchet wheel.

Counterweight *F* serves to keep the chain taut over the pulleys.

To wind the clock the cord is pulled, the ratchet wheel running under the pawl *E*, which prevents its running back. It will be seen that with this motion, driving continues even during winding.

Sometimes a modification of the Huygens system is met with in electrically wound turret clocks.

## Spring Driving

A clock spring consists of a long strip of special steel coiled into what is known as a spring case or barrel. The inner end of the spring is attached to the spindle or arbor on which the barrel rotates, while the outer end is fastened to the barrel itself.

Usually the spring is wound by rotating the central arbor, back motion of which is prevented by a ratchet and pawl. During unwinding the arbor remains stationary, the barrel rotating. Suitably cut teeth on its periphery enable its motion to be communicated to the going train of the clock.

## Methods of Control

THE PENDULUM. A simple pendulum consists of a relatively small heavy body suspended at the end of a light thread or freely pivoted rod. When set in motion it will vibrate to and fro at a certain definite rate, dependent entirely on its effective length, i.e. distance from the pivot to the centre of gravity of the weight or "bob."

The time of swing is not controlled in any way by the weight of the pendulum, but a heavy pendulum is more satisfactory than a light one, as its rate is less likely to be affected by air resistance and climatic conditions.

The formula for ascertaining the time of one vibration is—

$$t = \pi \sqrt{\frac{l}{g \times 12}}$$

in which $l$ = effective length of pendulum in inches.
$t$ = time to swing—from extreme left to extreme right or *vice versa.*
$g$ = acceleration due to gravity which may be taken as 32·2 ft. per second, per second.

The length of the pendulum beating seconds in England is about $39\frac{1}{8}$ in.

The length of a half-second pendulum is $9\frac{3}{4}$ in., and of one for two seconds beats, $156\frac{1}{2}$ in.

It should be noted that adding weight *above* the centre of gravity of the bob shortens the effective length of the pendulum, while adding weight to the bottom of the bob increases the length and the time of swing, so this method is often used in finely regulating a clock.

Another method of regulating frequently used in smaller clocks, is actually to raise or lower the bob by rotating a nut on which it rests.

Unless steps are taken to counteract such an effect, the time of swing of a simple pendulum varies with its temperature. This is because the pendulum expands on heating which, therefore, causes the effective length to increase and *vice versa.*

An increase of temperature will, therefore, cause an uncompensated pendulum-controlled clock to lose.

The expansion of the rod is counteracted to a small extent by the upward expansion of the pendulum bob, but unless the metals are very dissimilar it is very difficult to secure accurate compensation in this way.

The steel and mercury pendulum seen on old-fashioned clocks is an example of a successful application of this principle.

Almost all modern high-class pendulums have a cast-iron or steel bob, and a rod of an alloy of steel and nickel known as "INVAR" which has the property of being practically unaffected by heat.

The upward expansion of the bob almost exactly compensates for the slight downward expansion of the rod.

The most satisfactory pendulum for high-class regulator clocks is one having a swing of one second, and nearly all electric master clocks have such pendulums.

Mechanical turret clocks are usually fitted with pendulums of two seconds length.

Domestic mantel clocks have short, quick swinging pendulums on account of the small space available.

Escapement. The escapement provides the link whereby the amount of power driving the clock hands is controlled by the rate of swing of the pendulum.

The principle of working is that at each swing of the pen-

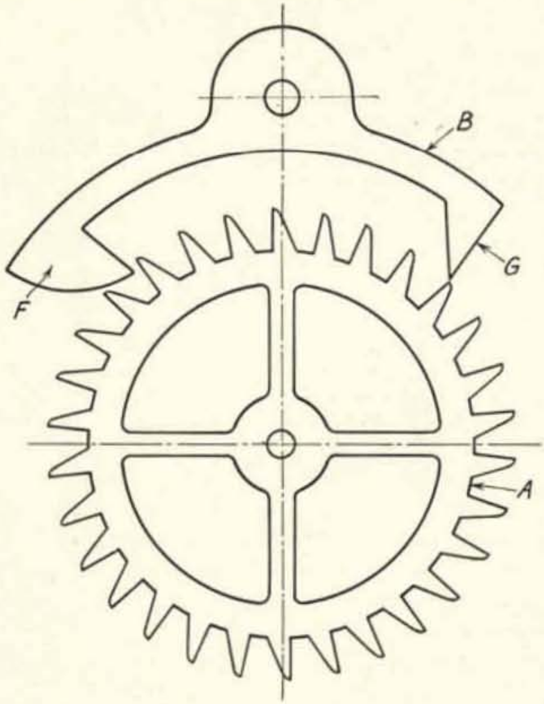



Fig. 18. Anchor Escapement

dulum the 'scape wheel is allowed to move forward the space of one tooth, and the escapement is so designed that at the same time the pendulum receives an impulse to keep it in motion. It is essential that this impulse be gentle, or erratic time-keeping will result.

There are several types of escapement. One of the most common is the anchor type, shown in Fig. 18.

Here $A$ is the 'scape wheel having 30 teeth, and $B$ is known as the pallet.

Fig. 19 gives a side elevation of the mechanism of this portion of the clock. *A* is the 'scape wheel, *B* the pallet, *C* the pendulum crutch (a strip or wire bent to engage with the pendulum rod as shown), and *D* is the pendulum rod supported at *E*.

As the pendulum swings to the left, Fig. 18, left-hand pallet *F* rises and allows the tooth of the 'scape wheel to travel

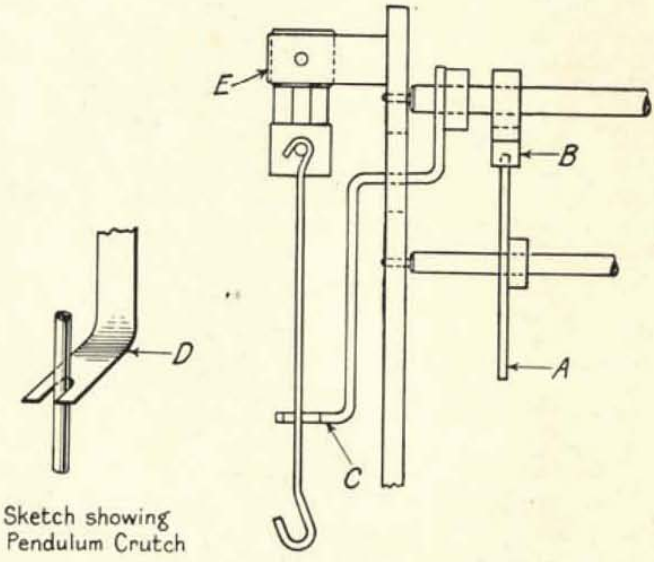



FIG. 19. SIDE ELEVATION OF CLOCK, SHOWING RELATION OF 'SCAPE WHEEL, PENDULUM, ETC.

forward, an impulse being imparted to the pendulum in so doing. At the same time the right-hand pallet *G* falls and arrests any further motion of the 'scape wheel. As the pendulum comes to the end of its travel the cycle is repeated.

If a clock having one of these escapements be examined it will be seen that for a fraction of each stroke the pendulum is called upon to drive against the spring. Thus the pendulum cannot be considered "free," but for domestic clocks this is not important.

High-class weight-driven clocks or "regulators" are often fitted with an escapement known as the dead beat type, in which this "recoil" action does not take place.

Clocks with dead beat escapements require very careful levelling, and a substantial mounting to work properly. This is one of the reasons why domestic clocks are almost always fitted with the recoil type of escapement.

Mechanical turret clocks are usually fitted with another form of escapement, known as the gravity type, invented by the late Lord Grimthorpe. In this the pendulum is driven by a pair of gravity arms raised by the train at each beat, but falling on the pendulum rod by their own weight only. The power used in lifting the arms is not taken from the pendulum, and the weight applied to the pendulum is always constant.

THE BALANCE. There are many instances where it is impracticable to employ a pendulum, as for example in portable clocks, watches, and ships' clocks. In these cases a balance wheel and spring is used.

The vibration of the pendulum is replaced by the to and fro motion of the balance wheel under the influence of its control spring, the escapement being operated by a suitable link motion. As with pendulum control, the balance is kept in motion by an impulse taken from the spring.

Having now briefly outlined the principles and constructional features of mechanical clocks, we may briefly consider the various types of electric clocks to be found.

These may be divided into five groups, viz. (1) impulse clocks or regulators, electrically driven and arranged to operate any number of subsidiary dials, (2) self-contained clocks driven by a battery, (3) mechanical clocks, wound electrically, (4) synchronous motor clocks operated from and controlled by the electricity supply mains (the time-keeping of these is really dependent on an impulse clock covered by class (1) ), and (5) synchronized clocks which may have any form of driving power, and can only be called electric as their time is electrically corrected at hourly or other intervals.

Electric clocks possess the following principal advantages: no attention as there is no winding to be done, accurate time-keeping (the pendulum can be relieved of practically all work and has merely to keep time), all the dials in the building can be operated from one master clock, and every clock will show the same time.

# CHAPTER IV

## IMPULSE CLOCKS

### Introduction

The most used and undoubtedly the most familiar type of electric clock is that operated on the impulse system, which is met with in all large factories, railway stations, schools, and other institutions where accurate time is required throughout. Tremendous loss of time is a regular occurrence in places where independent or unreliable clocks are in vogue. Employees are never certain when the cease work signal will sound, and consequently prepare to leave sometimes as much as five minutes before time. A saving of even two minutes twice a day in this manner represents two hundred hours per week in a factory employing a thousand men.

On tramway and railway undertakings uniform time all over the system is, of course, an essential, and can only be obtained by electrical means.

The dials of impulse clocks are characterized by the fact that the hands usually move forward in jumps of a half minute at a time, although in some systems jumps of a full minute are made.

In most systems it is possible for the hands to be arranged to advance in steps of a second at a time when necessary, such as in clocks used for testing purposes, telegraph timing, or the accurate time regulation of industrial processes.

Slow advancement is also desirable for public clocks at railway termini. A "minute jumper" as this type of clock is termed in America, may show a prospective traveller that he has a minute to join a train. An instant later the hands might advance to the departure time and the train leave without him.

Numerous systems of impulse clocks have been invented from time to time, many of which have dropped into disuse. There are, however, several systems giving good service in this country to-day.

All impulse clock systems comprise three essentials.

1. A master clock arranged to transmit electrical impulses at regular intervals to the clock dials.

2. The dials or secondary clocks.

3. The battery or other source of power.

Other refinements, such as battery warning indicators, programme controllers, etc., are often included, but do not concern us at this juncture.

The master clock is invariably a very high-class time-keeper, and may be a mechanically wound clock fitted with suitable contacts which close at half-minute intervals, or it may be electrically driven. The latter is almost universal practice to-day.

While spring- and weight-driven clocks require weekly attention, electrically driven master clocks work, of course, without any attention being necessary except very occasional lubrication, and even less occasional renewal of the driving battery.

Incidentally, electrically driven master clocks represent the simplest and, therefore, most accurate type of clock. Modern designs rarely have more than one wheel in their mechanism—in fact, one commercial type has been evolved which has no wheel at all—and the pendulum is as nearly as possible free.

It has been shown in a previous chapter that to obtain absolutely accurate time-keeping the pendulum must swing freely, that is to say, it must not be called upon to do mechanical work such as the driving of a clock mechanism, nor must its swing be interfered with in any way.

In a mechanical clock the pendulum is bound up with the escapement mechanism, from which it receives an impulse at every stroke.

In the electrical clock, the master pendulum is not concerned with the driving of the dial mechanism—this is done by electric power—and it is only given a very gentle impulse when required, usually twice a minute. For the rest of the time, the escapement is held clear of the pendulum.

In the ordinary commercial electric master clock the only work the pendulum is called upon to do is to turn a light "count wheel" one tooth at a time to enable a contact to be made once per revolution. The closing of this contact causes the dial hands to move forward one step, and at the same time the pendulum is given a gentle impulse to keep it in motion.

It may be mentioned here that commercial forms of impulse clocks are capable of being regulated to keep accurate time to within a second a week.

Special forms for observatory work have been found to keep within a second a year—a truly remarkable performance.

The standard time-keepers at Greenwich observatory are electric impulse clocks, and the familiar six-dot-seconds time signal transmitted by the B.B.C. is obtained from one of these clocks.

The clock dials themselves call for little mention. They are exceedingly simple in construction. Assuming that the impulses are received at half-minute intervals, the minute hand spindle is fitted with a 120-tooth ratchet wheel, and the necessary train of gears to drive the other hand at one revolution per twelve hours. This represents all the gearing. Adjacent to the 120-tooth ratchet wheel is an armature operated by an electromagnet so arranged that each impulse advances the ratchet through one tooth, and with it the long hand through one half-minute.

The dials are usually connected in series with the master clock and battery, and there is no limit to the number which can be operated from the same master clock. Installations of 100 clocks or more are quite common.

In practice, of course, such a big number of dials would be split into groups to ensure that a breakdown of one dial would not stop the whole system. This will be discussed later.

The power for impulse clock systems is generally derived from batteries—either primary cells or accumulators—the latter often being arranged to be "trickle charged" from the electric supply mains.

The current consumption and voltage per dial varies with different systems, but it is very small, 0·2 amperes and one volt respectively being about the average.

Dry batteries are eminently suitable for supplying the current for driving the clocks. A good make of battery will work an installation for two or three years continuously without attention.

Direct drive from the ordinary power supply mains is not usually desirable, as complications are introduced into the various components and their wiring, besides which a failure of the supply will cause the clock to stop. A battery failure, on the other hand, takes place gradually, and the need for renewal is apparent long before actual failure takes place.

Accumulators are useful when they can be "trickle charged" from A.C. mains through a transformer and rectifier. Trickle charging from D.C. mains is not practicable without first disconnecting the accumulator from the clock circuit, which calls for a reserve battery and special arrangements for quick change-over to ensure that a beat is not missed in the process.

The question of power supply and wiring of impulse clocks will be discussed at some length in a later chapter.

We have now seen that the electric impulse system is capable of giving absolutely accurate time at as many points as wanted with practically no maintenance.

Impulse clocks cost little to buy and install, and the wiring is of the simplest nature.

The master clock is generally provided with an advance and retard device by which all the clocks on the system can be adjusted together at the change-over from Greenwich to summer time and *vice versa*.

Besides being used to actuate clock dials the time impulses can be used to operate workmen's time recorders, and to control industrial processes. The number of applications of this nature is legion.

Impulse clocks are eminently suitable for home use, and are much used in large residences.

In smaller houses, however, they have not come into favour, mainly because one or two good clocks are all that are required in the ordinary household, and broadcasting provides a frequent and accurate means of checking the time-keeping of domestic mechanical clocks.

The master clock is the greatest single item of expense in an impulse system, and would thus represent a large proportion of the total cost of a domestic installation, whereas it would be insignificant in that employing several hundred dials. Incidentally there is usually no difference between the construction of a master clock controlling two or three dials only, and one controlling a whole community.

The additional wiring is often an objection as far as private houses are concerned. Generally speaking, one of the other systems to be described in later chapters is to be recommended for home use.

It is now proposed to describe in detail some typical examples of the impulse clock systems used in this country. Space does not permit of a description of all of them. It should be remembered, too, that every large installation has some special feature requiring individual treatment by the manufacturers.

For instance, a factory may be equipped with a half-minute impulse installation, and require seconds indicating dials in certain departments, or again it may desire to have its workmen's time recorders brought into line with the other clocks without upsetting their maker's guarantee.

**The Synchronome System.**

The Synchronome is one of the best known systems of electric clocks, and enjoys a world-wide reputation, not only for commercial time-keepers, but also for very high-class instruments such as are used in observatories.

It is also the oldest of present-day electric clock systems, dating from 1895, the patent for which was the first of a long series of inventions on which British practice is now largely founded.

Space does not permit of a detailed exposition of its development, and for this the reader is referred elsewhere.[1]

Suffice to say that the aim of the inventors, of whom Mr. F. Hope Jones is the principal, has been to produce a commercial clock approaching as near as possible to the performance of a free pendulum.

Step by step the clock mechanism has been simplified in order to relieve the pendulum of any duties liable to influence its free performance until master clocks are available having no wheels at all in them, and a Synchronome free pendulum clock installed at Greenwich Observatory has proved so accurate and regular in its time-keeping, that it is actually used to check the inconsistencies of the periodic motions of the heavenly bodies such as the rotation of the earth. The maximum discrepancy of this time-keeper is of the order of 0·75 second in a year.

Like other impulse clocks, the Synchronome comprises three

[1] See *Electric Clocks* by F. Hope Jones.

essentials, viz. the master clock, the dials, and the battery. It is proposed first of all to describe the more common type of Synchronome clock and its associated equipment, then to follow with a description of the special free pendulum model. It will be seen that even the commercial model master clock, such as installed in factories and similar places, has only one wheel.

Fig. 20 shows a typical master clock. The dial does not form part of the clock mechanism, but is controlled electrically in the same way as any other dial in the circuit.

The pendulum is of seconds length, the bob weighing 16 lb., and impulses are transmitted every half-minute. A lever is provided enabling the dials to be advanced and retarded as desired.

Fig. 21 shows the master clock movement, the lower part of the pendulum and also its suspension being omitted.

*A* is the base plate of cast iron, and *B* the pendulum rod of "Invar," a nickel steel alloy having a negligible coefficient of expansion, supported on a light, flexible spring in the usual manner of high-class clocks.

The switch motion, which performs the dual function of closing the dial circuit every half-minute, and giving the pendulum a gentle impulse to keep it in motion at the same time, consists of two parts: (1) the right-angled lever or gravity arm *C* pivoted at *D* and normally resting with its longer arm on a projecting catch *E*, which is pivoted at *F*. (2) The armature *G* pivoted at its lower end at *H*.

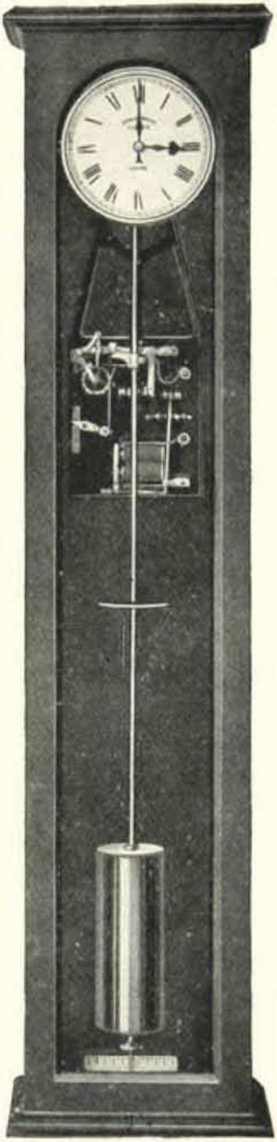


Fig. 20. Synchronome Master Clock

The pendulum carries a small hook

or gathering jewel $I$ which engages with the ratchet wheel $J$, drawing it one tooth forward for every complete swing of the pendulum, i.e. every two seconds.

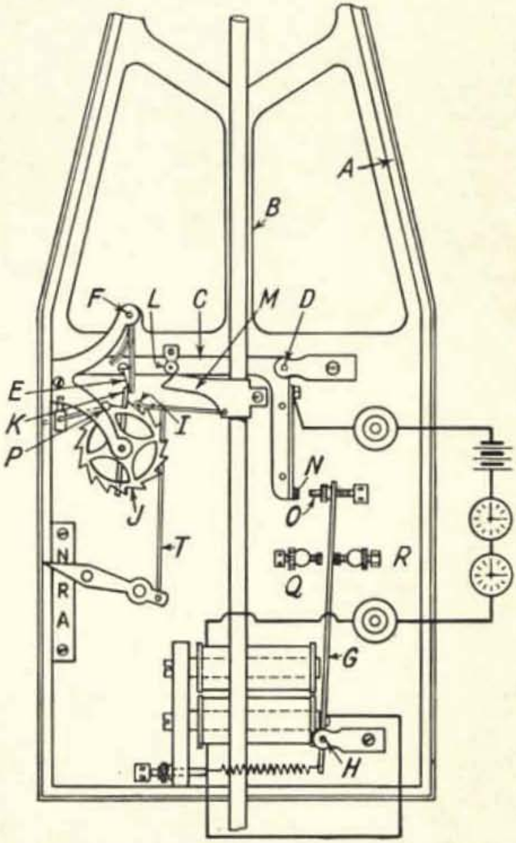



FIG. 21. MOVEMENT OF SYNCHRONOME MASTER CLOCK

This wheel has 15 teeth and, therefore, makes one revolution in half a minute.

Attached to the ratchet wheel is the vane $K$, so arranged that once in every revolution it pushes catch $E$ aside, letting the gravity arm fall by its own weight.

The glass roller *L* on the gravity arm drops on the pallet *M* fixed on the pendulum, and rolls down its curved surface, giving the pendulum a driving impulse sufficient to maintain its swing.

At the same time the contact *N* also fixed to the gravity arm touches contact *O* on the armature of the electro-magnet.

This completes the circuit through the dials and through the magnet coils which are in series with them. The immediate effect of this is to advance the hands of the various clocks one step, and to cause the armature to be drawn to the magnet core. This latter action lifts the gravity arm and replaces it on its catch *E* ready for the next cycle of operations.

An important claim for this system is that the impulse to the dials is not an instantaneous one (which might cause sluggish dials to miss occasionally), due to the fact that the current grows to its maximum gradually, owing to the self-induction of the circuit.

The back stop catch *P* prevents the ratchet wheel being pushed back as the next tooth is being gathered.

The stops *Q* and *R* limit the travel of the armature. The former are so set that the gravity arm is not taken right home by the armature, but completes the journey under its own momentum, thus ensuring a clean break of the contact points.

The action of the advance and retard lever is interesting. When in the upper or "normal" position the clock acts precisely as described above. In the lower or "accelerate" position the wire *T* is lifted so that the gathering jewel trips the gravity arm catch at every stroke, therefore the dials are rapidly advanced.

In the centre position (retard) the gathering jewel is held out of engagement with the ratchet wheel, and thus the dial circuit is not operated. The pendulum meanwhile swings free, and for long stoppages, such as at the change from summer to winter time, it is generally necessary to restart it by hand.

It may be noted with interest that by this means any number of clocks can be advanced the one hour necessary at the commencement of summer time in a little over four minutes. The time this operation would take if, say, 100 dials had to be attended to individually is better imagined than described.

Fig. 22 illustrates the standard dial movement in which *A* is the main ratchet wheel having 120 teeth, *B* the electro-magnet connected in series with all other clocks, *C* the armature, *D* the armature lever, *E* the driving click which pushes the ratchet wheel one tooth forward every time the magnet is energized, *F* is the driving spring holding the armature away from the magnet normally, *G* the back stop lever whose function it is to prevent the ratchet wheel from running backwards,

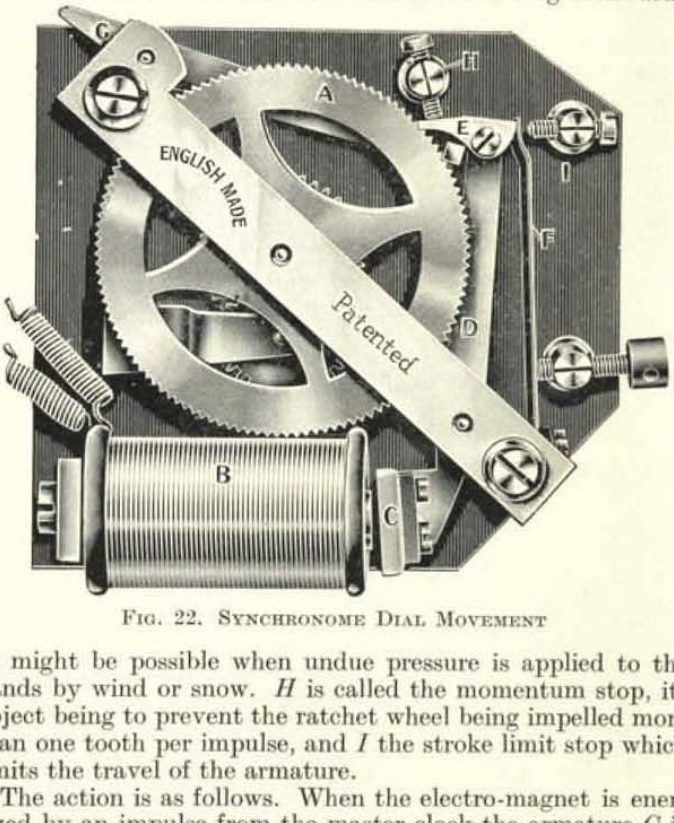



FIG. 22. SYNCHRONOME DIAL MOVEMENT

as might be possible when undue pressure is applied to the hands by wind or snow. *H* is called the momentum stop, its object being to prevent the ratchet wheel being impelled more than one tooth per impulse, and *I* the stroke limit stop which limits the travel of the armature.

The action is as follows. When the electro-magnet is energized by an impulse from the master clock the armature *C* is attracted. This causes lever *E* to be propelled to the right against the pressure spring *F*, and to drop into the tooth behind that which it formally occupied.

Immediately the current ceases, the electro-magnet becomes de-energized, and spring $F$ drives the armature lever forward causing the ratchet wheel to turn through a distance of one tooth equivalent to half a minute on the dial.

The ratchet wheel is fixed to the hour hand spindle, a train

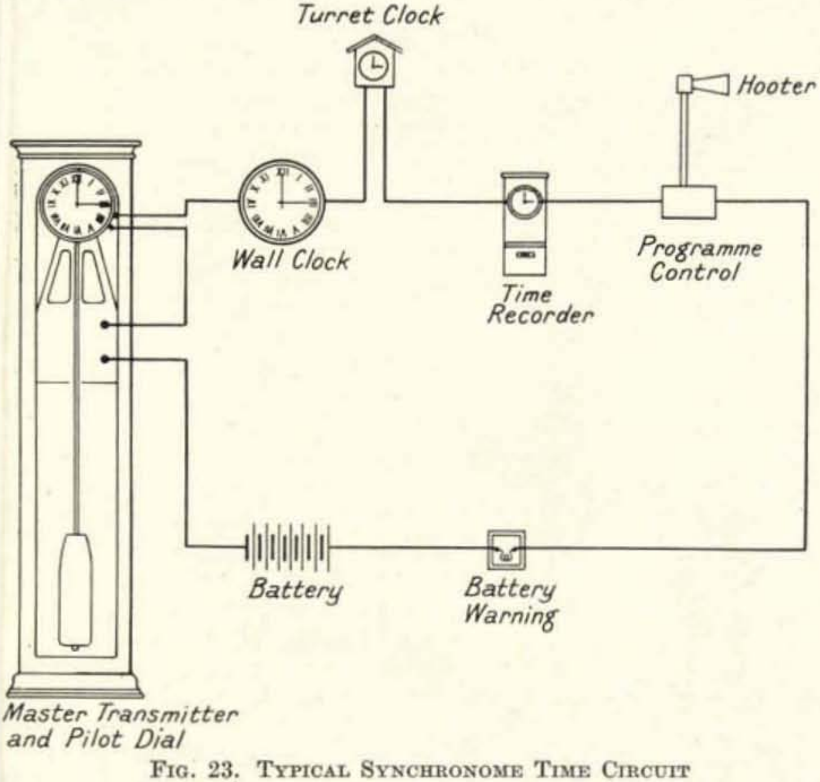



FIG. 23. TYPICAL SYNCHRONOME TIME CIRCUIT

of gears having a 1 : 12 ratio being provided for driving the hour hand.

The maximum current taken by the coil is ·25 ampere.

Any source of electrical energy can be used, but the use of mains electricity supply is not advocated. Accumulators of small capacity are recommended for large time circuits and dry cells of good quality in smaller installations.

With the Synchronome system, a battery warning device is not necessary because a weakening battery is immediately

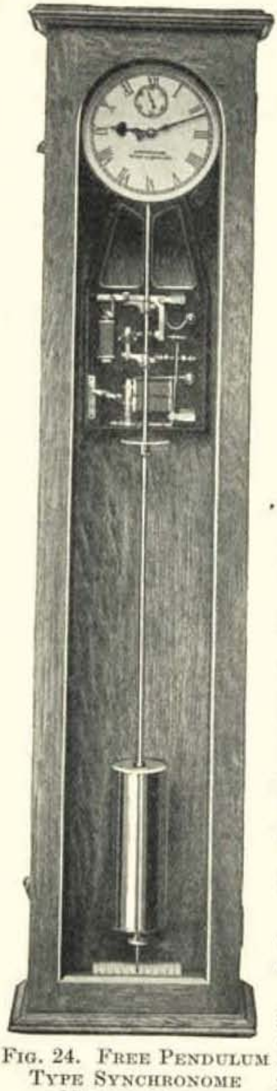


FIG. 24. FREE PENDULUM TYPE SYNCHRONOME MASTER CLOCK

noticeable by the sluggish movement of the hands of the clock dials. It should be noted that the time-keeping is not affected—that is the hands "get there" every time, but take longer than when the battery is fully charged.

The sluggish movement of the hands is due to the fact that with a weak battery the magnet is unable to throw up the gravity lever, and the pendulum on its return to the left assists it. The duration of contact is thus prolonged, and is apparent on the clock dials.

An installation will continue to work perfectly for some days in this weak battery condition.

If the warning is neglected and the pendulum allowed to stop, the battery is automatically disconnected because the last act of the pendulum is to hold the contact points open by supporting the gravity arm.

Where a battery warning is specified, a carbon filament lamp mounted in a suitable case is included in the circuit. The time during which the current flows under normal conditions is insufficient to allow the lamp to light up. When the longer impulses appear, the filament has time to reach full brilliancy.

A typical Synchronome time circuit is shown diagrammatically in Fig. 23.

Items such as programme controller, etc., will be dealt with in a later chapter.

Turning now to some of the specialized forms of the Synchronome clock, we will consider first the free pendulum type, a view of which is given in Fig. 24.

The inventor insists that this shall not be called a free pendulum, since it is not entirely relieved of duty. There is just a "trace" left as it has to close a small switch at every

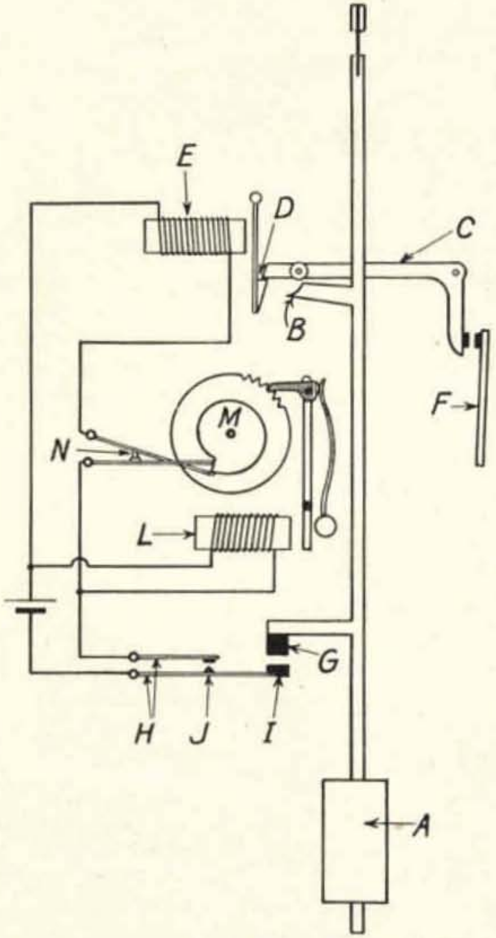



FIG. 25. SYNCHRONOME FREE PENDULUM TYPE MASTER CLOCK

swing, which is done by the attraction of a small permanent magnet attached to its pendulum. This represents such a small amount of work as to be practically negligible.

The pendulum receives its impulses every half-minute by the dropping of the gravity arm, but instead of being released by a mechanical device attached to the count wheel of the ordinary clock, it is operated electro-magnetically. Thus the pendulum is relieved of even having to turn the count wheel.

The Synchronome master clock of this free pendulum type, transmits half-minute impulses in the usual way and, in addition, enables seconds to be indicated on one or more dials, a feature which was hitherto impossible on the Synchronome standard clock without special arrangements.

Fig. 25 shows a diagrammatic view of this type of Synchronome clock and a portion of the dial movement.

*A* is the pendulum, *B* the pallet, and *C* the gravity arm as previously described in connection with the standard master clock movement.

The gravity arm is held up by catch *D*, which is drawn away when electro-magnet *E* is energized. Contact with the armature *F* is then made, and the dials given an impulse as in the standard clock, the gravity arm being subsequently reset ready for the next release. *G* is a small permanent magnet attached to the pendulum swinging freely over a pair of contact springs *H*, one of which is provided with an armature *I*.

Thus every time the pendulum swings, i.e. every second, *I* is attracted and contacts *J* closed, thus completing the circuit through the battery and the magnet *L*, the armature of which is provided with a driving click operating a 60-tooth wheel —this being the seconds hand drive of one of the dials.

On the same spindle is a cam *M* and contacts *N*, so arranged that the latter are closed for one second every thirty seconds, thus enabling every thirtieth impulse to energize magnet *E* in the master clock, giving the pendulum its driving impulse as previously described.

The second hand mechanism of the first dial is not normally mechanically connected to that of the minute and hour hand, these being driven by half-minute impulses in the usual way.

Seconds Indication on all Dials. In special instances such as for testing purposes, timing telegraph and telephone messages and the like, it is necessary that all the dials of an installation indicate seconds.

Owing to the extreme lightness of the contact in the free pendulum clock it is not desirable to operate more than one or two dials in the manner described above.

In such a case a standard clock is taken and fitted with another Synchronome switch released by the pendulum at every semi-vibration, thus the hard and fast rule which the Synchronome Co. have set themselves, to take no appreciable energy from the pendulum for contact making purposes, is not violated. They actually employ a subsidiary Synchronome switch for the purpose of producing and transmitting seconds impulses although it is not wanted as a Remontoir.

In such cases, of course, the gearing of the dials is arranged to work from second impulses instead of half-minutes only.

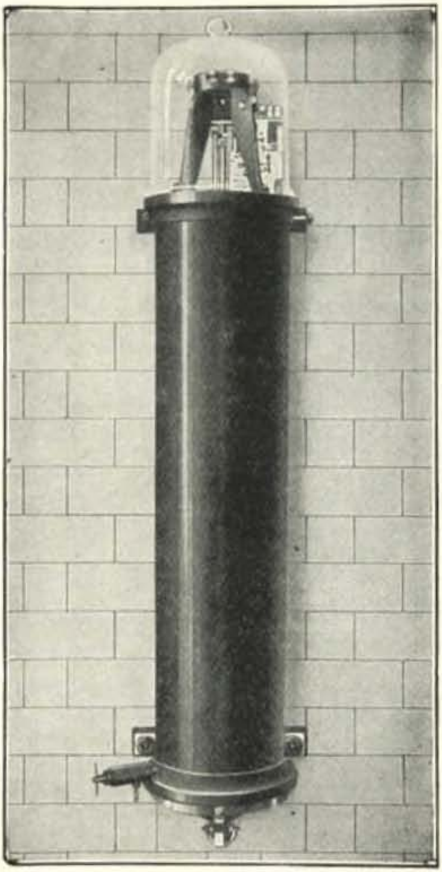


FIG. 26. OBSERVATORY CLOCK

### Observatory Clocks

The time-keepers used in observatories are of necessity of an accuracy far above that of even the best ordinary clock, and the fact that electric clocks are invariably used nowadays is a striking example of the accuracy of these instruments. For instance, one of these installed at Greenwich Observatory has been found to have lost 5 seconds in three years! No less than 45 "Shortt" clocks, designed by Mr. W. H. Shortt, M.Inst.C.E., in association with the Synchronome Co., are in use in different observatories of the world.

It is somewhat beyond the scope of this work to describe observatory time installations in detail. The following notes give a brief outline.

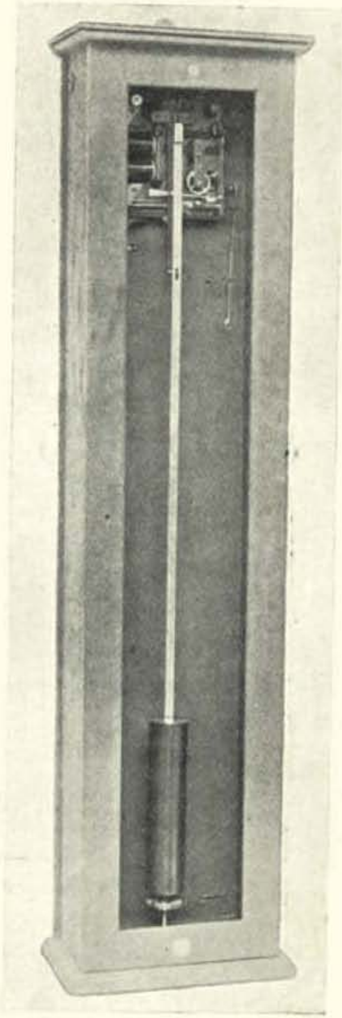


Fig. 26a. Gent Master Transmitter

The free pendulum, Fig. 26, is built on the Synchronome principle, and kept in motion by the falling of a gravity arm.

The whole clock movement is enclosed in an air-tight case and exhausted of air to obviate change in rate due to alterations of barometric pressure.

The gravity arm is released electro-magnetically from the circuit of a Synchronome free pendulum clock working in exact synchronism with it—called a slave clock—the arrangement being that the free pendulum measures the time and the slave clock does the work, keeping the free pendulum in motion and operating the time-indicating circuits.

## The Pul-syn-etic System

The Pul-syn-etic system of Messrs. Gent & Co., Ltd., of Leicester, is one of the foremost of the present day, and its development is mainly due to the work of Messrs. Parsons and Ball, whose initial patents were filed in 1904.

A special feature of this system is the simplicity and robust construction of the various units. It is also most flexible and can be adapted to all sorts of special requirements such as programme controls, workmen's time recorders, turret clocks, the unification of existing spring or weight driven clocks, and marine purposes.

The master clock or transmitter is illustrated in Fig. 26A.

The movement is mounted in a teak case fitted with a glass front-panel. Fixing plates for attachment to the wall are provided, and also alignment studs to ensure its being fixed in a vertical position. If desired a dial is fitted in front of the

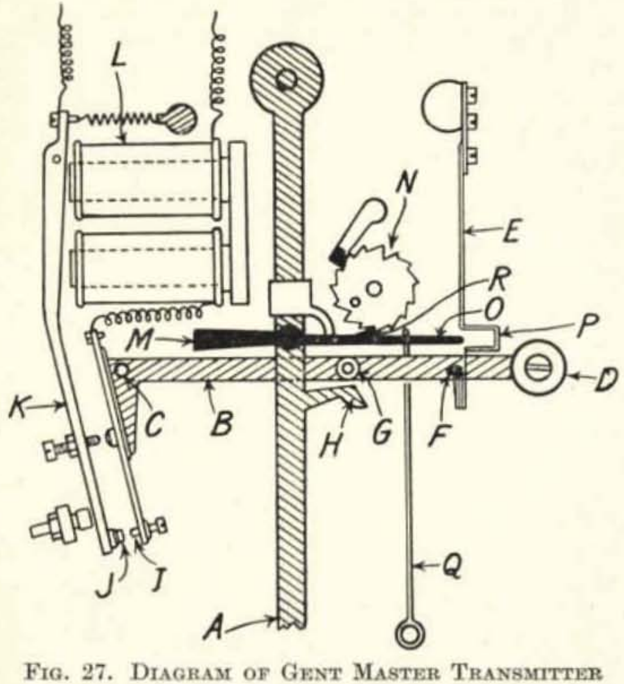



FIG. 27. DIAGRAM OF GENT MASTER TRANSMITTER

master movement, but this has not any mechanical relation with it, being merely connected in the ordinary time circuit.

The pendulum is arranged to beat seconds, i.e. the time taken to swing to and fro is two seconds, but time impulses are transmitted at half-minute intervals.

The pendulum bob is of steel and weighs 10 lb. The pendulum rod is made of a special non-expanding alloy known as Sinevar. The bob and the rod taken together compensate for any error due to variation of temperature.

The transmitter can be regulated to keep time within one second per day by means of the "rating" nut seen below the pendulum. This has a number of marks each representing one second per day gain or loss, according as to whether the weight is raised or lowered. (The shorter the effective length of a pendulum the quicker it swings.) Provision is also made for small weights to be placed above and below the pendulum for minute alterations to the rate.

The transmitter is provided with an advance lever by which all the clocks in the circuit can be advanced one half-minute every two seconds when required, as, for instance, at the day-light saving change.

The movement of the transmitter is shown diagrammatically in Fig. 27.

*A* is the pendulum crutch, a lever which is pivoted at the same centre as the pendulum suspension and coupled at its lower end to the pendulum, as more clearly seen in Fig. 26A. The crutch carries the operating mechanism instead of it being mounted directly on the pendulum.

*B* is the gravity lever pivoted at *C* and provided with a weight *D*. It is held in a horizontal position by the stirrup catch *E* engaging with the detent *F*. Also mounted on the gravity lever is the roller *G*, which is arranged to roll down the surface of the pallet *H* of the pendulum crutch when the gravity arm drops every half-minute, thereby giving the pendulum a gentle impulse to keep it in motion.

At the extreme end of the gravity lever is the contact *I*, which is opposite to, but normally not touching, the contact *J* on the armature *K* of the electro-magnet *L*.

Mounted on the crutch is a lever *M* which engages with the teeth of the 'scape wheel *N*, advancing it one tooth forward for every complete swing of the pendulum. The wheel, therefore, makes one complete revolution every half-minute.

Now one of the teeth of the wheel is cut extra deep so that when the pawl *R* of lever *M* engages with it, its end *O*, instead of passing into the open stirrup *P*, makes contact *above* the opening.

This pushes the stirrup lever aside and causes the gravity lever *B* to drop. The roller *G* runs down the pallet face giving the pendulum an impulse and the contacts *I* and *J* close. This closes the time circuit, and all the clocks advance half a minute. At the same time electro-magnet *L* is energized and attracts armature *K*. This has the effect of lifting the gravity lever *B* back to the horizontal, in which position it is held by the stirrup catch (the pendulum having now swung away from it) until the pawl again meets the deep tooth when the cycle is repeated.

When it is desired to advance all the clocks rapidly, the cord *Q* is held down which has the effect of making the lever *M* push

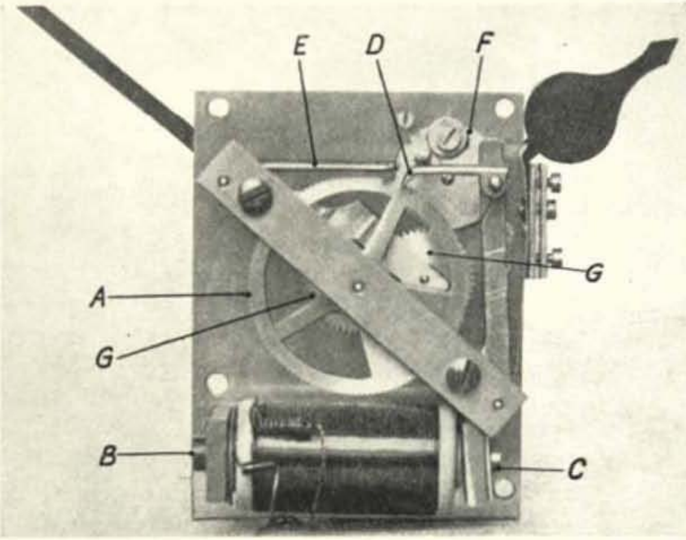



FIG. 28. GENT STANDARD DIAL MOVEMENT

the stirrup lever aside and advance the clocks every stroke instead of every half-minute.

Two types of dial movement are supplied for use with these clocks—the standard simple type, and the inaudible type. The latter is desirable for bedrooms, hospitals, libraries, and other places where the slight half-minute click of the standard movement may prove distracting.

A back view of the simple movement is shown in Fig. 28.

*A* is the ratchet wheel having 120 teeth mounted on the minute hand spindle. *B* is an electro-magnet which attracts armature *C* every time an impulse is received from the master clock, and in doing so advances the ratchet wheel one tooth by means of pawl *D*.

The stop $E$ prevents the ratchet wheel slipping back as the pawl gathers the next tooth. The disc and associated mechanism $F$ is for the purpose of adjusting the stroke of the pawl lever so that the advance is only one tooth. If more than one tooth were picked up at a time the clock would, of course, rapidly gain. The gear wheels $G$ $G_1$ are driving train for the hour hand.

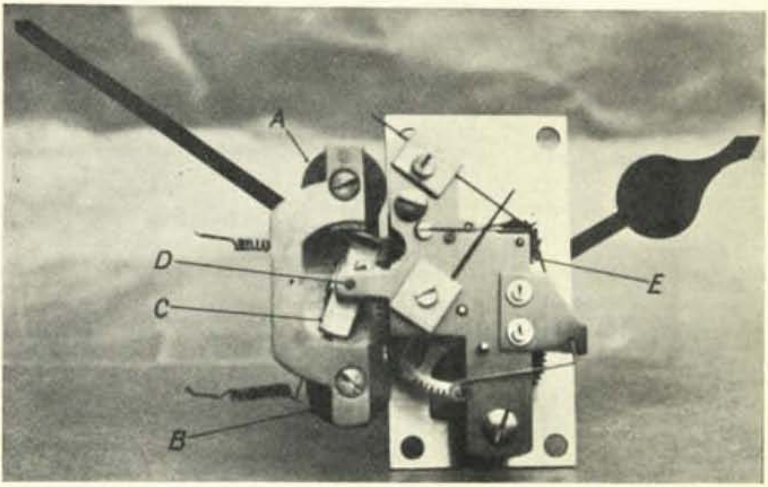



FIG. 29. GENT INAUDIBLE DIAL MOVEMENT

Three sizes of dial mechanism are made according to the size of the clock.

The "inaudible" movement is shown in Fig. 29, in which $A$ and $B$ are the coils of an electro-magnet, and $C$ is an iron armature pivoted at $D$, normally held in the position shown by a spring.

When an impulse arrives from the master clock, it is momentarily attracted to the vertical position, and in so doing advances the ratchet wheel $E$ by one tooth. Suitable gearing couples this to the hand mechanism.

The movement owes its silence to the fact that the armature does not come against any metallic stop when attracted by the magnet.

The working current taken by the PUL-SYN-ETIC clocks is ·22 ampere, and the voltage per dial approximately 1 volt.

Leclanché batteries of either the wet or dry type can be used provided they are of a good quality, and will operate the clock system for two years or so without attention.

Where alternating current electricity supply is available,

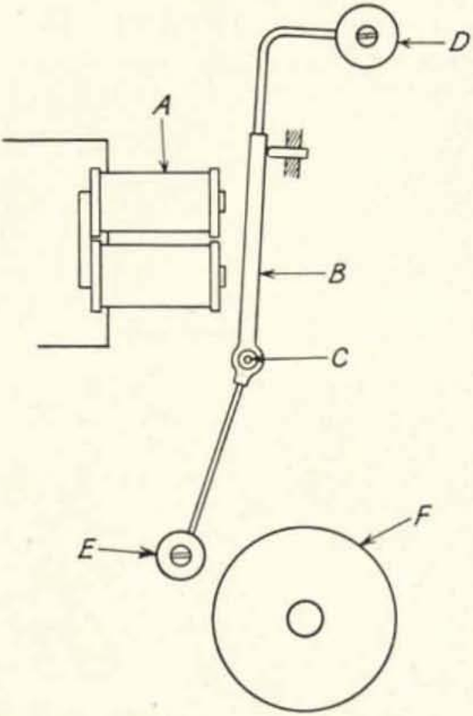



FIG. 30. PRINCIPLE PUL-SYN-ETIC BATTERY WARNING BELL

however, the makers recommend the use of a battery of accumulators—this being continuously "trickle charged" from the mains.

When primary cells are used, an audible weak battery signal can be fitted if required. This is of particularly ingenious construction, and is shown diagrammatically in Fig. 30.

*A* is an electro-magnet connected in series with the clock, and *B* an armature pivoted at *C* and provided at one end with weight $D$, and at the other end with hammer $E$ adjacent to gong $F$.

The action is as follows. When the battery is up to normal strength, the duration of contact in the master clock is extremely short, but when the battery weakens it is longer, or, simply, more time is taken to raise the gravity arm on its catch.

Now when the impulse reaches the electro-magnet shown in the figure the armature is momentarily attracted. Owing to the inertia of the weight $D$, the impulse is over before the striker $E$ has time to hit the gong. When, however, the impulses become longer due to weakening of the battery, the armature is fully attracted, and causes the bell to ring at every stroke. The warning is so adjusted that the bell rings some time before the failing point of the battery. It may be mentioned here that should the warning be neglected and the clocks fail, the pendulum will hold the master clock contacts open to prevent further discharge, and consequent complete exhaustion of the battery.

The battery warning device cannot be used where accumulators are employed, because even when discharged their voltage is 1·8 per cell, which is still sufficient efficiently to work the clocks, although, of course, the accumulators would be damaged by any further discharge.

In addition to the standard transmitter described in this chapter, special types are available for marine work, turret clocks, clocks which require synchronizing by time signal, etc., to which reference will be made in later chapters.

### The Magneta System

Another popular impulse clock which has stood the test of time is that of the Magneta Time Co., Ltd.

Strictly speaking, there are now two distinct Magneta systems, the magneto operated, and the battery operated.

THE MAGNETO-OPERATED SYSTEM. The magneto-operated system actually generates its own current for each impulse, and there are consequently no contacts to open and close. The system is, therefore, very reliable, and the current generated in this manner is sufficient to work a large number of clock dials in series. Such instruments as programme controllers, time recorders, and the like, which are a common feature of time circuits to-day are, however, operated by interposing a relay.

The master clock consists of a high grade pendulum controlled, spring and weight driven regulator—hand or electrically wound. The principle of the generator is shown in Fig. 31.

$A_1$, $A_2$, $A_3$, $A_4$ are the poles of two permanent magnets. $B$ is the armature which is given a rapid throw every minute, taking up the position shown one minute, and the position indicated by the dotted line the next. The coil $C$ is fixed and

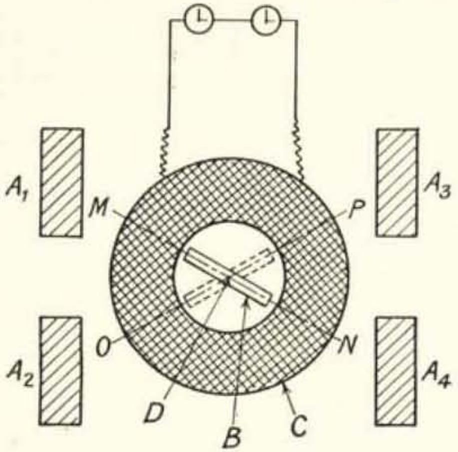



FIG. 31. PRINCIPLE OF "MAGNETA" MAGNETO-OPERATED CLOCK

the ends are connected to the external time circuit. The armature is pivoted at $D$, and successively takes up the positions shown; thus every minute its position is changed from $MN$ to $OP$, or *vice versa*. In so doing an electro-motive force, sufficient to operate the secondary movements, is generated in the coil, and a current flows through the circuit.

The dial mechanism is polarized to take care of the alternating positive and negative currents.

The power necessary to turn the armature is not taken from the master clock movement, but from a separately wound motion which is released every minute.

Fig. 32 shows a front view of the mechanism of the Magneta master clock.

The magneto can be clearly seen on the left, and also its operating lever.

THE BATTERY-OPERATED SYSTEM. The Magneta battery-operated system has several features different from the magneto-operated system previously described.

The master clock is much smaller than usual, having a

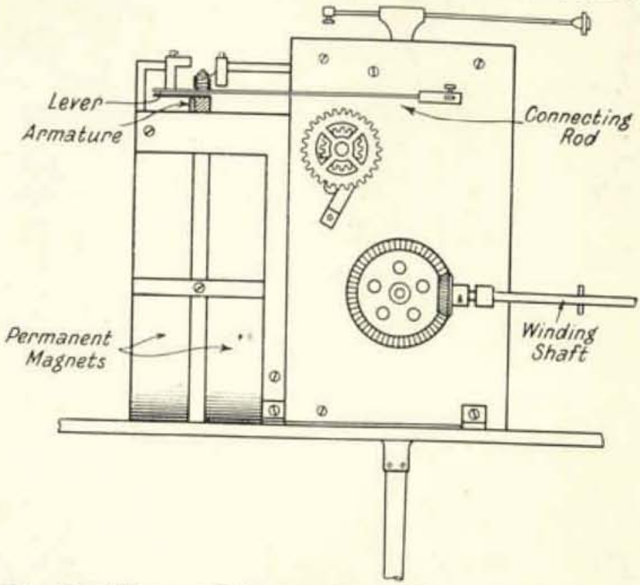



FIG. 32. "MAGNETA" MASTER CLOCK MECHANISM, MAGNETO-OPERATED TYPE
View from Front, Dial Removed

pendulum of half seconds length, and is arranged to receive a driving impulse every second, thereby maintaining it at a constant amplitude. The impulses are given by a solenoid, and there is, therefore, no physical contact with the pendulum.

The time circuit impulses can be sent out once per minute or every half-minute.

The master clock is driven from a separate cell of the Latimer Clark type, which will maintain the clock for about three years without attention—the battery being contained within the clock case.

A feature of the Magneta master clock, whose appearance is shown in Fig. 33, is the centre seconds hand which is mechanically connected with the pendulum, and serves as an independent check on the secondary clocks.

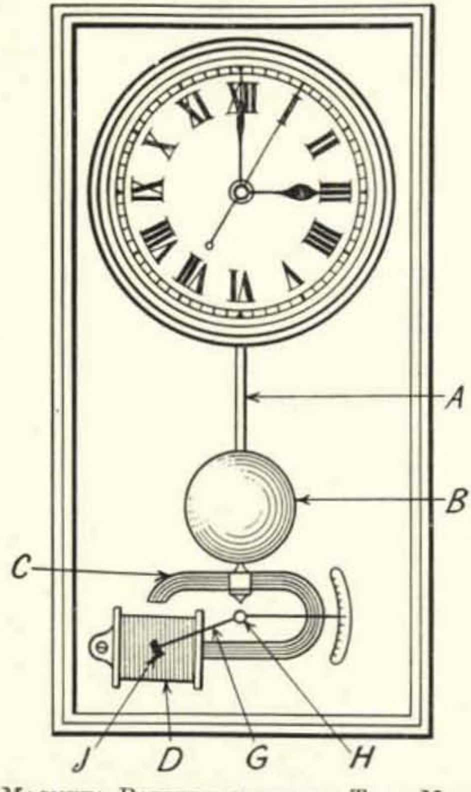



FIG. 33. MAGNETA BATTERY-OPERATED TYPE MASTER CLOCK

Strictly speaking, this clock should be classified under the heading of Self-contained Battery-driven Clocks.

*A* is the pendulum, *B* the pendulum bob which can be raised or lowered to afford coarse adjustment of the rate, and *C* is a permanent magnet attached to the pendulum, the one limb of which enters solenoid *D*. Contacts are so arranged that this is energized just as the magnet enters, and so attraction takes place, thereby maintaining the swing of the pendulum.

A pivoted finger on the pendulum turns a count wheel a tooth at a time, and by means of a cam action contacts are closed in the time distribution circuit.

The fine adjustment consists of lever $G$ pivoted at $H$, one end of which passes over a rating plate, and the other has two branches spanning the sides of the coil, each carrying a small piece of iron $J$. The position of this affects the degree of attraction of the magnet to a slight extent, and therefore forms

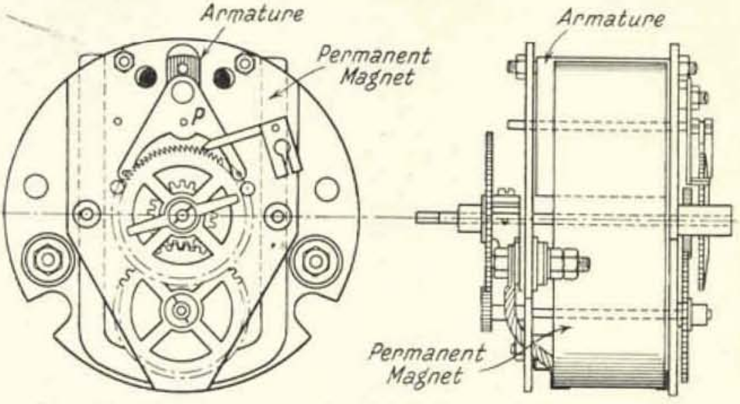



Fig. 34. Magneta Secondary Movement, Battery-operated System

a simple and reliable means of adjusting the rate of the clock without touching or interfering with its pendulum.

The secondary clock movements are of a polarized type fitted with wound armatures, and have no spring or gravity replacement. They are, therefore, silent and economical in current consumption.

Fig. 34 gives a detail drawing of the secondary clock movement.

The rocking motion of the armature is transformed into a rotary one by means of the escapement shown which is pivoted at $P$.

For small and medium sized installations dry cells are recommended for operating the secondary clock dials. The current consumption is only about 55 milliamperes, and one cell will operate six secondary clocks. Ordinary bell size cells will give twelve months service or more.

For large installations the use of dry cells would necessitate a considerable capital outlay, and in such instances, accumulators automatically charged are used instead.

A typical wiring diagram for a Magneta battery system time circuit is given in Fig. 35.

It will be seen that the secondary clocks are not connected

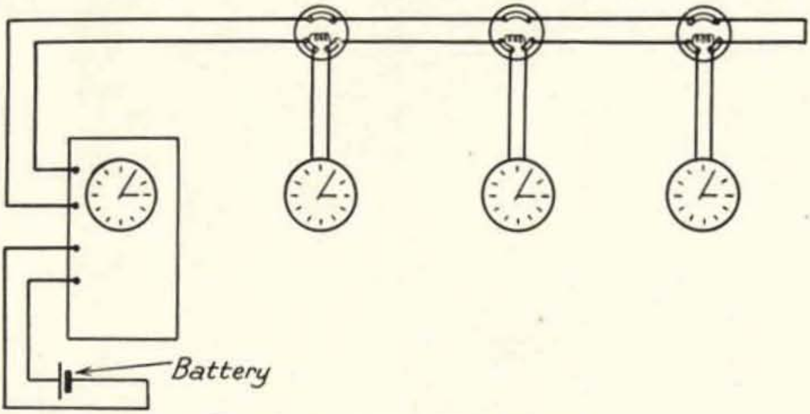



FIG. 35. MAGNETA TIME CIRCUIT

directly in series with each other, but are in shunt with a resistance connected in a porcelain container.

The value of the resistance depends on the size of the secondary movement, being 10 ohms for the small size and higher for larger diameters of dial.

This system of wiring ensures that each clock gets the right amount of current, and that the contacts of the master clock are not injured by having to deal with excessive currents. A break in the internal wiring of the clock does not affect the rest, and clocks can be removed or taken out of circuit at will.

Up to 70 clocks can be run in one group. Above this number a relay is desirable to deal with the second and subsequent groups of dials.

The arrangements for operating programme controls, time recorders, etc., by the Magneta system will be described in a later chapter.

## The Octo System

The Octo system is the product of Messrs. T. & F. Mercer, of St. Albans, who are well known as manufacturers of high

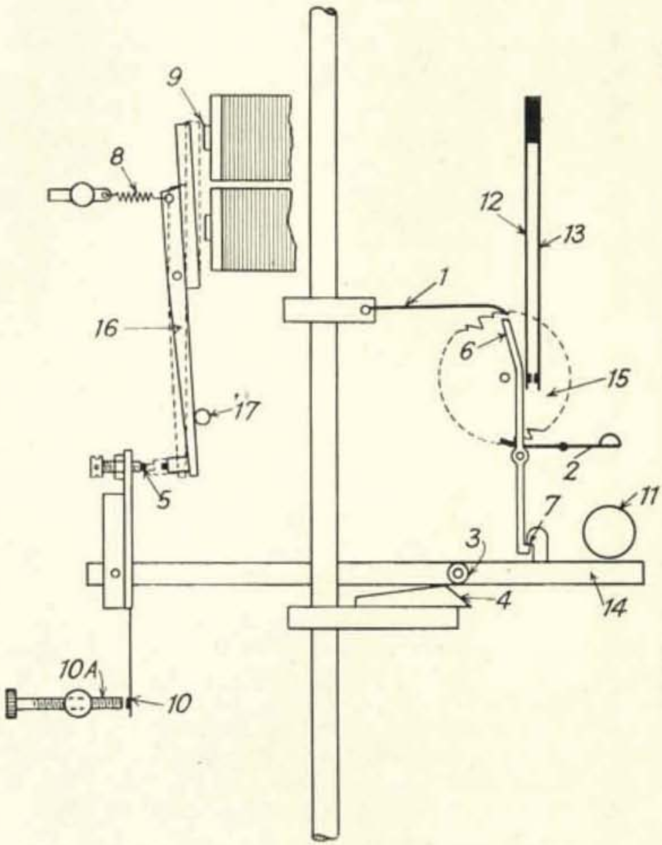



FIG. 36. PRINCIPLE OF "OCTO" MASTER CLOCK

grade chronometers, and whose business was established in 1858.

Two forms of Octo impulse clock systems are available—one controlled by a standard master clock, and the other in which the secondary dials are controlled by contacts contained in a chronometer. The second system is particularly intended for ship installations, and will be dealt with in a later chapter.

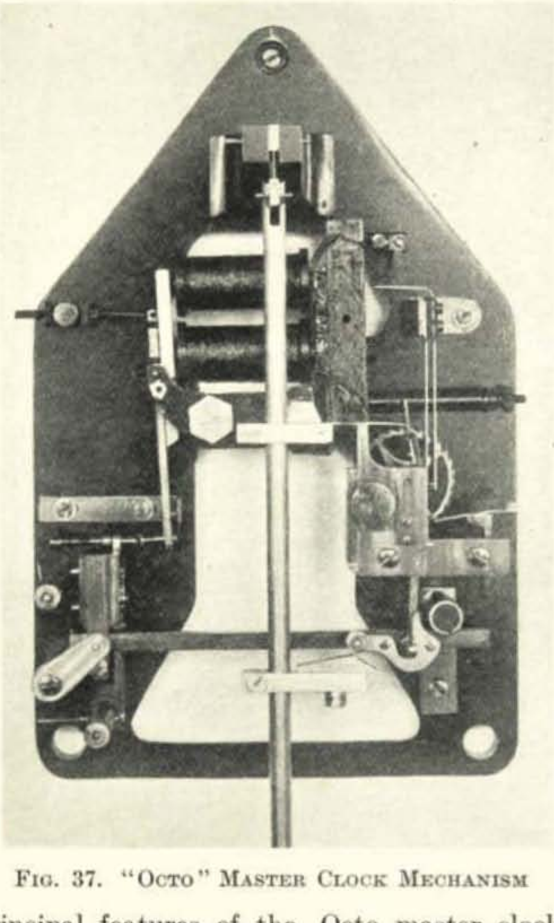


FIG. 37. "OCTO" MASTER CLOCK MECHANISM

The principal features of the Octo master clock are as follows. The pendulum rod is of full seconds length, and is compensated, being of Invar whose coefficient of expansion has been certified by the National Physical Laboratory.

The pendulum bob is further fitted with a compensation tube and also a tray for weights, and a degree of accuracy to within one second per week is ordinarily obtainable.

Impulses are given to the secondary dials every half-minute, the duration of contact being regulated by a special arrange-

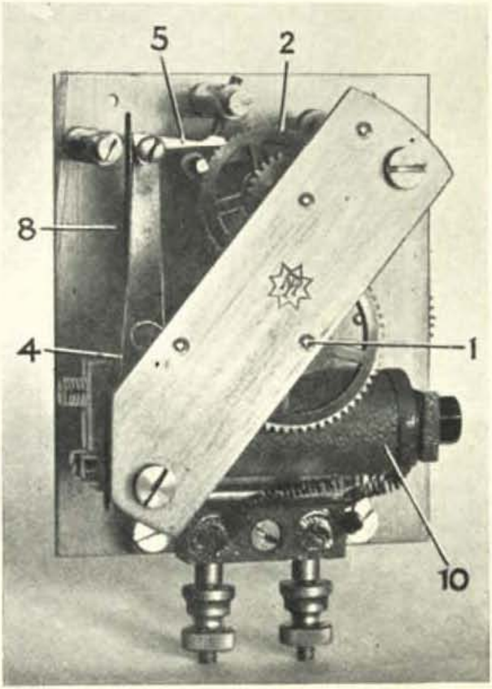



FIG. 38. "OCTO" DIAL MOVEMENT

ment, according to the size of the circuit, to ensure that each dial receives its proper working current.

The principle of working of the master clock is shown in Fig. 36.

(1) is the pendulum feed pawl which swings backwards and forwards rotating the count wheel (15) tooth by tooth. The count wheel has two deep notches which allow the feed pawl to drop a little deeper each half-minute, the feed pawl then

pushes the latch lever (6) forward, releasing gravity arm (14) allowing roller (3) to fall on impulse pallet (4), and giving impulse to the pendulum.

FIG. 39. "OCTO" IMPULSE CLOCK, "PERIOD" MODEL

At the same time as (6) is releasing the gravity arm it is ılso pressing contact (12) on to contact (13) partly making ircuit for resetting the gravity arm.

As the gravity arm (14) is falling, contact point (10) makes contact with (10A) sending an impulse to the line. This contact is adjustable to allow longer or shorter contacts as desired to be transmitted to the clocks. The gravity arm (14) still falling comes into contact with the reset lever (16). This sends a current through the coils (9), which immediately pull the lever (16), resetting the gravity arm. These coils must remain energized until the gravity arm is properly latched, when latch (6) allows contacts (12) and (13) to break the circuit, lever (16) then returning to stop (17). This process is repeated each half-minute.

An Octo master clock movement removed from its case is shown in Fig. 37.

The Octo dial movement is shown in Fig. 38, its action being as follows—

Coil (10) is energized each half-minute, pulling armature arm (4) towards it at the same time allowing click (5) to drop in the next tooth. Directly the coil is demagnetized, spring (8) pushes the armature and click forward, rotating action wheel (2) round one tooth. This action wheel is geared down 1 to 2 on to the centre spindle (1), which in turn rotates the motion work and hands. When at rest the movement is locked against any hand pressure.

Another feature is the cannon spring fitted to the centre spindle, which allows the hands to be set to the correct time very quickly, and is a great help when fitting up large installations.

A comprehensive range of cases is available for all uses, Fig. 39 being a typical example of a period clock.

About 50 ordinary sized clocks can be operated in series with one master clock, but for larger circuits a relay is desirable. Where it is particularly required that all the secondary dials of a very large system be in series the master clock is arranged to operate a relay only—the clocks being controlled from its secondary contacts.

The minimum working current is 175 milliamperes. This can be doubled without harming the system.

Either primary or secondary batteries can be used for the operation of these clocks. Primary batteries are recommended for small installations where the dials are all in series, and accumulators for larger installations where clocks are grouped in parallel circuits.

# CHAPTER V

## SELF-CONTAINED CLOCKS

THE title of this chapter requires some little explanation. It is obvious that any of the master impulse transmitters described in the previous chapter could be taken and mounted in a case with the necessary driving battery, and so constitute a self-contained clock—independent of electricity supply and free from external wiring. The result would be a very high-class time-keeper, but it would be large and heavy, and require very rigid fixing. It would be expensive because the same transmitting mechanism would have to be provided for the one dial as would be necessary for hundreds of dials, and such clocks are rarely therefore met with in practice.

Again, any of the electrically wound clocks to be described in Chapter VII could be arranged to be battery operated by suitable winding of the coils.

The class of clock which it is proposed to consider here, however, is that which is sold as an independent clock, its motive power being derived from a small battery actuating the clockwork directly.

Most clocks of this type are opposed to strict horological principle, in that the pendulum is made to drive the clockwork instead of merely to control its rate. As has already been explained, one of the principles of accurate time-keeping is to leave the pendulum as free as possible.

Great care has, therefore, to be taken in the design of these clocks to render them good time-keepers, and though many types have been evolved since the early days of electricity only a few have survived.

The principal advantage of the domestic self-contained clock is the fact that it does not require winding. It will usually go for two or three years on one dry cell. As mentioned above, time-keeping depends on design and construction, and in the case of well-made instruments compares most favourably with that of high-class spring clocks.

The self-contained battery-driven clock possesses the merit of portability, but it requires the same care and attention as regards regulating and levelling, as would be afforded a spring-driven clock.

The self-contained battery-driven clock has a certain fascination of its own, in that it is obviously electric, and yet

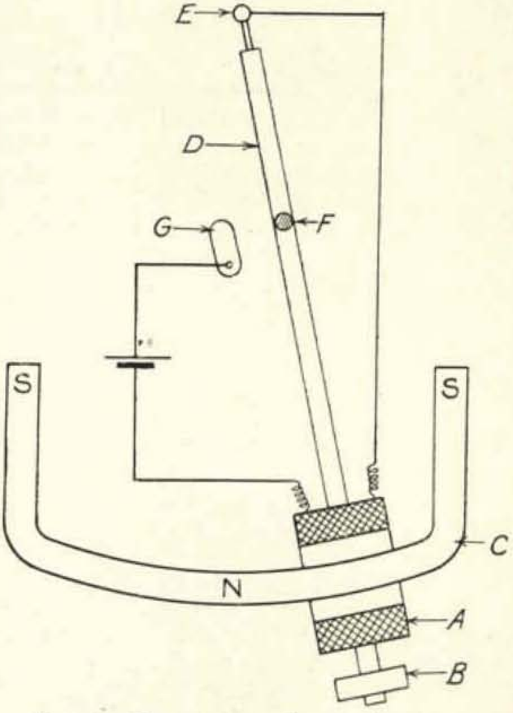



FIG. 40. PRINCIPLE OF BULLE CLOCK

possesses the "tick" of an ordinary clock. This is a point which seems to weigh with some buyers.

## The Bulle Clock

One of the best known types of battery-driven clock is the "Bulle," of which a wide range of domestic models is available. The principle of working is briefly as follows—

Referring to Fig. 40, *A* is a solenoid which together with the adjustable weight $B$ constitutes the pendulum bob and swings over the permanent magnet $C$.

$D$ is the pendulum rod supported at $E$, and $F$ is a silver pin

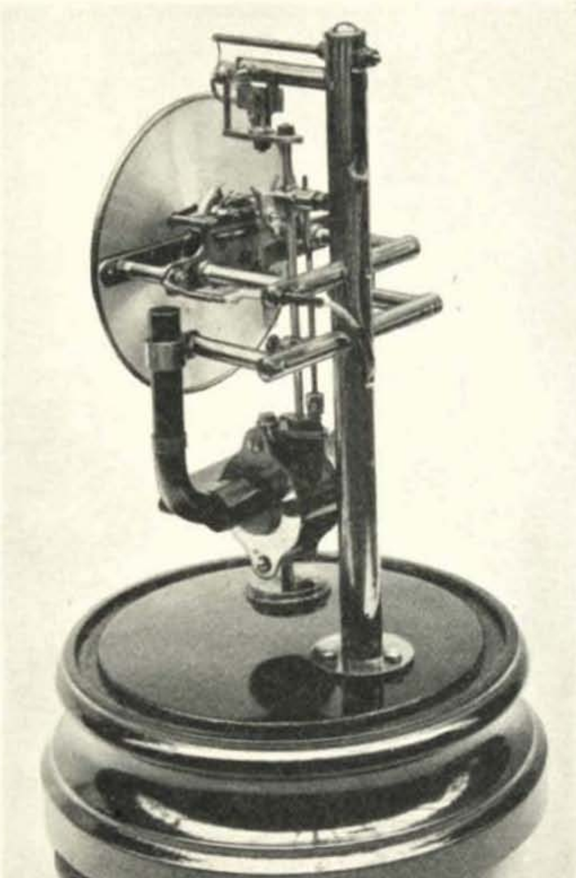


FIG. 41. BULLE CLOCK MOVEMENT

which makes contact with plate $G$ every time the pendulum swings to the right, thus completing the circuit through the electro-magnet and causing the pendulum to be repelled from the middle pole of the magnet, giving it an impulse to the right.

One of the features of this particular clock is the consequent

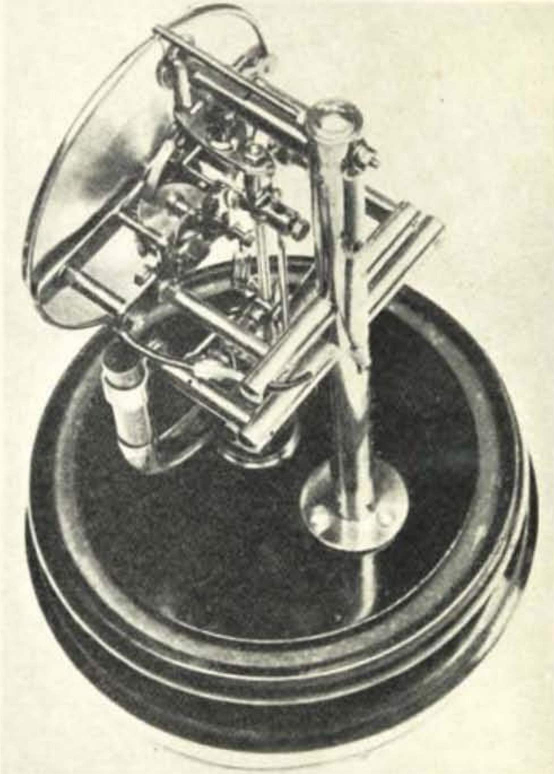


FIG. 42. ANOTHER VIEW OF THE BULLE CLOCK MOVEMENT

pole magnet adopted which is said considerably to increase the efficiency of the electro-magnet owing to the more favourable position of the lines of force in relation to the moving coil.

The mechanism is ingeniously arranged so that contact with $G$ is not made on the return journey of the pendulum. The drive to the clock hands is taken through suitable gearing from the to and fro motion of the plate to which contact plate *G* is secured, and it is claimed that with the pawl and ratchet crown wheel adopted, the clock does not need to be accurately levelled.

The current consumption is infinitesimal, being of the order of ·002 to ·003 ampere at the contact moment, and a small $1\frac{1}{2}$ volt dry cell will operate the clock for two to three years. The clock is regulated by raising or lowering the nut at the lower extremity of the pendulum. The pendulum is secured in position when the clock is moved from one place to another by means of a clip specially made for the purpose. This is a useful point as all the user has to do is to take away the clip and the clock is ready for use.

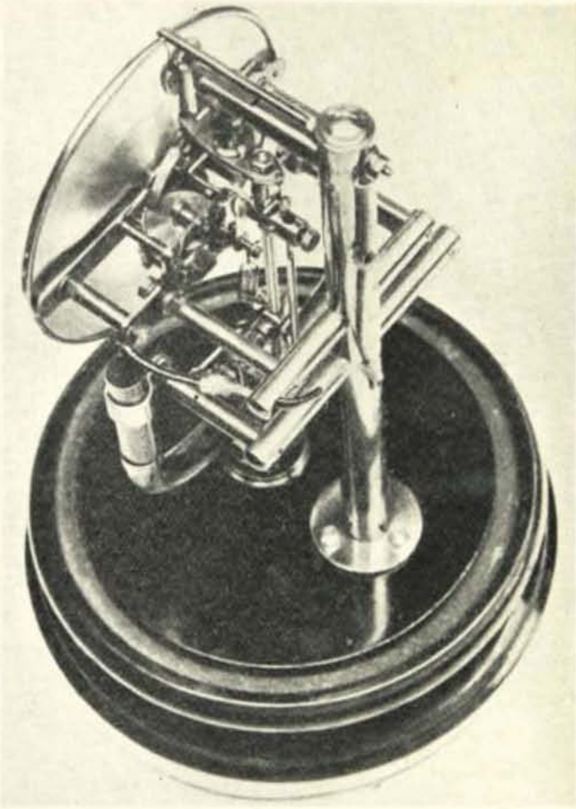
Figs. 41 and 42 give two views of the movement from which a general idea of the construction can be obtained.

It will be seen that the actual mechanism possesses many refinements to which reference has not been made. The driving battery is contained within the base of the clock.

The pendulum clip referred to above is seen in position in Fig. 41.

the middle pole of the magnet, giving it an impulse to the right.

One of the features of this particular clock is the consequent



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The current consumption is infinitesimal, being of the order of ·002 to ·003 ampere at the contact moment, and a small 1½ volt dry cell will operate the clock for two to three years. The clock is regulated by raising or lowering the nut at the lower extremity of the pendulum. The pendulum is secured in position when the clock is moved from one place to another by means of a clip specially made for the purpose. This is a useful point as all the user has to do is to take away the clip and the clock is ready for use.

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It will be seen that the actual mechanism possesses many refinements to which reference has not been made. The driving battery is contained within the base of the clock.

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1) synchronous синк-ро-нос. одновременный
быть одновременным, совпадать
2) supplys сэп-плай снабжать заменять служить
вместо чего, пособие

## CHAPTER VI

### SYNCHRONOUS MOTOR CLOCKS

#### Introductory

THE synchronous motor type of clock is one of the lates developments in electrical horology. It is entirely different i principle from any other class of electric clock, and possesse a number of advantages over older systems, also some dis advantages. It can only be worked from alternating curren supply mains.

The hands of this form of clock are driven, through suitabl gearing, from a very small electric motor whose speed i governed entirely by the frequency or number of cycles pe second of the supply.

This method of clock control was suggested as long ago a 1895 in this country by Mr. F. Hope Jones in an article ir *Lighting*, but it is only during the last few years that any attention has been paid to the accurate control of frequency, which is, of course, paramount to success.

Hitherto, electricity supply in this country has been from a large number of small or medium size generating stations—each district having its own, some generating direct current and others alternating current. There was no standard frequency (or number of reversals of current per second) for the A.C. supplies, and thus one found all sorts of periodicity from 25 to 100—50 being the most common.

Further, the stated frequency was only nominal—a discrepancy of one or two cycles above or below the correct number made little difference to the operation of motors, lamps, or other apparatus connected to the mains, and was quite common. The power stations were only called upon by the Board of Trade (which regulates such matters), to maintain the frequency within $2\frac{1}{2}$ per cent above or below the declared value, and little attention was paid to scientific accuracy of control.

A synchronous motor-driven clock designed to work on a 50 cycle main supply will lose nearly half an hour per day of twenty-four hours if the supply be only 49 cycles, an inaccuracy which could not be tolerated in any clock.

All this has now been altered by the advent of the great National Electricity Grid scheme, by which the generation of current for the whole of the country is to be concentrated in a comparatively small number of super-stations—all connected together. Now it is one of the first principles of parallel working of generators, or of power stations, that the frequency of all the machines must be identical. This is comparatively simple where there are only one or two generators under the same roof, but not easy where stations are hundreds of miles apart.

Thus two things have had to be done. The frequency of supply over the whole country has been standardized at 50 cycles per second, and means devised to maintain this value to a high degree of accuracy. In actual practice, as will be described later, the frequency is measured by comparison with a high-grade master clock, and thus although only a by-product as far as the power supply authorities are concerned, a source of accurate time control is available to all consumers of electricity within the grid scheme.

It should be noted that the change from local to national supply must necessarily be a gradual one, and it is, therefore, essential to ensure that the supply is what is generally termed "time controlled" before connecting a synchronous clock to it.

Having briefly dealt with the events which have made the synchronous motor clock possible, it is now proposed to discuss some of its advantages and disadvantages.

Synchronous motor clocks are very simple in construction, and are, therefore, cheap—very much cheaper than any form of electric or mechanical clock of the same accuracy.

Time-keeping properties are, of course, independent of the user, and rely entirely on the accuracy with which the supply frequency is maintained. This depends on two factors—viz. the accuracy of the master control clock at the power station, and the care with which the frequency, as represented by the speed of the generators, is maintained in accordance with its indications. As regards the first consideration: the clock is invariably of high-grade character arranged to be checked at intervals with time signals from Greenwich Observatory. The second consideration is not serious as a discrepancy of only a few seconds between Greenwich time and frequency time is clearly visible to the switchboard attendant, who can take the necessary steps to increase or reduce the generator speed.

The writer has made continuous tests of one of these clocks over a period of six months on a controlled main, not yet, however, connected to the "Grid." Readings were taken each day by the B.B.C. 6.30 p.m. Greenwich time signal, and at no time did the indications of the clock vary more than 10 seconds from the previous day's reading and generally less.

Over the whole period there was a constant gain of about 3 seconds per week, which is accounted for by the master clock at the power station having a slight gaining rate. An error of less than one minute in six months is a good performance for any clock, and even this will no doubt be improved upon when the station in question is linked up with the Grid scheme. Check tests at other times failed to show any wider discrepancy than that mentioned, though there is no doubt that this does occur occasionally.

It is thus seen that the synchronous motor clock is capable of holding its own as a time-keeper. A disadvantage is that if the electricity supply fails, all the clocks stop, and have to be re-set when the supply is resumed. Modern power supply is nevertheless very reliable, and it is a rare occurrence for the power to be cut off.

Synchronous motor clocks may be self-starting or non-self-starting. The self-starting type has the disadvantage that if, as is quite conceivable, the supply is shut off for only a few minutes, all the clocks will be this amount slow, and may not be noticed. The non-self-starting type, on the other hand, will stop altogether in such a case, and is bound to be quickly noticed. Some makes of clocks are provided with an indicator to show if the supply has been interrupted or if the clock is stopped.

The synchronous clock movement is exceedingly compact, and can be fitted to any type of case. There is no pendulum, consequently no regulating or levelling is necessary, and time-keeping is not affected by temperature or climatic conditions. The moving parts are light, and in some makes sealed in an oil-filled compartment. No oiling is, therefore, necessary, and the clocks are very quiet in running. The hands move steadily forward, a decided advantage over the half-minute jumps of the impulse type of electric clock, particularly for domestic clocks.

The power consumption is very small, varying from ·65 watts to 4 watts, according to make and voltage. Taking 1 watt as an average a clock can be run for 1,000 hours for one unit of electricity, which works out at 8¾d. per year with current costing 1d. per unit.

It is, of course, necessary to connect these clocks to the supply. Clocks can be fitted with an ordinary lamp adaptor or plug, but to be of any use at all they must be permanently wired. Where private houses are concerned it is usually comparatively simple to provide a plug point at the side of the

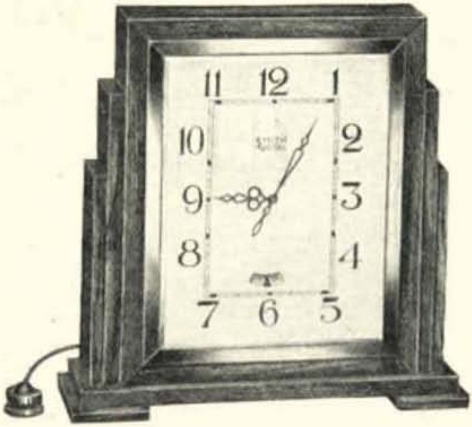


FIG. 43. TYPICAL SYNCHRONOUS MOTOR CLOCK

mantelshelf or to couple to the "live" side of an existing plug point, inserting a small fuse in the leads.

Summing up, the principal advantages of the synchronous clock are—accurate time-keeping coupled with low capital and running cost and negligible maintenance.

A typical synchronous clock, made by Smiths English Clocks Ltd., is shown in Fig. 43. Below the centre of the dial can be seen the small black and white sector which indicates seconds and shows that the clock is working.

### The Principle of the Synchronous Motor

The synchronous electric motor is so called because it runs in synchronism with the supply frequency. Alternating current motors which do not run in step are called "asynchronous," their speed varying with the load on the motor, but thes are not used in electric clocks except in winding mechanisms

The power required to turn the hands of a clock is ver small indeed, so that clock motors are invariably of smal dimensions and simply constructed. They bear little resem blance either mechanically or in principle to the huge syn chronous motor met with in heavy electrical engineerin

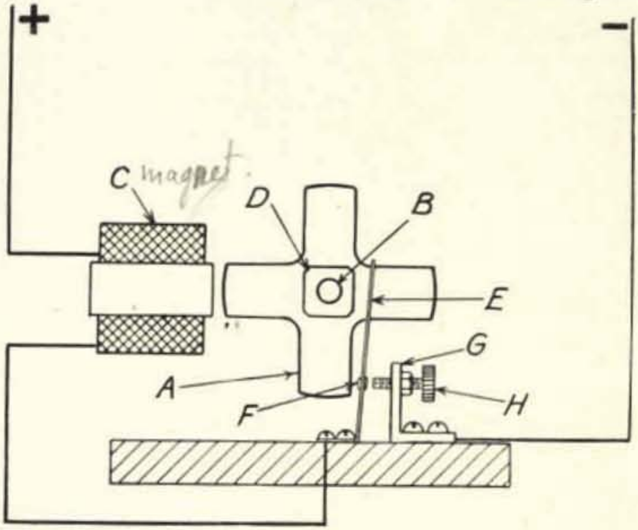


FIG. 44. SIMPLE FORM OF DIRECT-CURRENT MOTOR

practice, and motors from various makes of clocks often differ in construction to a surprising degree.

Synchronous motors, although new to clocks, have been used for scientific purposes such as time marking, etc., for many years, and also for regulating the speed of automatic telegraphic equipment. In the latter connection they are usually called phonic wheels.

In order to fully understand the principle of operation, let us first consider the simple D.C. motor shown in Fig. 44, a type which is also used to some extent in electrical apparatus, such as windscreen wipers for motor vehicles. *A* is an iron rotor shaped in the form of a cross, mounted on spindle *B*, the bearings of which are not known. *C* is an electric magnet in close proximity to the rotor. $D$ is a piece of brass having as many sides as there are poles of the rotor. $E$ is a piece of spring brass having a contact $F$, and $G$ a brass bracket having the adjustable contact screw $H$. The brass block is so positioned on the spindle that the contacts are open, i.e. not touching, when the rotor is in the position shown, but when it revolves through 45° they are closed.

The contacts are connected in series with the magnet as shown. The action is such that when a rotor pole leaves the magnet pole, the current is switched on and the *next* rotor pole is attracted to it, but just as it arrives the current is again

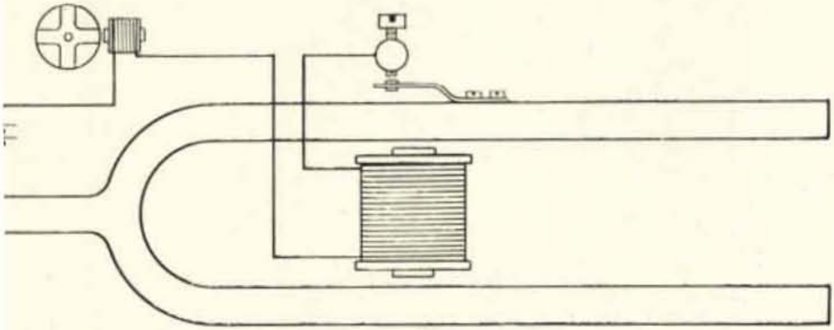

FIG. 45. MOTOR CONTROLLED BY ELECTRICALLY-MAINTAINED TUNING FORK

switched off and the pole passes the magnet owing to the momentum of the rotor, and so the cycle of operations is repeated.

Thus it is seen that if the motor be given a start—in either direction—it will continue to rotate at a steady speed, but the speed will not be controlled in any way.

Now if instead of the contacts $F$ and $H$ being operated by the rotation of the rotor they are attached to one arm of an electrically maintained tuning fork, as shown in Fig. 45, the rotor will run, but now its speed, when once started, will depend on the frequency or note of the tuning fork, and as the latter is known accurately and is a constant, the motor can be used for time measuring purposes.

Fig. 46 shows a simple motor of this form made by the Cambridge Instrument Co. for scientific time marking purposes, and Fig. 47 the tuning fork for controlling the speed of t motor.

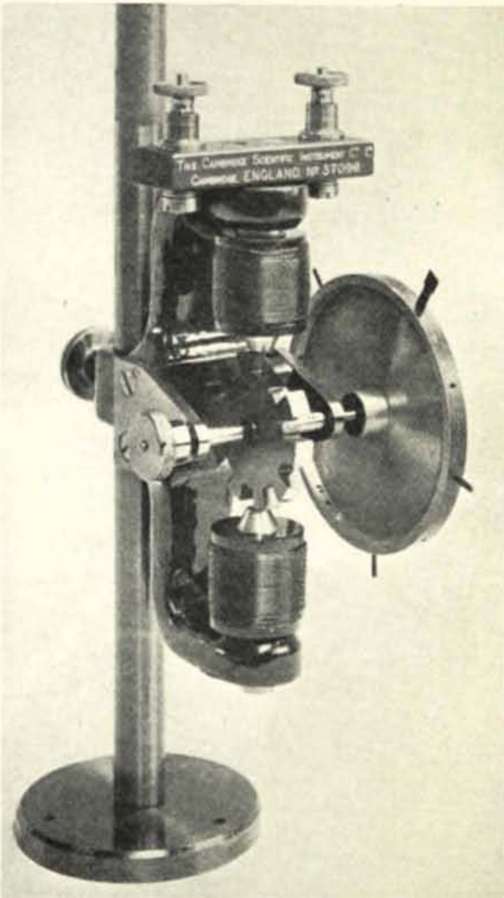


FIG. 46. SIMPLE ELECTRIC MOTOR, TUNING FORK CONTROLLED
*(Cambridge Instrument Co., Ltd.)*

Reverting now to the simple motor of Fig. 44, if instead o supplying the magnet with pulsating direct current we suppl it with alternating current almost similar conditions will obtain, and the rotor will still rotate—the speed now being controlled by the frequency of the supply, that is, the number of reversals per second. It should be noted that the motor will still require starting because there is no force whatever tending to produce rotation in the position shown in the illustration.

In actual practice it would be necessary to modify the motor somewhat. The core of the electro-magnet would have to be laminated, that is, built up of a number of thin iron sheets,

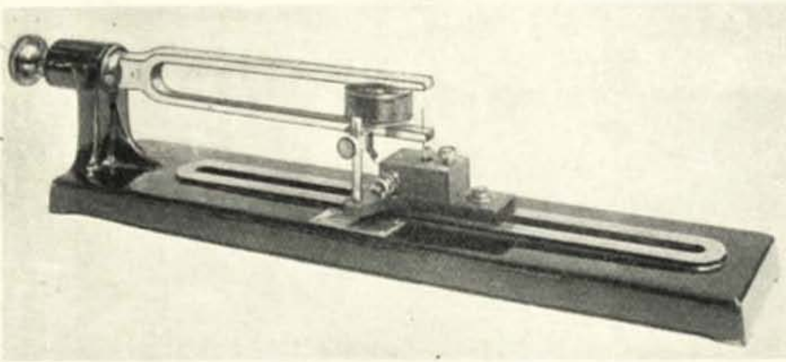

FIG. 47. ELECTRICALLY-MAINTAINED TUNING FORK
*(Cambridge Instrument Co., Ltd.)*

lightly insulated from each other, otherwise eddy currents would be generated in the core causing heat and unnecessary expenditure of power. It would not be necessary to modify the rotor, although considerably better results will be obtained if the poles be made of magnetic steel instead of soft iron. It will be found in clock practice that some makers favour the first method and others the second.

The speed of the rotor will depend on the frequency of the electricity supply and on the number of poles in the rotor. It should be remembered that each cycle of current consists of two pulsations—one positive and one negative, so that two rotor poles are attracted to the magnet pole in every cycle.

Thus the higher the frequency, the *higher* the speed will be,

and the more the number of rotor poles the *lower* the spe
The speed in revolutions per minute is given by the formul

$$\text{r.p.m.} = \frac{2 \times \text{frequency} \times 60}{\text{rotor poles}}$$

In actual practice we shall find rotor speeds ranging fr 3,000, which is the speed of a two-pole rotor on a 50-cy supply, to 120 or less according to the number of poles.

In the slower speed motors, the rotor poles or teeth are v small, and the magnet poles are in consequence usually mu plied to pull several teeth together after the manner of Fig.

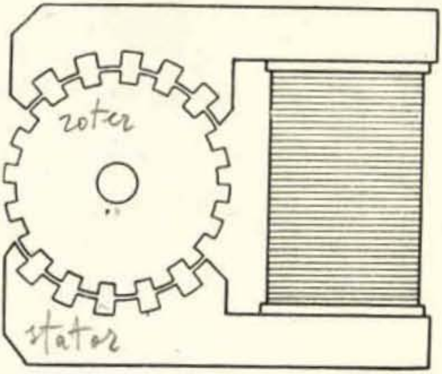

FIG. 48. SIMPLE FORM OF SYNCHRONOUS MOTOR

It should be carefully noted that the number of stator ( magnet) teeth does not affect the speed of rotation.

In starting these motors, they are spun rather faster tha the normal running speed, and then allowed to fall into ste with the magnetic pulsations. In order to do this readily has been found generally necessary to provide some suc device as a comparatively heavy flywheel loosely mounted o the rotor spindle, or to make the magnet capable of sligl rotation against the action of a spring.

It will be realized that considerable reduction gearing necessary to obtain the one revolution per hour by the minut hand of the clock from the fast running rotor. This gearin is of very light character, and is often contained in an oil-fille chamber—this serving the dual purpose of keeping the mechar ism oiled and absorbing all the gear noise.

Before going on to a description of some of the actual clocks on the market, we must consider the self-starting type of motor. This is shown diagrammatically in Fig. 49.

*A* is the stator which in this instance has two poles, the rotor, shown dotted as *B* then running at 3,000 revolutions per minute. The stator poles *C* and *D* are each divided into two

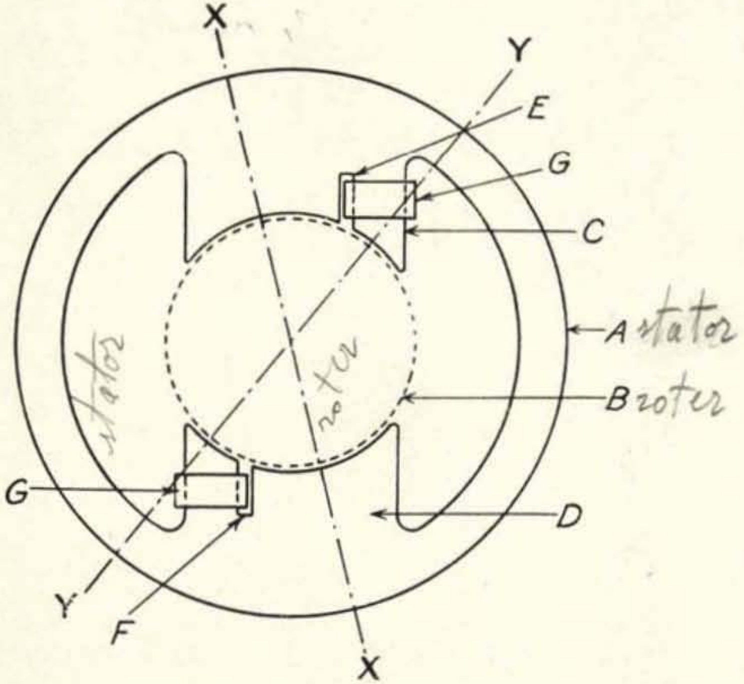


FIG. 49. PRINCIPLE OF SELF-STARTING SYNCHRONOUS MOTOR

halves by the slots *E* and *F* respectively, and a copper ring *D* fitted over the half of each pole as shown.

The stator is magnetized by the coils on each pole (not shown). The effect of the copper rings is to retard the growth of the magnetic flux in the part of the pole they surround, due to the induction of electric currents within them, thus the maximum field is along the line *XX*, when the exciting current in the coil is at a maximum. An instant later the shaded portion of the poles attain their full magnetic strength, the flux in the unshaded parts meanwhile beginning to die dow The line of maximum magnetism, therefore, moves to *Y* and this movement is sufficient to draw the rotor roun giving it the starting movement required.

"Shaded pole" starting is very suitable for small moto such as clocks, gramophone motors, fans, etc., but owing to it inefficiency is never used in large electric motors.

It will be noticed that the direction of the rotation is alway from the plain to the shade pole. Self-starting clock therefore, always run i the correct direction. Non self-starting mechanism on the other hand, will g in whichever direction the are started.

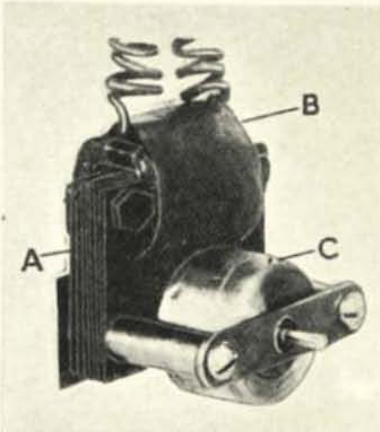


FIG. 50. WARREN SYNCHRONOUS CLOCK MOTOR

A few of the many syn chronous motor clocks o the market will now b described in detail, in orde to illustrate how the abov principles are applied i actual practice.

### The Synclock

The clock manufactured by Everett Edgcumbe & Co., and sold under the trade name of "Synclock" represents the pioneer frequency controlled clock to be introduced into this country. It is fitted with a motor invented by H. E. Warren in 1918, and sold in America as the Telechron, where it is immensely popular.

Fig. 50 shows the motor unit. *A* is the field magnet, *B* the exciting coil, and *C* an oil-filled chamber containing the rotors and reduction gearing. The final speed of the spindle shown in the photograph is one revolution per minute. Further reduction gearing is carried in the clock movement.

A diagrammatic representation of the motor is given in Fig. 51.

A laminated electro-magnet *A* is provided with a winding *B*, connected to the alternating current supply mains.

This magnet has two poles, half of each of which is surrounded by a copper shading coil $C$, the object being to retard the growth of the magnetic field in the part which it encloses, compared with that in the adjacent half.

The effect of this is best understood by a consideration of

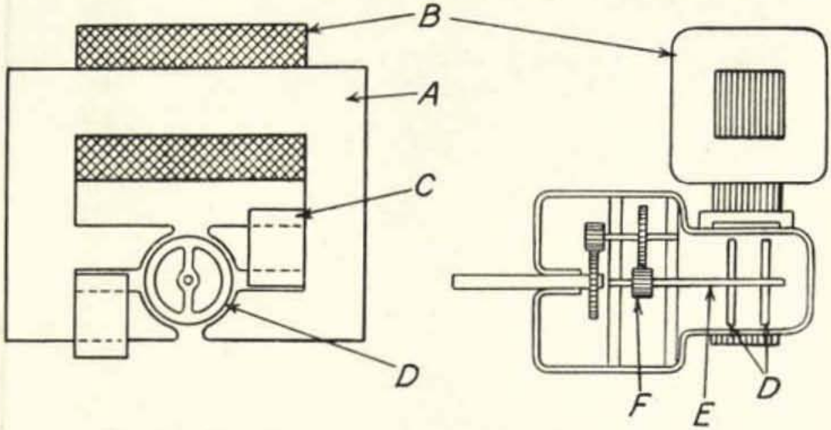


Fig. 51. Diagrammatic View of the Warren Motor

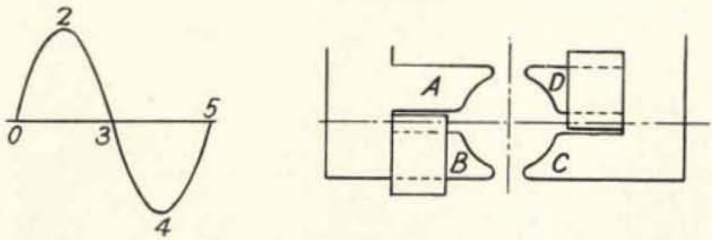


Fig. 52. Principle of Starting in the Warren Motor

Fig. 52, the four positions of the poles being designated $A$, $B$, $C$, and $D$.

Now taking one complete cycle of current as indicated graphically in the left illustration, at point $O$ the current is zero, and there is no magnetic flux in the gap of the electromagnet. The current gradually rises to a maximum in a positive direction at 2, and the unshaded polepiece $A$ becomes, let us say, fully magnetized of north polarity. The current now begins to die down, and with it the magnetism of pole $A$. As explained, the presence of the shading coil retards the growth of the magnetism in the pole it surrounds, so that pole $B$ attains its maximum magnetism an instant after pole $A$. In other words, the point of maximum magnetization moves from $A$ to $B$.

Now the current reaches zero at 3, and begins to build up

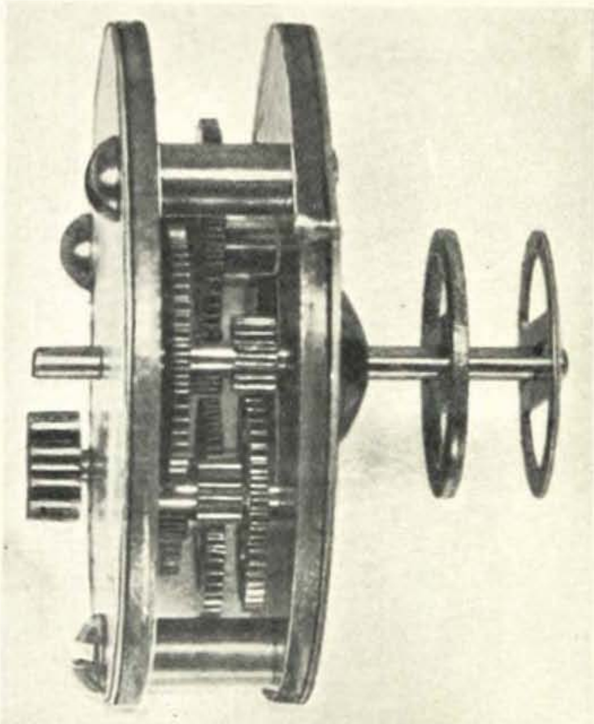

FIG. 53. THE GEAR CASE AND ROTORS OF THE WARREN MOTOR
(2½ times full size)

in the opposite direction, reaching a maximum at 4. Due to the reversal of the current, the north polarity is now on the opposite side of the magnet, and pole $C$ becomes maximum north pole, to be superseded an instant later by pole $D$, after which the cycle is repeated.

The effect of all this is that the magnetic field produced in the gap appears to rotate, making one revolution for every complete cycle of current. *D, D* (Fig. 51) are two light steel rotors mounted on a spindle, which owing to magnetic hysteresis are dragged round in exact step with the rotating magnetic flux, which in the case of 50 cycles supply, by the formula previously given, is 3,000 revolutions per minute.

Suitable gearing *F* encased in an oil-filled container is fitted to reduce the rotor speed to one revolution per minute, and further gearing effects the reduction to one revolution per hour, and per twelve hours required by the minute and hour hands respectively.

Fig. 53 gives an enlarged view of the gear case and the two rotors.

The first gear in the train is made of fibre in order to minimize noise.

Despite the high rotor speed, the Warren motor is extremely serviceable, and many have been running continuously in the United States of America for ten years without exhibiting any signs of wear. Owing to the quality of the gearing and total enclosure in oil, the clocks are almost noiseless in operation.

The Warren motor being self-starting, an indicator is fitted to all clocks to show when an interruption of supply has taken place. It is thus an easy matter to check if the interruption has been of sufficient duration to warrant the clocks being reset. It sometimes happens that a circuit is opened for only a few seconds, such as when a fuse is inadvertently drawn out.

## The Smith Synchronous Clock

A range of synchronous clocks, which are entirely British in patents, design, and manufacture, is made by Smiths English Clocks Ltd., London.

These clocks are not self-starting, but are provided with an ingenious arrangement by which the rotor is automatically given a starting impulse when the hands are set to correct time.

The motor has fifteen pairs of poles, and therefore runs at a comparatively low speed of 200 revolutions per minute. The bearings are self-lubricating, and no oiling or maintenance is called for. The power consumption is approximately one watt.

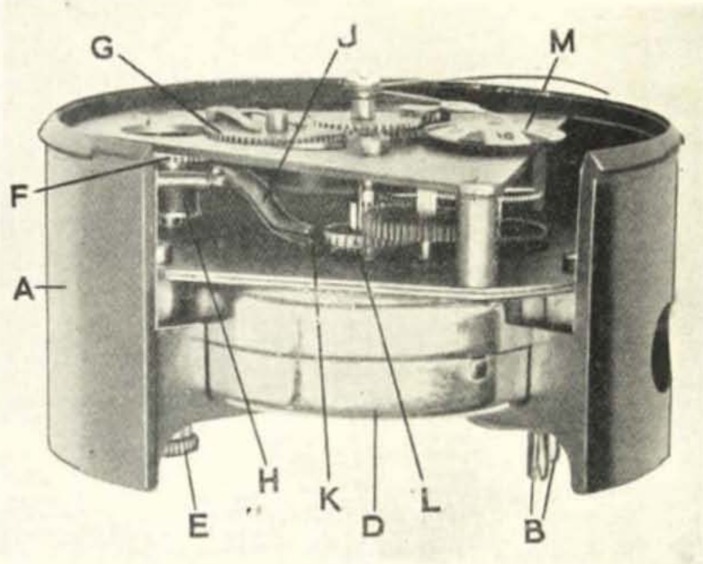


FIG. 54. MOVEMENT OF SMITH SYNCHRONOUS CLOCK

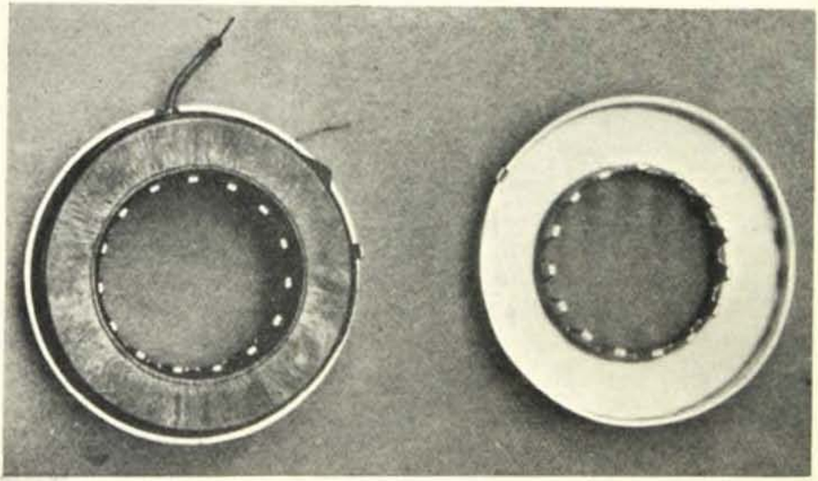

FIG. 55. CONSTRUCTION OF STATOR (SMITH ELECTRIC CLOCK)

Fig. 54 gives a view of the movement, a portion of the casing, the dial and cover glass being removed to facilitate reference.

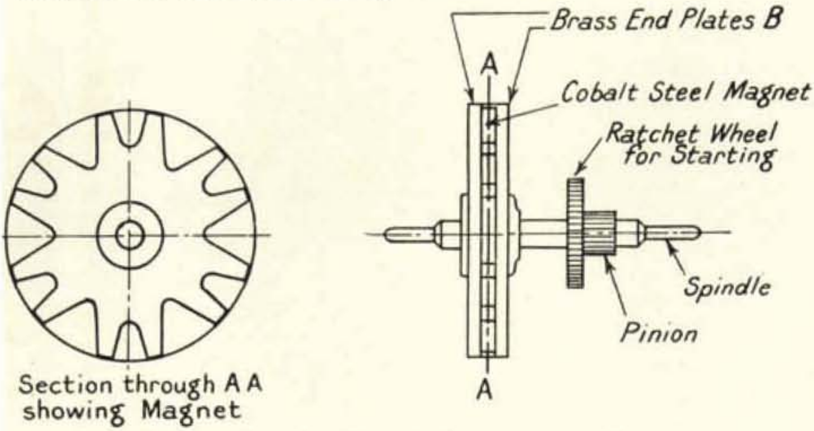


FIG. 56. ROTOR—SMITH'S SYNCHRONOUS CLOCK

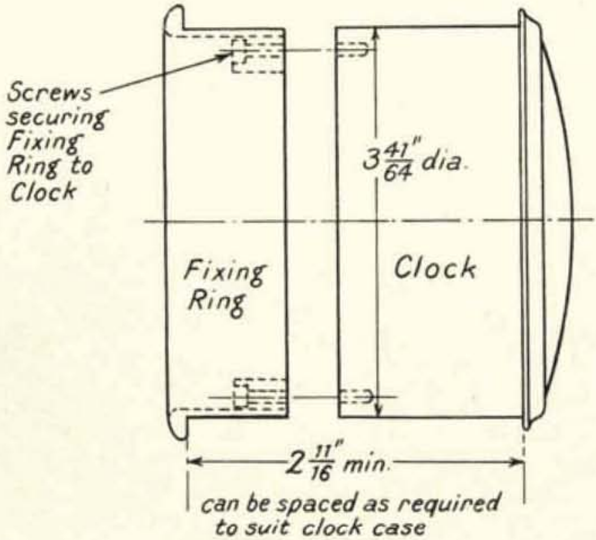


FIG. 57. DIMENSIONS OF SMITH MOVEMENT FOR FITTING TO EXISTING CLOCKS

*A* is the housing which is a bakelite moulding, *B* are the terminal pins which carry the connector socket (not shown), which is also of bakelite. *D* is the exterior of the stator of the small driving motor, the rotor being concealed within it. *E* is the hand-setting knob. When this is pushed in, wheel *F* is brought into engagement with wheel *G*, which is geared to the hands and so enables them to be set. At the same time cone *H* presses against the top portion of lever *J*, drawing it back, and as it returns to its original position, the blade *K* on its lower extremity engages with the teeth of the ratchet wheel *L* mounted on the rotor shaft, and so gives the requisite spin to set it in motion.

The first wheel of the gear train between the motor and the hands is made of bakelized fabric in order to ensure silent running. The sectors on disc *M* are visible through a slot in the dial, and indicate whether the clock is running or not.

The construction of the stator is shown in Fig. 55, the upper half being removed. It will be seen that alternate north and south poles are formed by the interleaving of the projections and the two portions. This construction besides being efficient magnetically affords complete protection to the coil. The construction of the rotor is shown in Fig. 56.

This consists of a star-shaped 6-pole cobalt steel magnet *A*, which is clamped between two brass discs *B* mounted on a suitable spindle.

In addition to being supplied as complete clocks, separate movements are available for fitting to existing clock cases.

The dimensions and manner of fixing are outlined in Fig. 57.

Various finishes are available, and one winding serves for all voltages between 200 and 250. The standard clock is made for 50-cycle supplies, but models are also available for other frequencies.

### The Sangamo Clock

Another popular range of synchronous clocks is produced by the British Sangamo Co., Ltd., one of the standard models being illustrated in Fig. 58.

The motor is of the slow speed non-self-starting type. The clock is characterized by the short rotating seconds hand, which provides second indication without the likelihood of confusion in reading which sometimes happens when the seconds hand is similar in form and length to the other two hands, and rotates about the same centre.


Fig. 58. Sangamo Synchronous Motor Clock

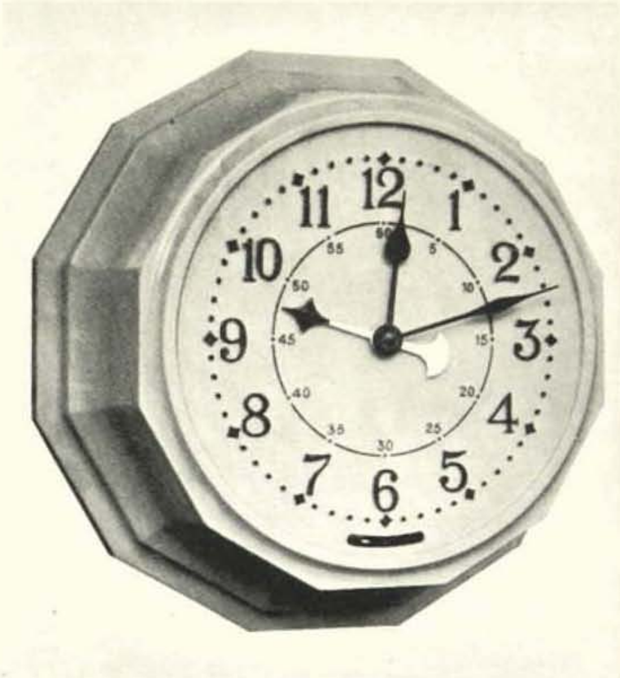

Fig. 59. Sangamo Synchronous Motor Clock—Wall Type

Fig. 59 illustrates a clock specially designed for kitchen use. It has a white bakelite case with bold black figures, and as no cover glass is fitted, the dial may be readily cleaned by wiping with a damp cloth.

The clock is started by moving the lever seen projecting through the dial below, and the construction of the synchronous driving motor is shown in Figs. 60 and 61, both being lettered to correspond.

*A* is a coil of many turns of fine wire, surrounding the iron core *B* which is mounted on plate *C*. The steel drum *D* surrounding the coil and the top plate *E* are each provided with

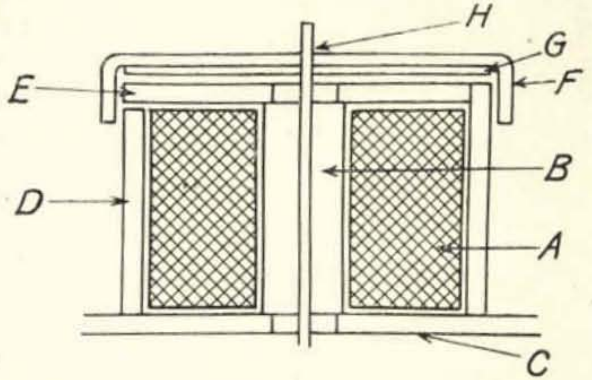


FIG. 60. SECTION OF SANGAMO CLOCK MOTOR

19 pairs of poles, so positioned as to interlock, giving 38 poles of alternate polarity, which gives a rotor speed of nearly 158 revolutions per minute.

This construction is clearly shown in Fig. 61. The rotor consists of a permanent magnet *F* mounted on a brass disc *G* and pivoted at *H*, whence it is connected to the hands through suitable gearing. The ends of the rotor magnet are bifurcated and bent over as shown, so as to come into close proximity to the poles of the stator.

When once started the rotor is kept in motion by the fact that its poles are always attracted by those of opposite polarity in the stator, and owing to the alternating nature of the current each stator pole rapidly alternates in polarity.

Fig. 62 shows a general view of the movement.

*A* is the starting lever, the operation of which causes a toothed sector to be brought into engagement with a gear

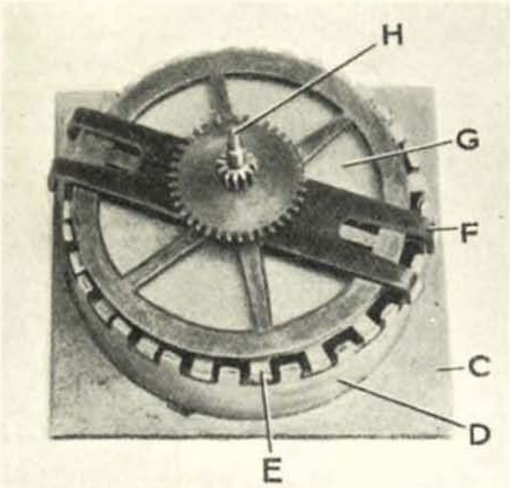


FIG. 61. SANGAMO ELECTRIC CLOCK MOTOR

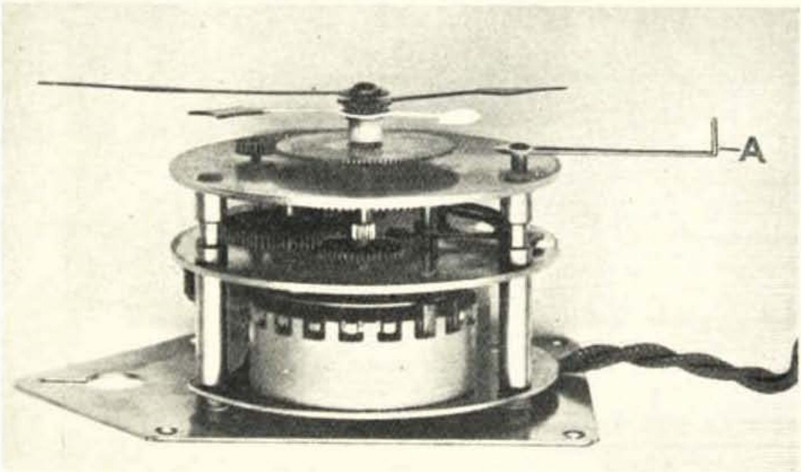


FIG. 62. MOVEMENT OF SANGAMO ELECTRIC CLOCK

wheel on the rotor spindle. It is disengaged by the pull of a spring, and the rate of travel is limited by a fan brake, thus ensuring that the rotor receives a steady starting impulse at the correct speed.

As with other types of synchronous clocks, the gear wheel following the rotor spindle pinion is made of fibre to give silent running. The power consumption is approximately one watt.

A self-starting type motor is also made. This starts as an induction motor, and when the rotor reaches synchronous speed it pulls into step, the motor then running due to both the induction and synchronous torques.

No starting lever is, of course, necessary in this type of motor. A red signal is provided to indicate any interruption in the electricity supply which may have taken place unnoticed.

### The Ferranti Clock

The Ferranti synchronous electric clock embodies a purely synchronous motor of the hand starting type. The rotor which is constructed from soft iron, and therefore not liable to demagnetization error has clearly defined poles on its periphery, the number of poles being such as to give a rotor speed of $166\frac{2}{3}$ r.p.m. The stator is similarly constructed of soft iron, and consequently a pull will be exerted on the rotor teeth every half cycle. The torque derived from the rotor shaft is 3 gr. cm.

The electrical energy taken by the clock is slightly less than one watt, so that with electricity at a penny per unit the cost to the user is something less than ninepence per year.

In the design of the Ferranti electric clock close consideration was given to the bearings to ensure long working life. It is known that, for a given speed, load, and torque, the wear which takes place is proportional to the diameter of the bearing and inversely proportional to the length, so that for ideal conditions the ratio of $\frac{\text{length of bearing}}{\text{diameter of bearing}}$ should be great.

As in all cases of machinery design, the mechanical strength is the governing factor as to how small the diameter of the shaft may be; the ratio in the case of the Ferranti clock is 3·5—a high value.

The material of the rotor shaft is a high carbon content steel, special care being exercised in the burnishing and polishing of the pivots.

The bearings which incorporate a lubricant reservoir are constructed from phosphor bronze, a special acid-free lubricant being packed in the cavity provided, sufficient to last for many years. A further feature of the bearings is that they are

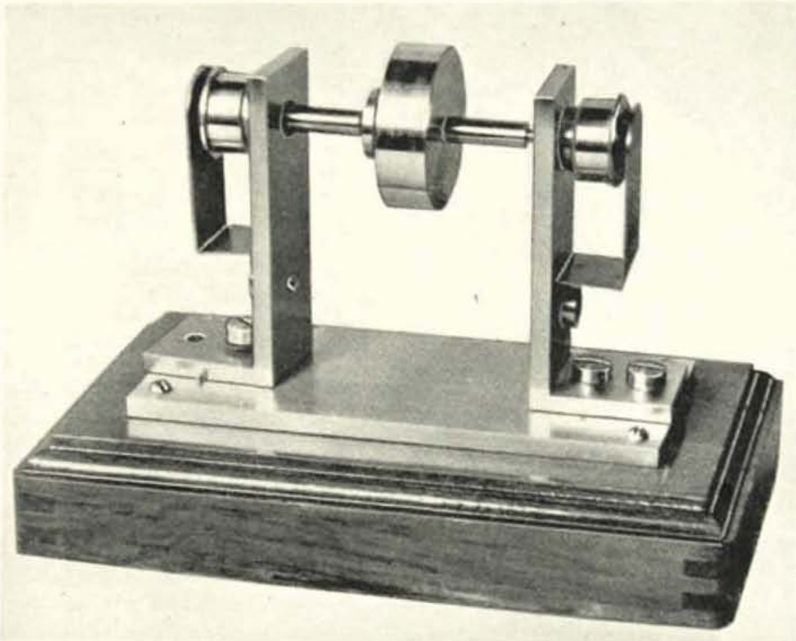

FIG. 63. BEARINGS OF FERRANTI CLOCK

so designed as to be self-aligning, thereby facilitating assembly, and allowing reasonable manufacturing tolerances in the assembling of the train plates.

Fig. 63, an enlarged model of the actual bearings used in the clock, shows a greatly exaggerated out-of-truth view of the train plates.

One plate, it will be seen, has intentionally been placed "askew," giving a deviation from the straight of about 20°. In spite of this the rotor still runs perfectly true.

Fig. 64 shows the motor element of the clock, and in the forefront of the illustration will be seen one of the self-aligning bearings with its holding down spring; also may be seen the notched rotor, and in the background the brass flywheel, which is provided to give stable running and easy starting.

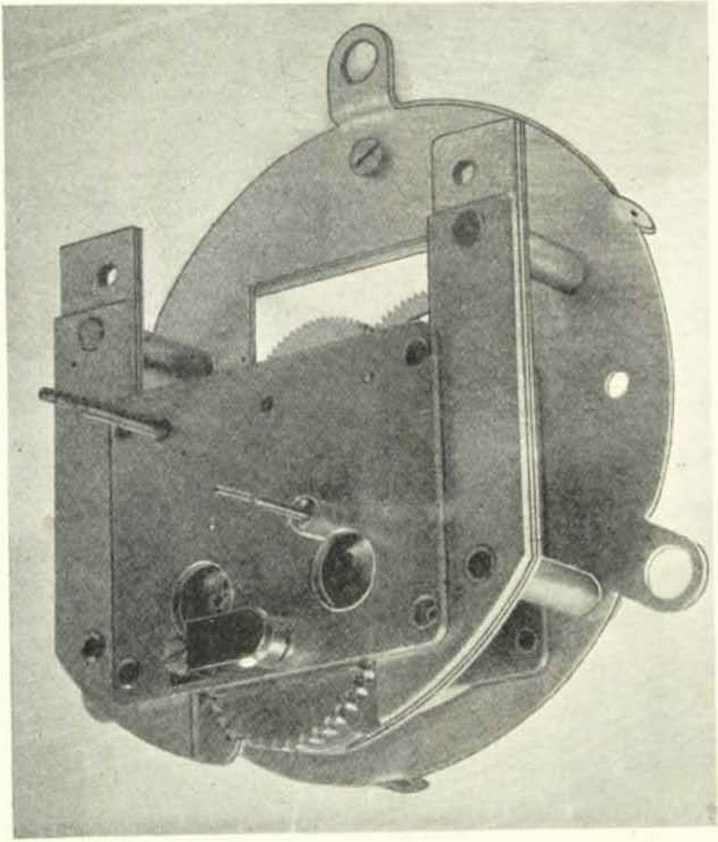

FIG. 64. FERRANTI CLOCK MOTOR

The flywheel is elastically coupled by means of a spring to the spindle to start the motor, one of the shafts being extended through the plates and a knob fixed thereto. This knob is gently spun which imparts to the rotor a speed

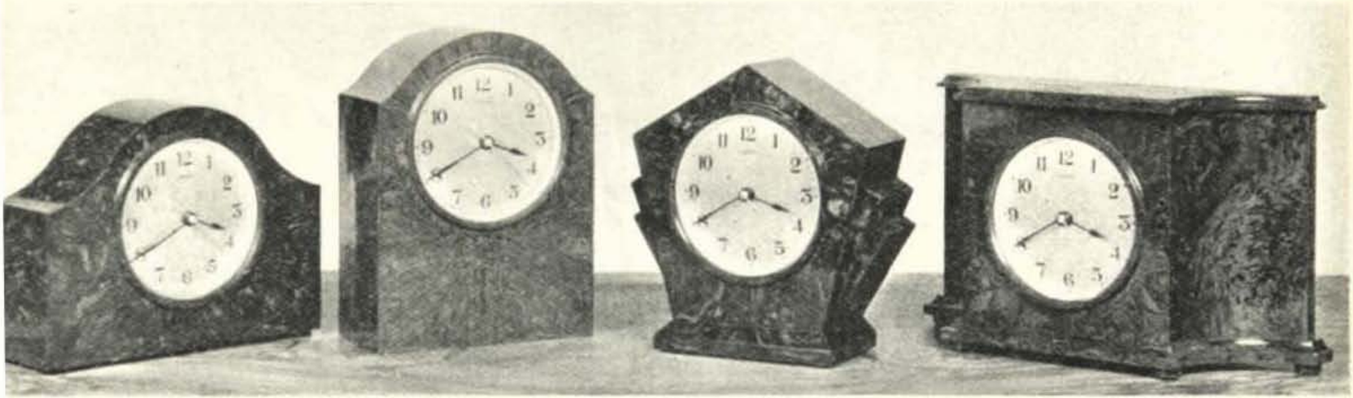

Fig. 65. Group of Ferranti Synchronous Clocks

somewhat higher than synchronous speed, whence on the outside motion being withdrawn the rotor will commence to decelerate. The rate of deceleration is governed by the combined weights of the rotor and its flywheel, and when the rotor comes to synchronous speed it will have stored a definite amount of energy, which is generally too great to be offset by the pull from the stator poles. The effect of the spring, therefore, is that on the rotor reaching synchronous speed it will be pulled into step with the frequency, as the actual energy stored in the rotor itself is sufficiently small to enable this to be effected. The energy required then to pull the rotor out of step will be such as to be greater than the energy in the flywheel, which consequently transmits its energy to the spring and dissipates it immediately after synchronizing.

The clock movement is fitted for sale to the public in two types of cases, namely—moulded "bakelite" or "beatl," and ornamental wooden cases. In this construction the movement is completely mechanically and electrically insulated from the case. Rubber shock absorbers are fitted in between the movement and the case; by this means any slight noise which may possibly occur is not transmitted to the case. In the ornamental wooden-cased clocks, the movement is again mechanically insulated from the dial, etc., by means of flexible springs.

Fig. 65 illustrates a group of models, and on reference to this it will be seen that a short delicate seconds hand is included.

## The Hammond Clock

One of the most popular of American synchronous clocks is that made by the Hammond Clock Co. of Chicago. It is of the non-self-starting type, and consumes only two watts. The cost of running is therefore negligible—500 hours for the cost of one unit of electricity.

The rotor runs at the comparatively low speed of 187·5 revolutions per minute on 50 cycles and is quiet in running. The rotor and the first stages of the reduction gearing are contained in an hermetically sealed oil-filled chamber. A window is provided in the dial, behind which a black and white sector revolves to indicate that the clock is running.

wafum ...



Fig. 66 shows a side elevation of the movement removed from the case.

*A* is the dial, *B* the hands, *C* and *D* are brass plates supporting the mechanism, *E* is the rotor casing, which, as previously mentioned, is oil tight, fixed against steel plates *F*. *G* is the exciting coil mounted in laminated core *H*. *I* is the twirling knob spindle. When it is pressed inwards against spring *J*, pinion *K* is pushed into mesh with the gear wheel *L*. As soon

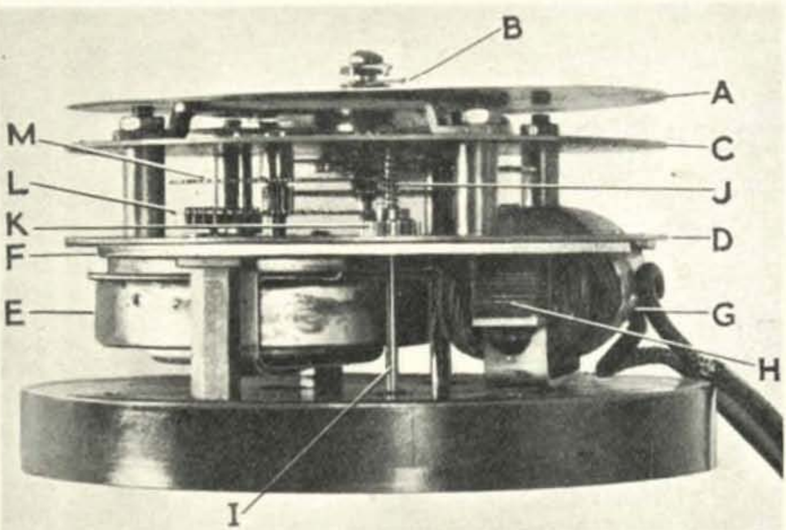


FIG. 66. SIDE ELEVATION OF HAMMOND CLOCK MOVEMENT

as the fingers are removed from the twirling knob, the pinion *K* flies out of gear. The gearing *M* is for the purpose of reducing the high speed of the rotor to that required by the hands. The first reduction gear (contained in the rotor chamber) is made of fibrous material to eliminate noise.

Fig. 67 shows the rotor and magnetic circuit of the motor. *A* is the rotor of a steel disc having a number of teeth on its periphery. The stator *B* comprises two pole pieces made up of several thin steel plates, the shoes being notched to correspond with the rotor teeth. The two pole pieces are mounted on a pair of larger plates *C* (*F* in Fig. 66) joined by the laminated core *D* on which is mounted the coil *E*.

A small brass flywheel, not shown, is mounted alongside the rotor, but loose on the spindle. This is to maintain the momentum and assists the rotor in dropping into step.

Fig. 68 shows the stator and rotor removed from the casing.

A special model of the Hammond clock is fitted with a half-minute contact device enabling it to be used as a master transmitter in an impulse clock system. Another model is

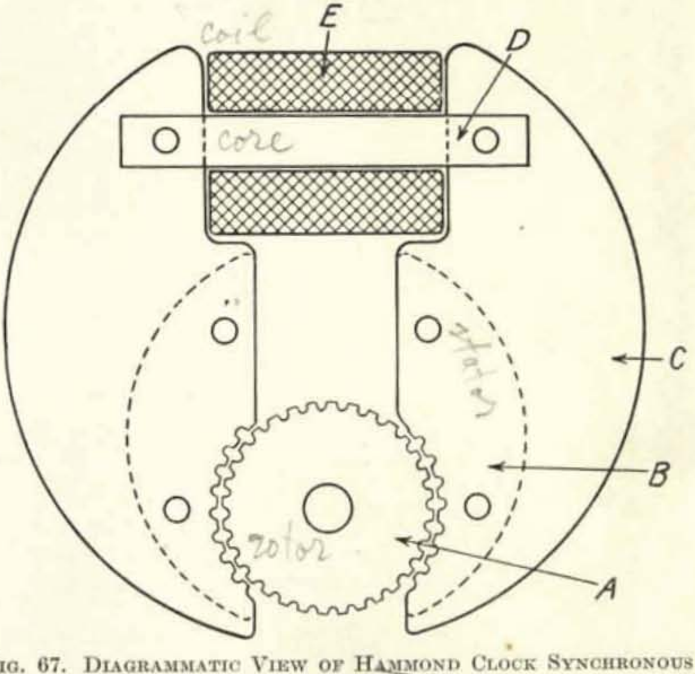


FIG. 67. DIAGRAMMATIC VIEW OF HAMMOND CLOCK SYNCHRONOUS MOTOR

fitted with an auxiliary spring clock movement which only comes into action in the event of a failure in the electricity supply, and another gives the date as well as the time.

## Frequency Control

The foregoing description of the principle and construction of synchronous clocks has shown how entirely dependent is this class of clock on the accuracy with which the actual frequency of the electricity supply is maintained in relation to the standard or declared frequency, which in this country is 50 cycles per second. It is now proposed to describe the method by which this control is effected.

The frequency of an alternating current electricity supply represents the number of complete cycles of change which the voltage or current makes in a second; one cycle comprising the following steps, viz. start from zero, grow to a maximum in a positive direction, die down to zero, grow to a maximum

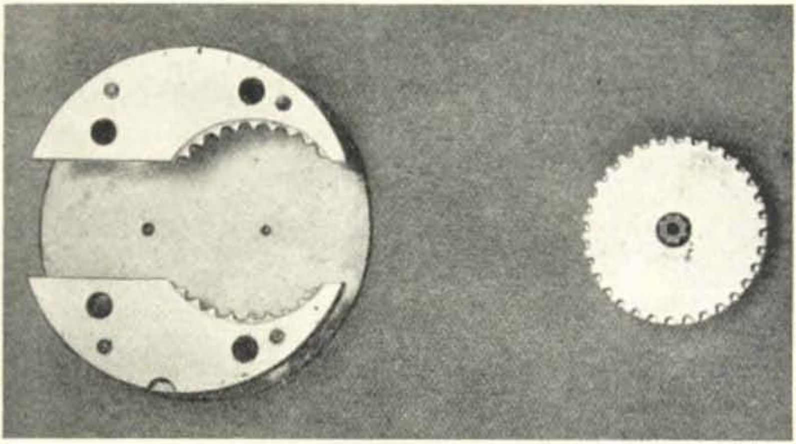

FIG. 68. STATOR AND ROTOR (HAMMOND CLOCK)

in a negative direction, and again fall to zero. This has already been illustrated graphically in Fig. 52.

The frequency depends on the speed and number of poles of the generators at the power station, thus—

$$\text{cycles per second} = \frac{\text{r.p.m.}}{\text{pairs of poles} \times 60}.$$

The number of poles, generally two in large alternators, cannot, of course, be varied, so that the frequency is dependent entirely on the speed of the generator, which in a two pole machine is 3,000 revs. per minute.

As its name implies, a turbo-alternator consists of a steam turbine directly coupled to an alternating current generator. The steam supply to the set is controlled partly by hand and partly by a centrifugal governor which keeps the speed constant, admitting more or less steam as the load on the generator varies. The speed of the set is also influenced to some extent by any other generators which happen to be working in parallel with it—that is, feeding into the same network—and a generator which is tending to slow up will tend to be pulled into step with the others, or rather, the other generators will take some of its load and enable it to gather speed.

It is thus seen that the control of frequency is not particularly easy, and is dependent partly on the human element. Recognizing this, the Board of Trade actually allows a limit of $2\frac{1}{2}$ per cent above or below the declared periodicity. In the days when each locality had its own power station this was good enough. So long as the frequency was within the B.O.T. limits, all was well, and the consumer did not worry whether his supply was 49 or 51. Such a supply, however, is no use for controlling the time of a clock, because the 5 per cent overall variation allowed would permit a clock to vary 72 minutes in twenty-four hours—an intolerable inaccuracy. Then came the Grid scheme of the Central Electricity Board, and power stations instead of serving their own district only were linked into a common network stretching all over the country.

It was mentioned above that a fast running alternator will take the load from a slow one. The same applies to power stations, a slight rise in the frequency of a station will cause it to take more than its share of the load—an occurrence often known as "load snatching." This would be followed by the other station's frequency increasing due to its loss of load, and the load would transfer itself back to this station, and oscillation of load is set up. The only way to evenly distribute the load between stations is to ensure that their frequency is identical.

The B.O.T. limits were hopelessly inadequate, as were the old frequency indicators, and an entirely new type of instrument now to be described was developed. The frequency is still controlled by the power station operator, but the slightest deviation from standard is readily seen, and can be immediately corrected. The next stage in development will undoubtedly be the fully automatic control of the generator speed by means of the frequency meter.

The principle of the master frequency meter is indicated in Fig. 69.

*A* is a high-grade master clock either mechanically or electrically driven, which indicates Greenwich time. *B* is a synchronous clock driven from the mains whose frequency it is desired to control.

*C* is an extra dial having two hands working from the same centre (other constructions will be described later). One hand is connected by means of the spindle *D* to the master clock, and makes one revolution in three minutes. The other hand

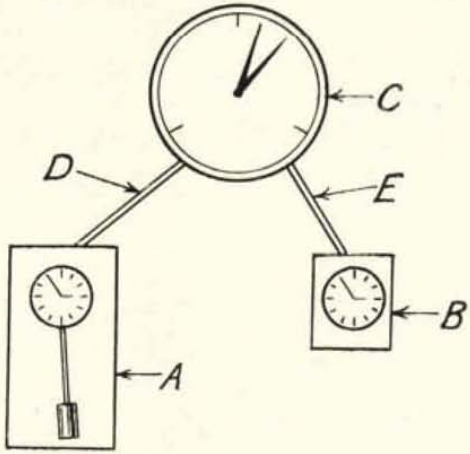


FIG. 69. PRINCIPLE OF FREQUENCY CONTROL METER

is connected to the synchronous clock through spindle *E*, and also makes one revolution in three minutes when the frequency is exactly 50 cycles. The two hands, therefore, rotate together. If, however, the frequency departs from the correct value the red hand will overrun or fall behind the other as the case may be. Thus the slightest discrepancy is readily apparent to the switchboard attendant. Any inaccuracy revealed by the master clock is, of course, reflected in the time-keeping of the clocks connected to the supply mains, but the act of correcting the frequency also brings the clocks back to the correct time.

It will be seen, therefore, that although synchronous clocks may depart slightly from absolute Greenwich time, the average time is correct, and in any case the deviation is never more than a few seconds. A deviation of one minute would represent one-third of the dial of the master frequency meter, and would compel attention.

The time shown by the master clock at the power station is immaterial, but if it gains or loses, the clocks on the system will gain or lose the same amount. As a matter of fact it is difficult to regulate any clock, particularly a mechanical one, to keep dead time day in and day out, and it is, therefore, essential that the master clocks be synchronized frequently with time signals from Greenwich Observatory, and gradual correction of the pendulum effected, as described in a later chapter. From the point of view of time-keeping the ideal scheme would be for there to be one master clock for the whole of the country, and that the mean time clock at Greenwich Observatory.

The business of the Central Electricity Board is, however, to supply electricity. The distribution of time is an incidental matter, and as at present arranged each important station will be provided with a master frequency meter.

In addition, indicating frequency meters of specially high accuracy will be installed at certain selected stations in order to check the momentary variations in frequency

The pioneers of frequency control in this country were Everett Edgcumbe & Co., Ltd. Fig. 70 shows a typical master control clock.

The lower right-hand dial indicates hours and minutes of "standard time." The dial on the left which shows "frequency time" has a red seconds hand in addition to the others. The large central dial is the one by which the frequency is controlled. Instead of two pointers, one black and one red, as shown in the illustration of the principle, the control dial has only one revolving pointer (connected to the master clock), and instead of the red pointer, a revolving disc driven at synchronous speed, on which is engraved a red line.

The disc and pointer rotate once in three minutes, the number of seconds discrepancy between the two clocks being shown by the difference in position of the pointer and red mark.

The early master clocks were weight-driven regulators electrically wound.

The latest practice employs an electric impulse clock to

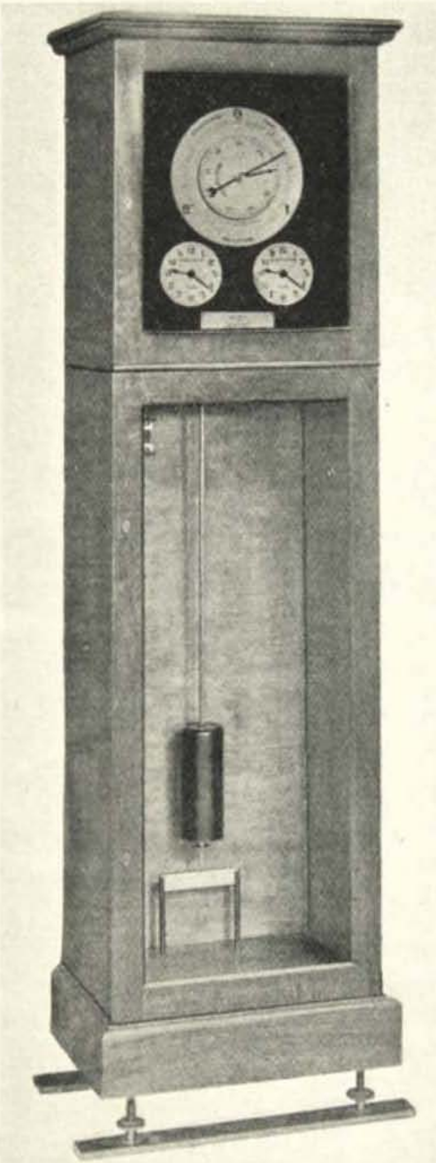

Fig. 70. Everett Edgcumbe Master Frequency Meter

maintain standard time, thus enabling the master control to be coupled into an existing impulse time circuit.

Fig. 71 shows how the control dial is operated. The synchronous motor drives both the black and red hands (or rather disc), the former through a slipping clutch.

On the spindle on which the black hand is mounted is a block having a number of vee-shaped depressions, into which

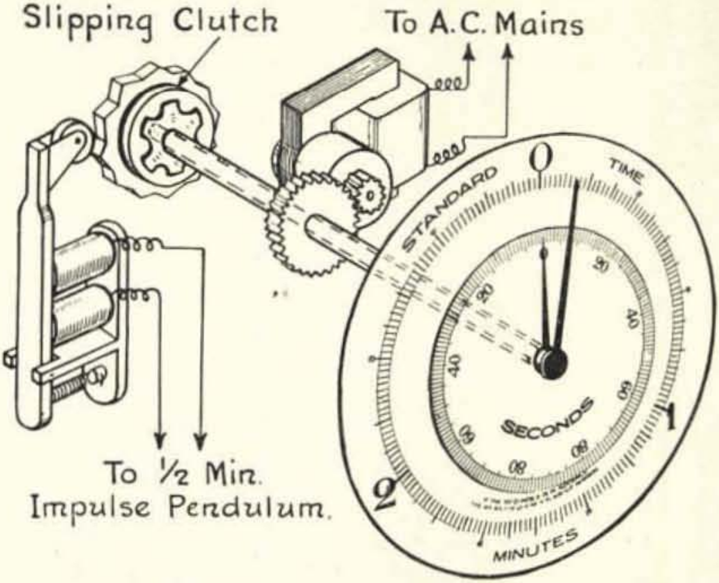


FIG. 71. MOVEMENT OF EVERETT EDGCUMBE MASTER FREQUENCY METER
Impulse pattern

a roller attached to the armature of an electro-magnet in the impulse time circuit is drawn every half-minute. The action, therefore, is that while the red hand rotates in exact synchronism with the frequency, the black hand also rotates at synchronous speed, but any advance or retardation, as compared with standard time, is corrected every half-minute by the descent of the small roller into one of the vee-shaped depressions.

The advantages of this arrangement are that the pendulum is practically free, so that the time-keeping is beyond reproach. The movement of both the black and the red hands is, therefore, perfectly smooth instead of being by jerks, as is the case if driven directly from the clock, and the pendulum and its contact maker can be installed in any convenient position, where it is free from vibration, etc., the indicating position,

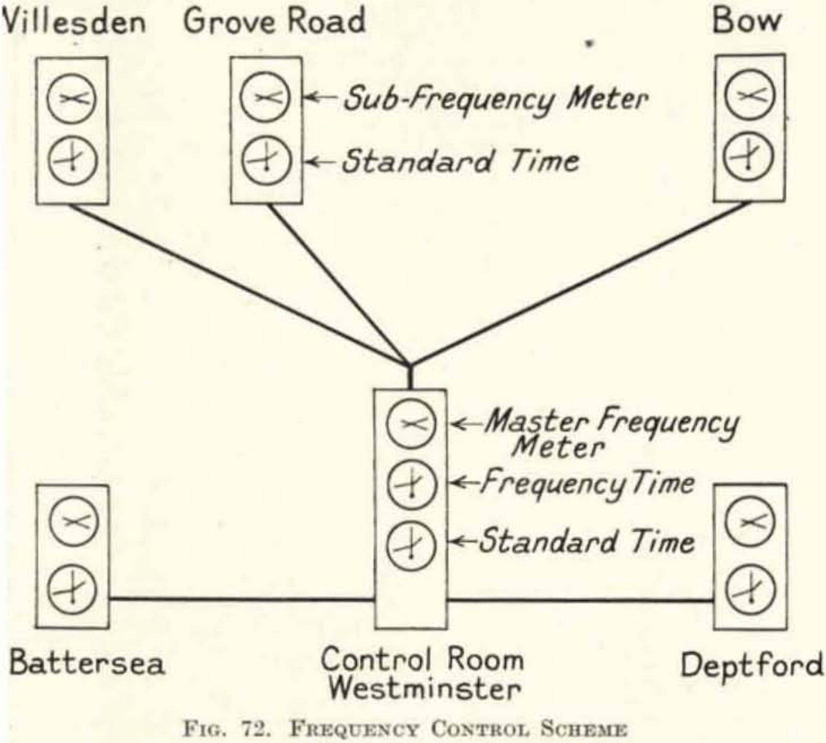


FIG. 72. FREQUENCY CONTROL SCHEME
*(London Power Co.)*

shown in the illustration, being installed in the control room. Moreover, duplicate indicators can be fitted at various points if required.

When once set the clocks of either the old or new patterns are capable of giving an accuracy of one or two seconds in twenty-four hours, or in other words, of indicating the frequency correctly within 1/1000 to 1/500 per cent.

Regarding the control of the frequency of a group of stations from one master control room, the following description of the method adopted by the London Power Company is typical of modern practice. The problem in this case was that any one of the five existing power stations at Willesden, Grove Road, Deptford West, Bow, and Battersea, should be in a position at any moment to take over the frequency control of the entire system. Further, that each station should have a continuous indication of the mean frequency of the system, or if that system were temporarily disconnected therefrom, of its own mean frequency, so that it could be at any moment reconnected with the least possible delay.

The system employs the Everett Edgcumbe master frequency meter in conjunction with the Synchronome impulse system. The master frequency meter is installed in the central control room of the London Power Co., Ltd., at Ergon House, Horseferry Road, Westminster, and has the usual three dials showing standard and frequency times, and difference. The master clock is a Synchronome transmitter, and each station is given a secondary dial which is an exact replica of the standard time dial at Ergon House.

In addition, at each station there is a second dial having two pointers revolving once in five minutes, the one pointer being connected to the Synchronome dial, and the other driven by a Warren motor connected to the station bus bars.

The lay-out of the system is shown in Fig. 72.

It is thus assured that so long as a station is connected to the system, the readings on the two dials will agree exactly with the readings on the master frequency meter at Ergon House. Should any one of the generating stations be disconnected from the main system for any reason, and therefore compelled to control its own frequency, it can do so by means of the upper dial, since the standard time hand is synchronized from the control room. By this means the station is at any moment in a position to connect once more to the system without the delay of equalizing frequency.

# CHAPTER VII

## ELECTRICALLY-WOUND CLOCKS

### Introduction

As their name implies, electrically-wound clocks rely for their time-keeping on a pendulum or escapement, and upon a spring or weight for their driving motion, electricity being called upon merely to wind up the spring or weight. An electrically-wound clock consists, therefore, of an ordinary clock with the addition of a suitable winding motor. The winding is always done at fairly frequent intervals, and is generally quite automatic in action. This enables the driving spring, or in the case of a weight-driven clock, the drop of the weight, to be smaller than would be necessary were the clock purely mechanically wound at weekly intervals. Some electrically-wound clocks have sufficient storage of driving power in their springs to go for several days in the event of failure of the electric current, others will only run an hour or so. Winding motors can either be driven from the ordinary electricity supply, or from batteries, according to circumstances.

The subject of electrically-wound clocks embraces a wide range and includes domestic clocks, time switches for operating street lamps and the control of shop window displays, motor-car clocks, turret clocks, and the master transmitters of some electric impulse clock systems.

The considerations which apply to one class of clock may not apply to the other, so each of the above will be considered separately.

For domestic purposes, the electrically-wound clock has several advantages. Its principal point, of course, is that it requires no winding. It is independent of interruptions of the electric power supply—which even of short duration are sufficient to upset the working of the synchronous type of clock. It is reasonably portable, that is, it can be removed from one plug to another without stopping the clock.

Being essentially a mechanical clock, it has a definite "tick," and the hands do not move in half-minute jumps as with the impulse type of clock.

The electrically-wound clock can be made suitable for direct or alternating current, and, in the case of the latter, it is independent of whether the frequency is time controlled or not.

The electrically-wound domestic clock, of course, has its disadvantages as well. Being both a mechanical clock and an electric motor, it is naturally more costly than either a mechanical clock of equal quality, or a synchronous motor clock.

Synchronous motor clocks cannot, however, be used where the electricity supply is direct current, or on alternating current if the frequency is not controlled.

The time-keeping of electrically-wound clocks is entirely dependent on individual construction and regulation, and there is no guarantee that several clocks in the same house will indicate the same time. As time-keepers the impulse and synchronous clocks are superior.

No special wiring is necessary for the electrically-wound clock. It can be plugged into any convenient point, and if it is desired to run any other appliance from the same point, the clock can be temporarily disconnected, and will carry on under its own power.

Time switches, which are nothing more than electrically-wound clocks without dials and hands, are used to a tremendous extent nowadays to save labour. They are fitted to nearly all street lamps in order to switch off in the early hours of the morning.

In business they enable shopkeepers to leave the windows lighted until late at night—a valuable form of publicity—and shut off the lights at a predetermined hour.

In industry they are used for controlling all sorts of processes. For instance, furnaces can be switched on in readiness for the operators to start work immediately they arrive, instead of having to switch on the furnace and wait for it to heat up.

Time switches must be independent of interruptions in the electricity supply, and the electrically-wound movement is the only solution. Synchronous clock motions are not desirable, as in the event of an interruption they would stop until restarted manually, or if self-starting would be slow by the amount of the interruption. A half-hour shut down in the daytime would mean all the lamps coming on half an hour late in the evening, or not at all:

The impulse system is not an economical proposition for such purposes as street lighting, because of the additional wiring that would be necessary. Electrically-wound clocks can be connected to the same supply as the lamp which it controls. Battery-driven clocks are generally out of the question for time switches as they are usually pendulum controlled, requiring careful mounting and levelling.

Time switches must work in any position, and must be capable of working under the most severe weather conditions.

Electrically-wound motor-car clocks are extensively used to-day. They usually consist of a spring-driven movement, which is periodically wound by energy derived from the 6- or 12-volt lighting circuit of the car. A pendulum clock, of course, would be impossible owing to vibration. The clock should preferably be able to carry on without winding for a day or two, so that it does not have to be reset if the battery has been taken off for charging.

It is in the case of turret clocks that the electric winding motor is seen to the greatest advantage. The time and energy required to keep a large clock, with chimes, fully wound is very considerable, and may amount to several days labour a week, which can be saved by installing a small motor-driven winding gear for each train. The existing mechanical trains require little alteration, and the dropping distance of the weights can be reduced to a fraction of the original, as the motor can be made to wind up at frequent intervals. The winding motors need only be small, and their cost will quickly be repaid by the saving of labour effected. The addition of the electric wind in no way affects the time-keeping of the clock itself.

The application of electric winding to master transmitters of impulse clock systems, when such are not electrically driven, requires a little consideration. The ideals of the electric impulse system such as reliability of service, accuracy of time-keeping, etc., would be utterly defeated if there was risk of the whole system stopping due to neglect of winding the master clock.

That some makers should essay to use a mechanical master clock instead of the simpler and more accurate electric time-keeper is not within the province of this chapter to discuss.

**Winding Methods**

In this section it is intended to give only a brief outline of the various principles which can be employed to perform the winding of spring or weight. Practical details will be reserved until actual makes are described.

It should be noted that the power required to wind a clock spring is very little when exerted through a train of gearing, and, except for large turret clocks, the winding motor is very small. Cost of running is so small as to be unimportant, and the aim of the designer is to reproduce a winding mechanism

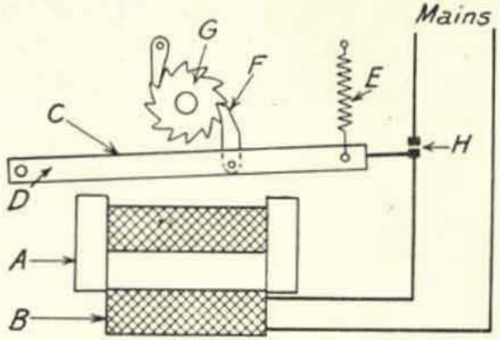


FIG. 73. SIMPLE ELECTRIC WINDING MOTOR

of low first cost and robust construction, rather than one which has a high theoretical efficiency of little practical value.

The simplest winding motor is the electro-magnetically operated type seen in Fig. 73.

*A* is an electro-magnet, *B* its coil, *C* the iron armature pivoted at *D*, and *E* a spring; *F* is a pawl mounted on the armature and engaging with ratchet wheel *G*, which is coupled to the going train, usually through a spring which acts as storage. The spring *E* is really the driving spring of the clock, and as the armature is pulled up it causes the wheel *G* to rotate, its rate of travel being limited by the escapement or pendulum. When *C* rises to a certain height it closes the contacts *H* which complete the circuit and cause the armature to be drawn to the magnet poles, when the cycle is repeated. The reserve spring carries on with the driving of the clock hands during the brief instant that the armature is being attracted by the magnet and is not driving the ratchet wheel.

A somewhat similar principle is illustrated in Fig. 74. Here the armature is made to vibrate rapidly in the manner of an electric bell, and in doing so turns the ratchet wheel which is geared to the winding spindle of the main spring.

No make and break contacts are required when the magnet

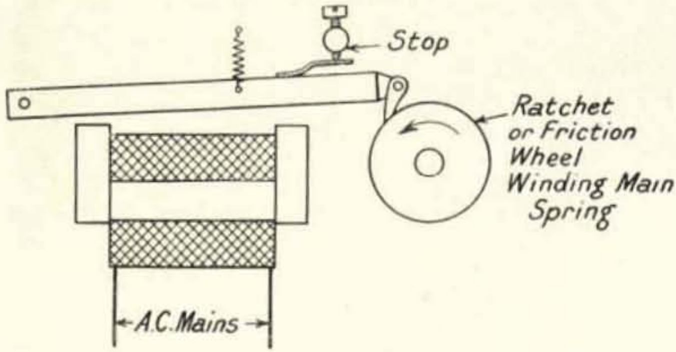


FIG. 74. SIMPLE VIBRATORY WINDING MOTOR FOR ALTERNATING CURRENT

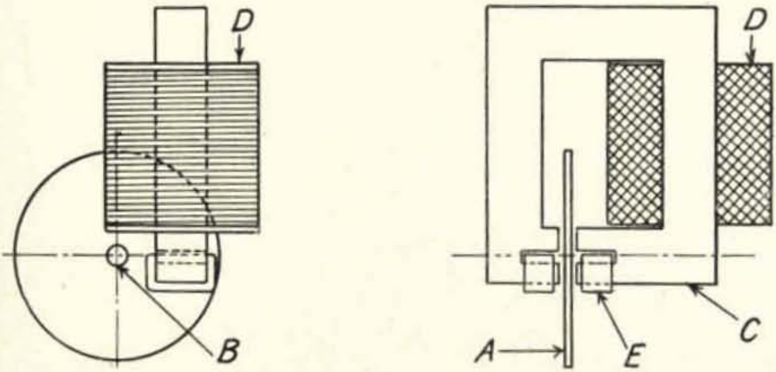


FIG. 75. SIMPLE FERRARIS TYPE INDUCTION MOTOR

is energized by alternating current, the armature being attracted by each pulsation of current, i.e. twice per cycle. Suitable switching mechanism is, of course, fitted so that winding takes place only when necessary, and stops as soon as the spring is fully wound. These vibrating mechanisms are apt to be noisy in use unless great care is taken in the design.

Coming to motors, a number of types is in use dependent on the size of the clock.

For the ordinary small domestic clock working from alternating current mains, the Ferraris type of induction motor is frequently used. In its simplest form, shown in Fig. 75, it consists of a disc of copper or aluminium $A$ pivoted at $B$, and mounted between the poles of an electro-magnet $C$ made of laminated iron and energized by the coil $D$, which is wound with a large number of turns of fine copper wire and connected

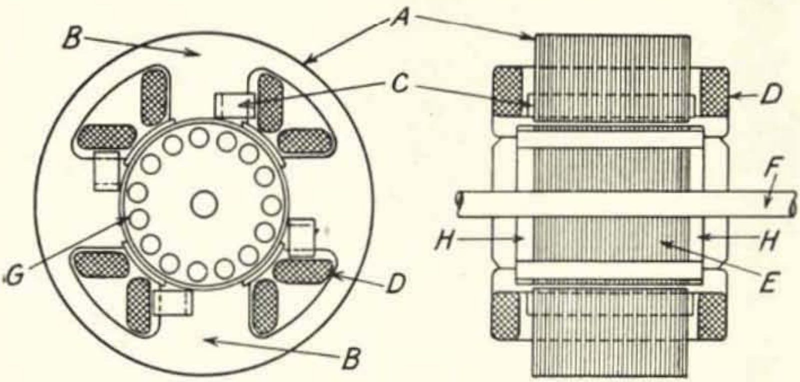


FIG. 76. SIMPLE SQUIRREL CAGE INDUCTION MOTOR

to the supply mains. The poles are slotted and one half of each is surrounded with a copper shading coil in order to make the motor self-starting.

The action is as follows. Magnetic lines of force pass across the air gap through the copper rotor and induce current in it, which in turn produces a rotor magnetic field. The magnetism in the shaded portion of the pole is an instant later in growing to the maximum than the unshaded half, so that as the magnetism in the unshaded half dies away, the magnetic pole in the rotor causes it to turn to the shaded portion. This happens with every cycle of current, so that continuous rotation ensues.

This type of motor has very small torque, and is little used except where only a small amount of power is required, as in the present instance.

The construction of the Ferraris type of motor is clearly illustrated in Figs. 81 and 82 (pages 113 and 114).

Larger clocks such as master regulators employing weights, often have a small squirrel cage induction motor, the construction of which is shown in Fig. 76.

*A* is a magnet built up of iron laminations, and provided with four internal poles *B*. Each pole has a shading coil *C* fitted over a portion of it, and a coil of wire *D* surrounding the centre pole. The rotor comprises a number of iron stampings

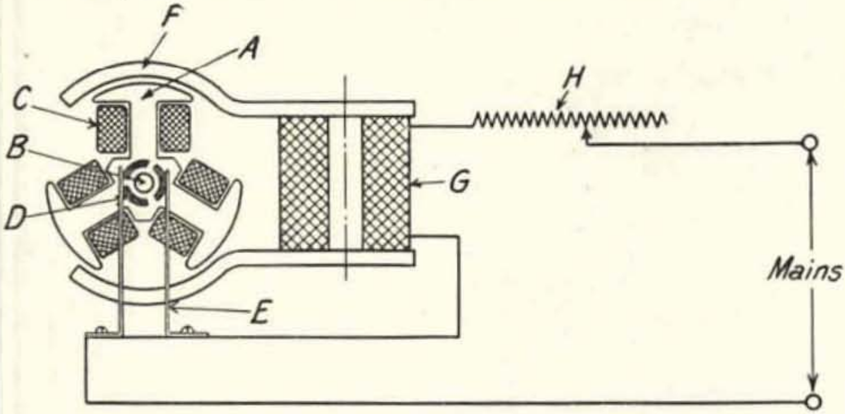


FIG. 77. SIMPLE TYPE OF D.C. WINDING MOTOR

*E* mounted on a shaft *F*. In the stampings are punched a series of holes and slots *G*, and these are fitted with rods of copper, the ends of which are soldered into copper end rings *H*. The coils are connected in series with each other across the mains so that the magnet poles are alternately north and south. The principle is similar to the Ferraris motor, the rotor taking the place of the copper disc.

This type of motor is used largely where small power is required, such as fans, phonograph motors, etc., but it is not made in large sizes owing to its inefficiency compared with some other types of motor. It is, of course, only suitable for alternating current. Small synchronous motors of the self-starting type are sometimes used for the winding of clocks.

As regards motors for direct current clocks, these are usually made of the simplest possible construction. Fig. 77 shows a motor of this nature.

*A* is the armature core built of iron laminations pressed on spindle *B*, and having three poles on each of which is wound a coil of wire *C*.

The ends of these coils are joined together, and their junctions joined to the three segments of the commutator *D*, upon which brushes *E* bear. In this class of motor these brushes are usually of silver or silver alloy. The armature revolves within the pole pieces *F*, which are magnetized by the coil *G*. The armature is connected in series with the field coil, and also in

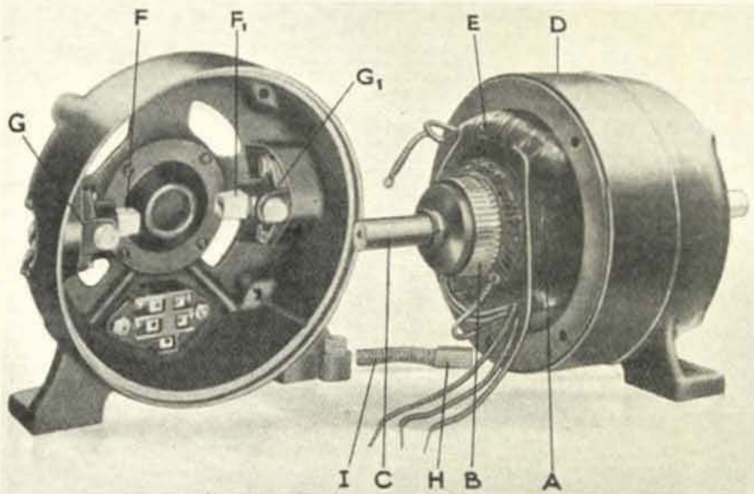


FIG. 78. PARTLY DISMANTLED DIRECT-CURRENT MOTOR
*(Crompton-Parkinson, Ltd.)*

series with the resistance *H*, the object of which is to reduce the voltage across the motor.

Small direct current motors for larger clocks are of more orthodox construction, and Fig. 78 illustrates the components of such a motor.

*A* is the armature and *B* the commutator both mounted on shaft *C*. The field magnet is integral with the casing *D*. *E* is one of the field coils. $F$, $F_1$ are the brush tubes insulated from the casing by the bakelite mouldings $G$, $G_1$, and *H* is one of the two carbon brushes which bear on the commutator under pressure of spring *I*.

For the winding of very large clocks and chimes standard D.C. or A.C. motors are used—usually of the compound type in the former case, and preferably of the repulsion-induction type in the latter. Both of these have the characteristics of starting up easily with the load on, but preserving an even running speed.

The simplest method of applying an electrical winding motor to an existing clock is shown in Fig. 79.

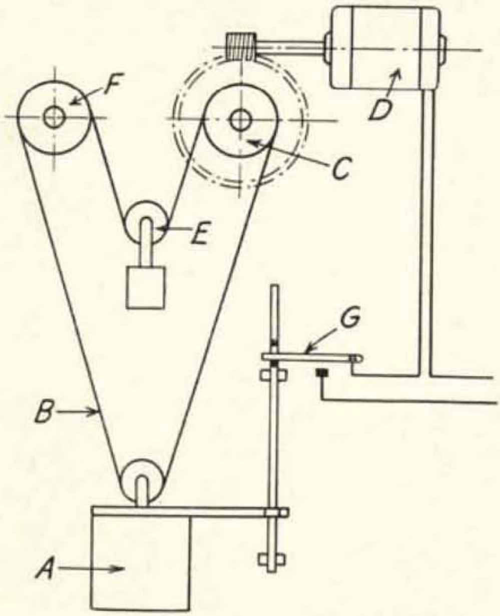


FIG. 79. SIMPLE ELECTRIC WINDING GEAR FOR TURRET CLOCK

This employs the principle of the Huyghens endless chain, which is often met with in 30-hour grandfather clocks.

*A* is the driving weight, *B* an endless chain which passes around sprocket wheel *C*, which is driven by the motor *D*. *E* is a jockey pulley to keep the chain taut, and *F* a sprocket wheel fitted to one of the wheels in the "going" train preferably the next, or next but one, to the 'scape wheel. The winding barrel and other wheels are, of course, dispensed with. A snap switch *G* is arranged so that the motor is switched on when the weight reaches the lower limit of its travel, and off when it reaches the top.

It is easily seen that when the motor rotates the weight will be drawn up and the jockey pulley will fall.

Meanwhile the pull of the driving weight remains on the driving sprocket. Sprocket *C* is prevented from turning back under the influence of the weight because of the worm drive between the motor and itself.

We will now see how the principles outlined in the foregoing are carried out in practice.

## Tangent Domestic Clocks

The Tangent self-winding clock was produced by Gent & Co. to meet the demand for a high-class clock electrically operated from the mains, but independent of changes of voltage and frequency, and capable of carrying on in the case of the supply being cut off for any reason.

In its essentials, the clock consists of a high-grade mechanical movement with a jewelled lever escapement and Breguet over coil hair spring. There are two springs—one the maintaining spring which normally remains fully wound, and comes into action only in the event of electricity supply failure, and is capable of driving the clock for nearly two hours. Supply interruptions are generally only of a short duration, and it is found in practice that the capacity of this spring is sufficient to meet all but the most exceptional emergencies. The driving spring is arranged to be wound by electro-magnetic means every minute.

The clocks are made in two sizes—wall clocks with 12 in. dials, and mantel clocks with 5 in. face diameter. For a given clock size, the same movement with different windings serves for either alternating or direct current supplies.

Fig. 80 shows the movement of one of these clocks with the escapement cover removed.

The action is as follows. *A* is the driving spring and slowly raises the driving lever *B* pivoted at *C*. The pawl *D* (attached to *B*) engages with the ratchet wheel *E*, to which the hand motion work is connected, and drives it slowly forward, its rate being controlled by the escapement *F* through suitable gearing not visible in the illustration. Behind the ratchet wheel, not shown, is the maintaining spring. The upward stroke of lever $B$ is arrested by its contact plate $G$ meeting the contact $H$ attached to the armature $I$ pivoted at $J$. This completes the circuit through the electro-magnetic coil $K$,

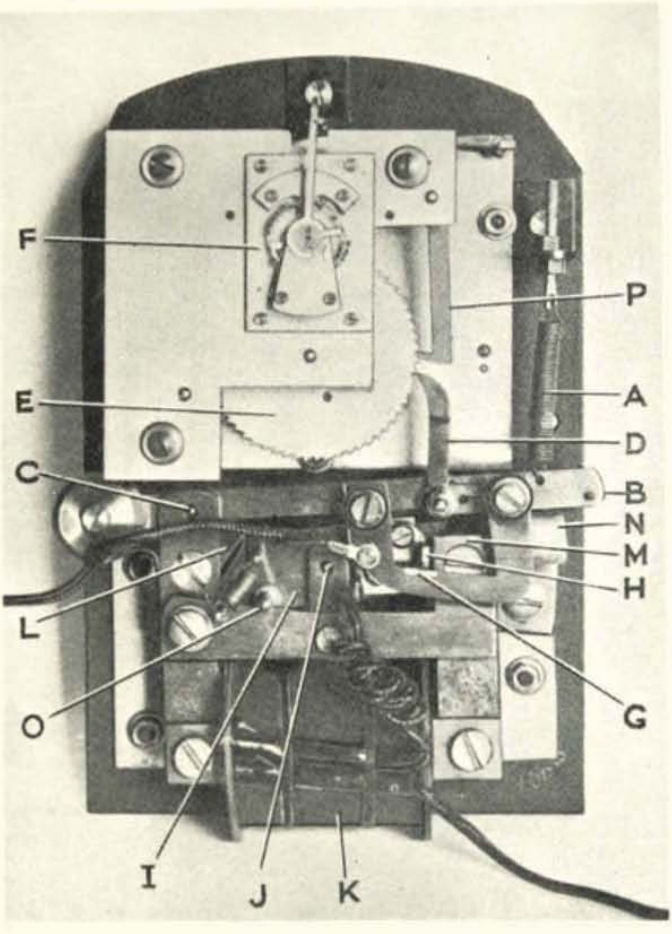


FIG. 80. "TANGENT" ELECTRICALLY-WOUND CLOCK MOVEMENT

as shown, and the armature is instantly drawn into line with the poles $L$ and $M$ of the electro-magnet.

The travel of the armature is limited by the stop $N$ made of felt, in order to minimize noise, but, owing to its momentum, lever *B* travels on, and so breaks the circuit at contacts *G* and *H*. The armature then returns to its resting position, its travel being limited by stop pin *O*. The cycle is then repeated and continues so long as the clock remains connected to the mains.

The stop *P* prevents the ratchet wheel from being drawn back. The magnet coil *K* is wound on a bakelite former with silk-covered wire, and is of such dimensions that any failure in the clock switching mechanism will not cause it to overheat and burn out. The possibility of such a breakdown is, of course, most remote, but such provision adds to the efficiency of the clock.

### Landis and Gyr Domestic Clocks

A range of electrically-wound domestic clocks is manufactured by Landis & Gyr, Ltd. Separate models are supplied for A.C. and D.C. working. The clock movement is substantially the same in each case, and consists of a high-grade spring-driven mechanism with a jewelled dead beat lever escapement. The latter is compensated for temperature error by the use of "Elinvar" metal. The spring is wound at intervals by means of a small electric motor—a Ferraris disc induction type in the alternating current models, and a simple form of commutator motor in those for direct current use.

This spring is capable of maintaining the clock for three days in the event of current failure.

The winding gear is so arranged that the spring can never be over wound nor completely unwound, so that even torque is preserved and with careful regulation the clocks can be relied upon to keep time within one minute a month or less.

The D.C. clock can be used on any voltage between 110 and 132 and 200 and 250 volts, and the A.C. model between 80 and 280 (50 to 60 cycles).

Fig. 81 shows a half-front view of the A.C. model, and Fig. 82 a rear view of same. Both are lettered to correspond, and the principal features are as follows.

*A* is the copper rotor of the winding motor, *B* the stator, *C* the coil, and *D* the copper shading coil to provide the starting torque. *E* is the terminal block. The plug supplied with the clock is attached to two of the pins according to the voltage of the electricity supply. *F* is the regulator which projects through the dial. *G* is the main spring, and *H*, *I*, and *J* are the two gears and the travelling weight respectively, which start and stop the ordinary motor, to be described later.

The coil of the A.C. clock is in circuit continuously, the

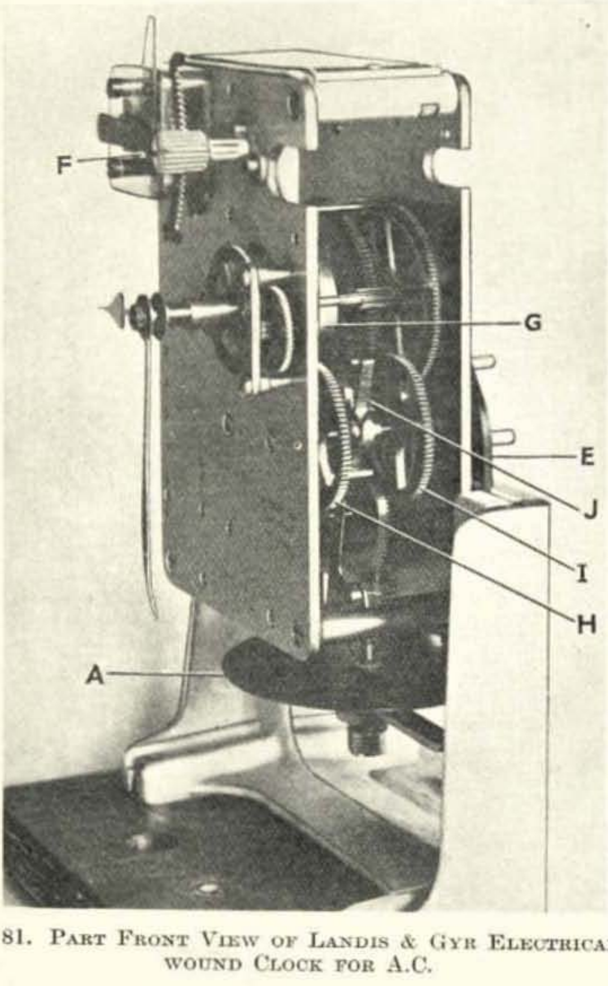


FIG. 81. PART FRONT VIEW OF LANDIS & GYR ELECTRICALLY-WOUND CLOCK FOR A.C.

winding motor being stopped by the application of a light brake to the rotor. The power consumption is exceedingly small, being approximately one watt, so that the cost of running is negligible. The current of the D.C. model is switched off when the spring is fully wound.

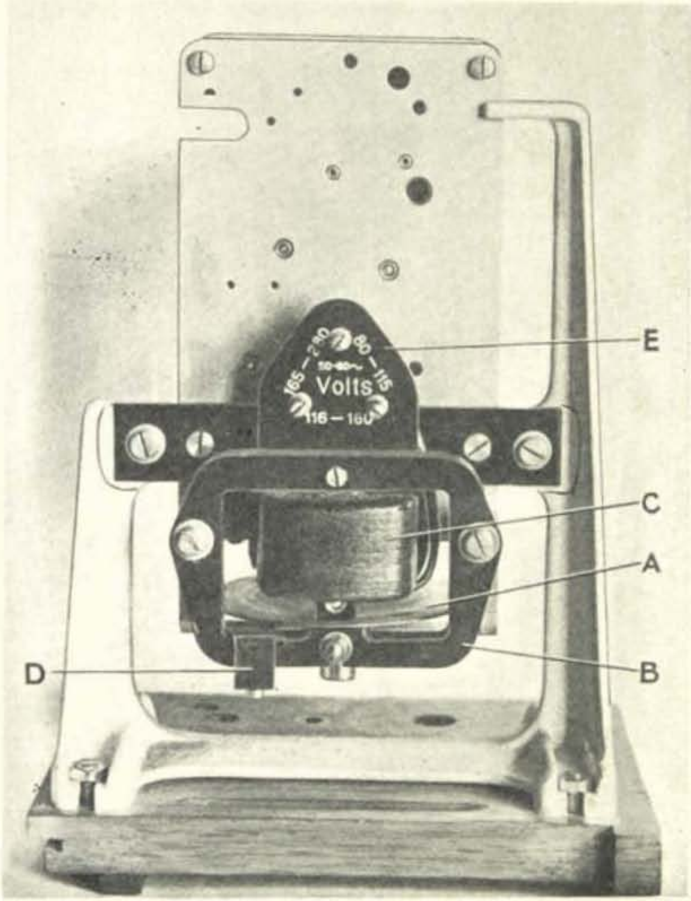


FIG. 82. REAR VIEW OF LANDIS & GYR ELECTRICALLY-WOUND A.C. CLOCK

Fig. 83 shows the automatic control. $A$ is the spindle having a screw thread $B$, $C$ is a gear wheel loosely mounted on $A$, and driven from the winding train of the clock—i.e. as the clock is wound $C$ rotates, and $D$ is a pin projecting from $C$. $E$ is another gear wheel, fixed to spindle $A$, and coupled to the hand-driving train of the clock so that it rotates as the spring unwinds. $F$ is a weight of the shape shown and $G$ a spring attached to it.

The action is as follows. During the winding, the wheel $C$ turns and pin $D$ comes into contact with weight $F$ rotating it on the screw thread and causing it to travel to the left. When it reaches the limit of its travel, made to correspond with the spring being fully wound, pin $H$ engages with a lever, not shown, which stops the winding motor as previously

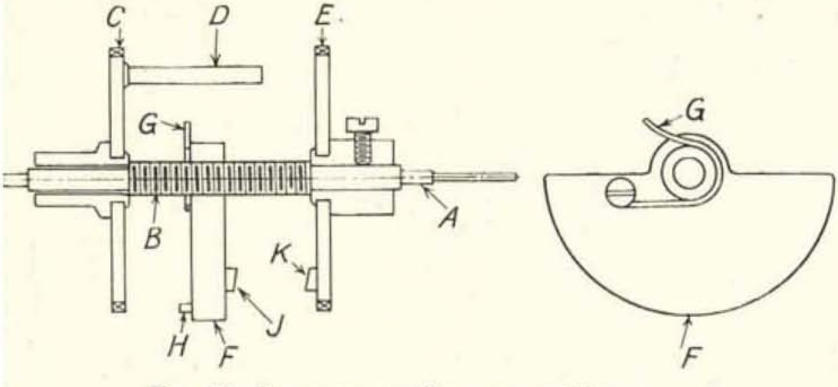


FIG. 83. PRINCIPLE OF CONTROL OF WINDING.
Landis & Gyr A.C. electrically-wound clock

described. Owing to the shape of the weight, it falls suddenly forward once per revolution, and so ensures a quick break of the switch. Spring $G$ acts as a buffer when it falls against pin $D$.

During unwinding, gear $F$, and with it spindle $A$, turns. Weight $F$ is prevented from rotating with it by its own weight and by pin $D$, so it is caused to travel along the thread to the right, eventually releasing the brake or switch and causing rewinding to start. A simple ratchet prevents the spring from driving the motor armature when the winding power is off. If the clock is allowed to run completely down, $F$ will move to the extreme right of the spindle $A$. To prevent it jamming against gear $E$, stops $J$ and $K$ are provided.

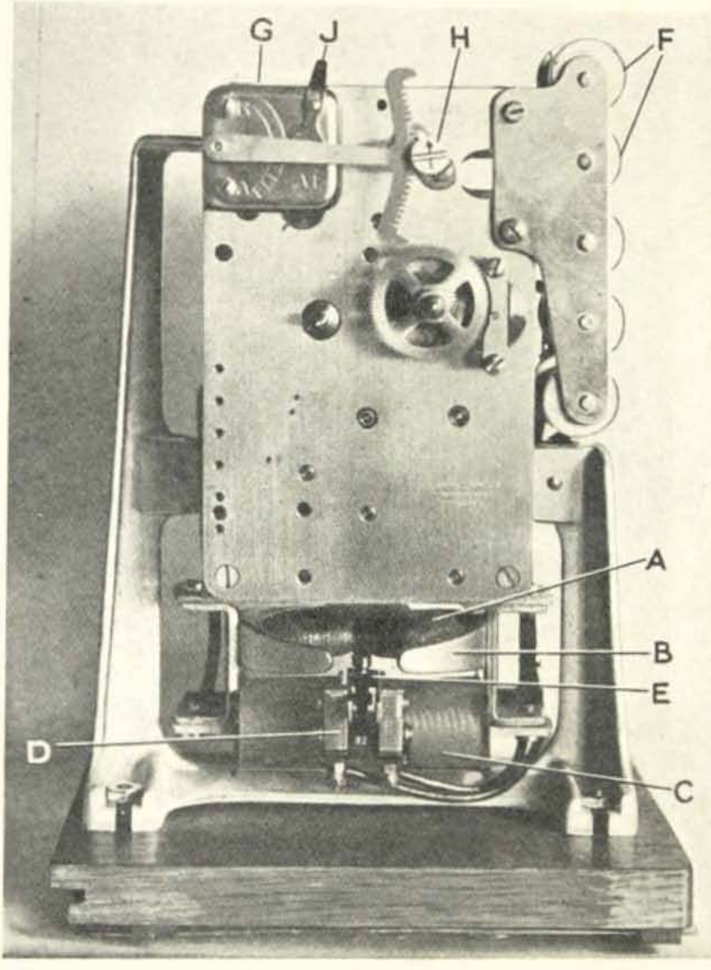


FIG. 84. FRONT VIEW OF LANDIS & GYR ELECTRICALLY-WOUND CLOCK FOR D.C.

Fig. 84 gives a front view of the direct current movement. *A* is the tripolar armature, *B* the pole shoes of sheet iron, *C* the field magnets, *D* the brush support pillars, and *E* the brushes and commutator. The bobbins *F* are resistances for the purpose of reducing the voltage across the motor armature. The escapement is contained in casing *G*, and regulation

FIG. 85. LANDIS & GYR ELECTRICALLY-WOUND CLOCK

of the clock is effected by rotating the knob *H*, which is arranged to project flush with the dial. The lever *K* locks the escapement in order to prevent damage to its delicate mechanism when the clock is moved about.

The clocks are manufactured in both wall and mantel patterns, and Fig. 85 shows one of the latter type. The small disc with the arrow and screw-driver slot seen above the centre of the hands is the regulator.

## Motor-car Clocks

A typical electrically-wound motor-car clock with cover removed is shown in Fig. 86, and is a product of English Watch and Clock Manufacturers, Ltd., Coventry.

The movement is spring-driven, controlled by a lever escapement, and will continue to run for about one and a half

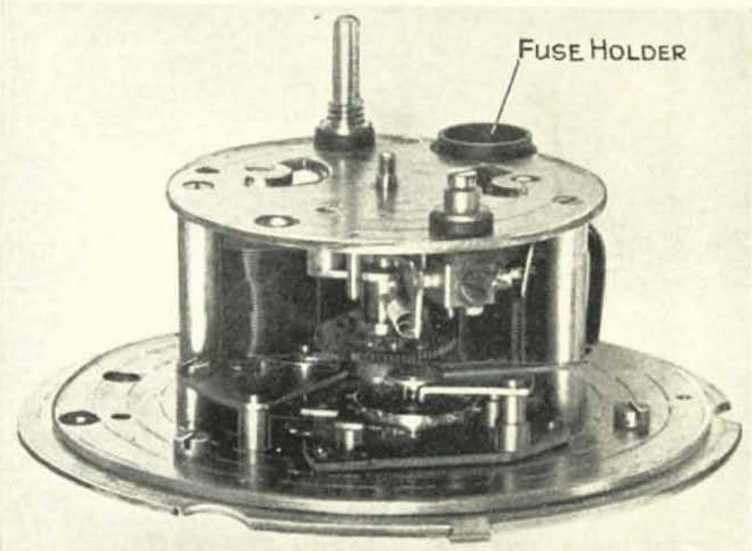


FIG. 86. EMPIRE MOTOR-CAR CLOCK, GENERAL VIEW

hours without the battery being connected, thus allowing minor repairs to the lighting system to be carried out.

The winding action of the clock may be followed by reference to the diagram Fig. 87.

$A$ $A_1$ are the coils of an electro-magnet having poles $B$ $B_1$. $C$ is an armature pivoted at $D$, $E$ is a spiral spring which is actually the main spring of the clock, $F$ is a fixed contact, and $G$ is a movable contact pivoted at $H$. On energizing the magnet coils, the armature $G$ is attracted into line with the poles, and in doing so spring $J$ which controls the movement of the contact $G$ passes over the pivotal centre, and so causes the contacts to rapidly separate, the arm of the movable contact coming to rest against stop *K*. The armature is then drawn back to its original position by spring *C*, and in so doing drives the clock through the medium of a ratchet and further spring, which provides the driving motion at the instant winding is taking place, and also when the battery is disconnected. When the spring has unwound a certain distance spring *J* again crosses the centre, closing the contacts and energizing the magnets, the cycle being repeated. The armature and contacts are clearly shown in the photograph Fig. 88.

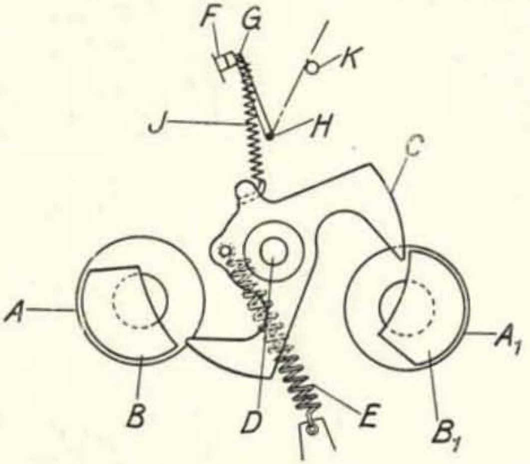


FIG. 87. WINDING ACTION OF "EMPIRE" MOTOR-CAR CLOCK

The periodicity of winding is normally every four to six minutes. Owing to the frequent winding, the main spring is kept in very even tension, resulting in good time-keeping.

A weakness which has been experienced in the past with motor-car electric clocks is that in the event of them stopping for any reason they would invariably do so with the contact points closed. In consequence the instrument would probably suffer damage due to overheating of the winding. This difficulty has been overcome in this clock by the provision of a fuse which comes into operation should the clock stop on contact.

## The Venner Time Switch

An excellent example of an electrically-wound clock as used for the operation of time switches for controlling the lighting of street lamps, shop windows, and the like, is provided by the Venner movement, a general view, with the casing removed, being shown in Fig. 89.

In its essentials, it consists of a high-class spring-driven clock movement which is arranged to be electrically-wound at intervals by an ingenious form of winding motor. The spring

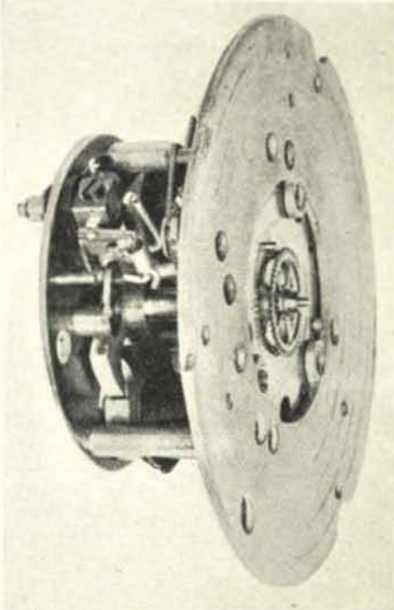

FIG. 88. EMPIRE MOTOR-CAR CLOCK, SHOWING ARMATURE AND CONTACTS

has a maintaining power of about three days in the event of supply failure.

All the gear wheels are made of brass, while the pinions and spindles are of stainless steel. The movement is mounted on a substantial brass framework, and fitted with a brass cover, sliding windows being provided to permit of adjustment being made without removing the cover.

Owing to the compactness of the whole unit, particularly the winding mechanism, it is somewhat difficult adequately to describe it in the space available.

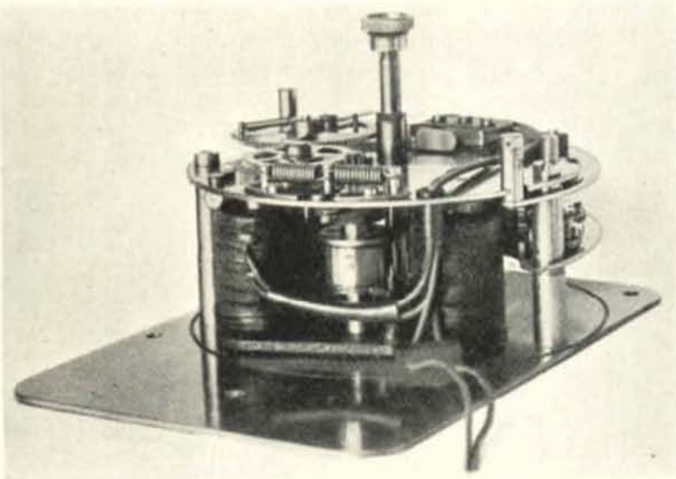

FIG. 89. GENERAL VIEW OF VENNER ELECTRIC TIME SWITCH

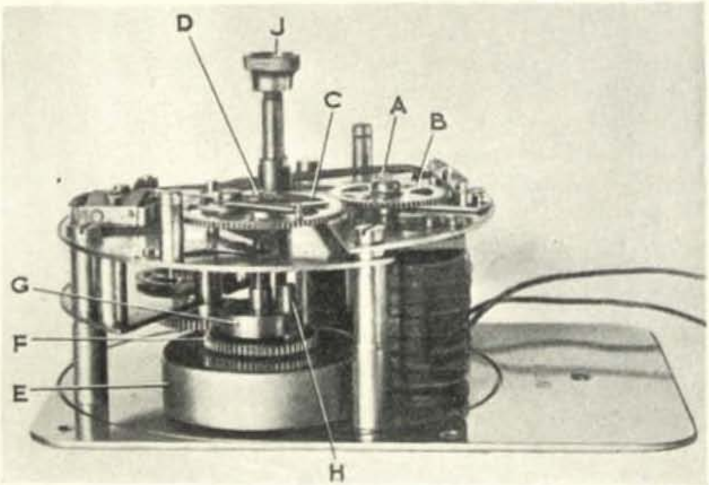


FIG. 90. VENNER TIME SWITCH

Referring to Fig. 90, $A$ is the output pinion of the winding motor whose construction will be described later. $B$ is an intermediate gear which transmits the motion to the wheel $C$ mounted on the spindle $D$ to which one end of the driving spring is attached. The other end of the driving spring is fastened to its housing $E$ on which is driving gear $F$. Thus gear $C$ rotates when the spring is being wound and gear $F$ when it unwinds. Spindle $D$ is threaded for a portion of its length, and has upon it a nut $G$ anchored by the pin $H$ fastened to gear $F$. The effect of this is that during winding, nut $G$ is caused to travel *up* the threaded portion, and during unwinding, because of the rotation of gear $F$, it is made to travel *down*.

When the motor is winding the nut reaches a point in its upward travel where it comes into contact with a small roller coupled to a quick make-and-break switch action. The effect of this is to stop the winding motor, and so the nut commences its slow downward travel, due to the unwinding of the spring. Immediately the nut passes beyond range of the roller the motor is switched on again and the cycle repeats itself.

The interval between the winds is approximately eight hours. Winding takes only a few seconds to accomplish so that the power consumption is infinitesimal. The driving gear $F$ is coupled to the driving spindle $J$ (which takes the place of the hands of this clock) by the usual train of gears, the rate being controlled by an escapement.

The winding motor is shown in Fig. 91, and comprises an electro-magnet having poles $A$, $A_1$ and coils $B$, $B_1$ energized from alternating current mains. $C$ is an armature mounted on the hollow spindle $D$, and is normally held a slight distance away from the magnet pole by tuning springs, which are so tensioned that the natural period of vibration of the armature and springs is that of the supply frequency. When the coils are energized, however, the armature vibrates rapidly owing to the reversals of the alternating current. Plate $F$ is mounted on the same spindle as the armature, and carries a clutch which engages with the inside of the drum $G$, integral with the winding spindle $A$ (Fig. 90) which passes through the centre of the spindle $D$. Plate $H$ carries another clutch also engaging with the drum $G$, and in addition is anchored at $J$.

The action is such that when the armature is attracted to the magnet poles, clutch $F$ grips the winding spindle and turns

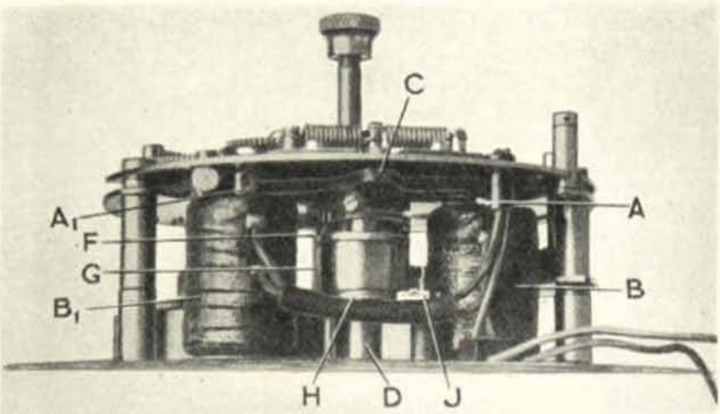


FIG. 91. VENNER TIME SWITCH
View showing winding motor

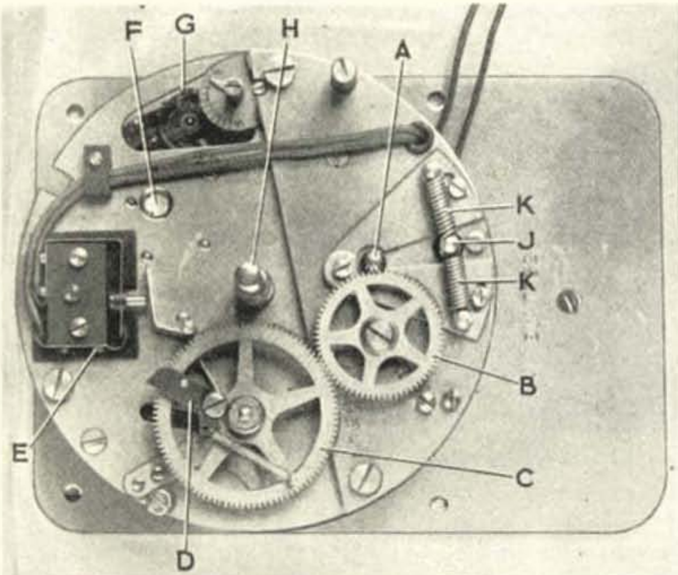


FIG. 92. VENNER TIME SWITCH
Top view

it forward. When the current impulse ceases, the armature returns to its original position by virtue of the springs, and clutch *H* comes into action to prevent the winding spindle turning back. Thus the vibrating motion of the armature is converted into a rotary one in a most efficient manner. When the motor is required for D.C. operation a suitable make-and-break is provided to give the necessary current impulse.

Fig. 92 gives a top view of the complete movement, and includes several details not shown in the other views.

*A* is the winding pinion, *B* the intermediate wheel, and *C* the winding gear. On this gear is mounted lever *D* which is part of the quick make-and-break mechanism. *E* is the switch, *F* a revolving graduated dial for setting the time of the clock, and *G* the escapement and regulator. *H* is the centre spindle to which the time switch mechanism is attached, *J* being a pin projecting from the vibrating magnet to which the tuning springs *K* are secured.

# CHAPTER VIII

## SYNCHRONIZED CLOCKS

### Introductory

UNDER the heading of synchronized clocks is included all those clocks, whether electrically or mechanically propelled, which are arranged to be corrected at intervals by signals transmitted from a source of standard time, generally represented in this country by Greenwich Observatory. Synchronization is usually carried out once or twice daily, so that however bad a time-keeper a clock may be, it cannot deviate very much from correct time.

Synchronized clocks are used only where it is essential that particularly accurate time be always maintained. The principal application is to public clocks and those of public service undertakings, but even here it is by no means common, for the accuracy of modern electric clock installations is such that only very occasional correction is necessary, and this can be readily done manually by checking against the Greenwich time signals of the B.B.C., thereby saving the expense of the synchronizing service.

The development of synchronized clocks is due in great measure to the fact that one of the conditions upon which clocks are permitted to be erected projecting over the public way in the City of London is that they shall be kept synchronized with Greenwich mean time by means of a wire from the Post Office "or other approved method."

Electrical synchronization is particularly applicable to mechanical clocks, as it enables an indifferent time-keeper to be transformed into a good one at little expense. A particular application of electrical synchronization is in connection with workmen's time recorders.

When electric clocks are installed in a factory, it is particularly necessary that the time recorders already in existence indicate the same time as the general clocks. It is not, however, generally possible, on economic grounds, to do away with the mechanical movement of these clocks and substitute an electrical one. The method generally adopted is to retain the clocks in their entirety, but control the swing of their pendulums by means of the half-minute impulses of the factory time circuit, so that their indications are similar to all the other clocks.

It is, of course, necessary to continue with the weekly winding of these synchronized mechanical clocks.

As is well known, the time standard so far as this country is concerned is Greenwich mean time, and this is available for the synchronization and checking of clocks in four ways, namely—

1. By wire from the G.P.O.
2. By radio from the B.B.C. stations.
3. By radio from the G.P.O. Rugby station.
4. In London only, from the mains of the Standard Time Company which was established in 1877 for the purpose of disseminating time signals.

There are two broad systems of synchronization in use both applicable to either electric or mechanical clocks, viz. forcible and gradual.

There are two kinds of forcible correction: (1) in which the reception of the time signal causes the minute hand to be quickly drawn to the zero position, and (2) in which the hand is made to reach the zero position before the arrival of the signal, the movement being then held up until its reception, when the clock is restarted.

Gradual correction, as its name implies, consists of the addition or subtraction of a small weight to or from the pendulum according to whether the clock is fast or slow when the signal is received, thus altering the effective length and time of swing of the pendulum.

Before passing to a consideration of the various time services and synchronizing systems, we will briefly consider the arrangements by which time is obtained and distributed from Greenwich Observatory.

## Greenwich Time

Time is determined with reference to the rotation of the earth. The fundamental unit is the sideral day—this being the time taken for the earth to make a complete revolution, or the time which elapses between the instant when a star is due south at a place, and the instant when that star is next due south at the same place. The sideral day is, therefore, the day as determined by observation of the stars. There are $366\frac{1}{4}$ sideral days in a year.

The solar day is taken from observation of the sun, and represents the length of time between two successive "southings" of the sun. There are $365\frac{1}{4}$ solar days in a year, i.e. one less than the number of sideral days, the difference of one day being due to earth's motion round the sun causing the sun to appear to make one revolution round the earth from west to east. As life in general is regulated by the sun and not by the stars, the solar day is taken as the basis of our system of time recording.

The length of the solar day is not uniform throughout the year for two reasons.

1. The speed of the earth round the sun is not constant, thus the time taken for the sun to appear due south on successive days varies. 2. The axis of the earth is inclined to the plane of its orbit, so that the sun does not appear to follow a path immediately above the earth's equator, but it is north of it from April to September, and south the remainder of the year.

Thus the average length of a solar day is taken as the unit of time, and is called Mean Solar Time, or Greenwich Mean Time if the observatory in question happens to be Greenwich.

Time observations are made by noting the exact time at which a star crosses a given point in the heavens—an electric signal being automatically transmitted as this occurs, which causes a mark to be made on a slowly moving chart. Observations are being constantly made so that the exact time at any instant can be readily determined. Means are also provided by which the beats of the observatory clocks are recorded, so that they can be accurately compared with the star time, and correction made if necessary.

It is, of course, desirable that the clocks used be absolutely constant, and it is noteworthy that at Greenwich and most of the principal observatories of the world these are electric—being a special form of the Synchronome clock, described in Chapter IV, designed by Mr. W. H. Shortt.

An observatory clock of this type is shown in Fig. 26 (page

43), and space will only permit of a brief description of its construction and working here. It is of the free pendulum type impelled by the fall of the gravity arm reset by a Synchronome "Remontoire."

The release of this arm is effected by an adjacent "slave clock" which is kept in exact synchronization with the free pendulum. The impulses to the indicating dials are also dispatched by this slave clock, and the free pendulum has nothing to do but swing to keep time. The pendulum is of Invar, and the whole of the mechanism is enclosed in an air-tight case—a copper cylinder with a glass bell cover—and exhausted of air to a pressure of 35 mm. or less.

The performance of these clocks is remarkable, and they can be relied upon to keep time to within a second in a year. Their accuracy is such that with their aid it may be possible to carry out further research on various astronomical problems—the clock being considered as the constant quality, and the stars or other bodies the variable ones—a reversal of previous practice.

There are three Shortt clocks at Greenwich Observatory, two used for determining sideral time, and one measuring mean time, for transmitting the six dot seconds by wireless, and the Rugby rhythmic time signals.

The mean time clock is checked with reference to the sideral clocks which, as explained above, are constantly checked by stellar observations. It may be mentioned here that the actual time indicated by the sideral clocks is immaterial so long as their rate of gain or loss is known, because the actual time at a given instant can be readily determined. The mean time clocks, however, must be correct to time, and thus means of adjustment are provided, and the clocks checked before the dispatch of any important signal.

The mean time clock at Greenwich controls several electrical circuits. A signal is sent once an hour to the Central Telegraph Office of the G.P.O., where it is distributed as required, and to the central station of the Standard Time Company. Another line is connected to the British Broadcasting Corporation, to which the last six seconds in every quarter of an hour are transmitted. These signals are, of course, only broadcast at certain times.

The signals for broadcast from the Rugby station of the

G.P.O. are transmitted from a separate pendulum, length of beat of which is $\frac{60}{61}$ of a second.

The Rugby signals are intended for the checking of ships' chronometers, and are also used by surveyors and explorers in the determination of longitude. A fractional beat facilitates this work; the radio beats periodically coming into step with those of the chronometer or clock being checked. By noting the time shown by the chronometer and the number of the dot at which coincidence occurs, it is possible by easy calculation or by reference to tables, to ascertain the error of the chronometer, to an accuracy of $\frac{1}{61}$ of a second.

At present Greenwich mean time is only available at certain hours by the various services mentioned, but it is hoped the time is not far off when a special wireless station will broadcast the beats of the Greenwich clock continuously day and night.

### The Post Office Time Service

Two services of time signals for the synchronization of clocks are available by wire from the Post Office as follows. (*a*) Greenwich mean time signal transmitted at 9.0 a.m. and 1.0 p.m. daily. This consists of a "dot" one second in length, sent by Greenwich Observatory exactly at the hour, and is available to subscribers in London and the provinces. (*b*) A similar service transmitted hourly from the Central Telegraph Office chronopher, and available in London only.

The difference between the G.M.T. services and the hourly service is that the former is transmitted direct from the observatory, whereas the latter is transmitted by the local Post Office master clock which is automatically synchronized with Greenwich daily. The signal transmitted by the hourly service cannot, therefore, be regarded as absolute Greenwich mean time or correct to a fraction of a second, but the subscribers' clock would be correct to a small fraction of a minute, which is generally all that is required. Where a greater accuracy is demanded the Greenwich mean time service must be taken. In this case synchronizing apparatus is more complicated on account of the brief nature of the signal.

Subscribers to the Post Office time service are required to provide their own synchronizing gear, which must be approved by the Engineer-in-Chief, and provision must also be made for the line to be earthed except for the short period preceding and following the time at which the signal is received. The line coil of the receiving relay or other apparatus must have a resistance of not less than 200 ohms.

The Post Office time service is generally the most convenient method of synchronization, particularly in the provinces, where it is the only "wired" system of synchronization available, but the rental charge for the use of the lines, etc., renders it fairly expensive to use.

### The B.B.C. Time Service

As has already been mentioned the British Broadcasting Corporation time signal consists of six dot seconds, the last of which marks the exact quarter hour. The times of transmission of this signal, which takes place several times daily, are not definitely fixed, and the reader is referred to the current issue of the *Radio Times* for up-to-date information on this point. The chimes of Big Ben and other public clocks are also broadcast at irregular intervals.

The synchronization or correction of clocks by hand from the broadcast time signal is, of course, quite straightforward. All one has to do is either to bring the minute hands to zero as the signal is received, or bring it to zero previous to the time, stop the clock, and restart as the last dot is received, as is the more convenient. The simplest method of correcting or checking a number of domestic or other clocks from one time signal is to use a stop watch, setting this going as the sixth dot is received. The various clocks can then be visited in turn, the time shown by the watch being added to the actual time of the signal. Thus if a signal is received at 6.30, the first clock can be set at 6.31, the second at 6.32, and so on.

To be of any use, however, particularly if the clock which it is desired to synchronize is inherently a good time-keeper, the synchronization must be automatic, and here the utilization of the B.B.C. signals presents some difficulty for two reasons, viz. (1) the times of transmission are not definitely fixed, and thus there is always the risk that the programmes may be re-arranged, and any synchronizing gear rendered useless. (2) The signals are often broadcast on top of another transmission, and are then useless for the working of any apparatus.

Thus the use of these radio signals for automatic corrections of clocks cannot become a practical proposition until their form and time of radiation are definitely fixed once and for all, and arrangements made that at least one of them shall be given free from any other transmission. A suitable interval of quiet must also be allowed before and after the reception of the time signals to enable the requisite radio receiver to be automatically switched on by the clock.

Considerable research on the automatic synchronization of clocks by wireless has been carried out, particularly by the late Mr. A. E. Ball, a full account of whose work has been published in the *Horological Journal*, to which the reader is referred for details.

Briefly the apparatus required for synchronization from the B.B.C. signals comprises—

1. A switch controlled by the clock to switch on the radio set a short time before the time of the signal and switch off on completion.
2. A radio set capable of giving strong signals.
3. A sensitive relay used in place of the loud speaker, connected to other relays to give the necessary current for synchronizing.
4. A selector switch so that only the sixth dot is utilized.
5. The necessary apparatus for synchronizing the clock. This depends largely on the form of correction, and upon the type and make of the clock.

Steps must also be taken to ensure that the mechanism is not thrown out of gear by the reception of a false signal.

### The Rugby International Time Signals (Radio)

This time service was established in 1927, and constitutes the highest grade of time distribution. It is mainly intended for the determination of longitude and the setting of ships' chronometers. Signals are broadcast at 10 a.m. and 6 p.m. (Greenwich mean solar time) on a wavelength of 18,750 metres. The signal consists of a series of dots 0·1 second in length, lasting from 9.55 to 10 a.m., and from 5.55 to 6 p.m. The intervals between the beginnings of the dots are $\frac{60}{61}$ seconds in length. The commencing signal, and also that at the end of each exact minute is sent in the form of a dash 0·4 seconds in length.

Great care is taken in the accuracy of these signals, and the time elapsing between the dispatch of each signal from Greenwich and that of its reception there by radio is recorded and accurately measured. The monthly mean error is about ·03 second. These signals have the advantage over the B.B.C. signals in that they are free from the liability of speech interference, but there is more likelihood of stray Morse signals being picked up which might upset the whole synchronizing mechanism. Also, owing to their complex nature, the Rugby signals are somewhat difficult to adapt for automatic synchronization of clocks.

### The Standard Time Company's Service

The Standard Time Company was formed in 1877 for the purpose of transmitting time signals in London.

Time signals are received hourly day and night from Greenwich Observatory, and are relayed automatically from the Company's headquarters at Queen Victoria Street, over more than twenty lines radiating in all directions, covering the greater part of London.

Signals are of two seconds duration, starting at the 60th second of the 60th minute of each hour, and lasting until two seconds after the hour. The current strength is about ·4 of an ampere. Besides many hundreds of mechanical and electric clocks the circuit includes bells, needles, time balls, and other indicating devices.

### Methods of Forcible Correction

Since the invention of the electric telegraph, many systems have been evolved for the purpose of forcibly bringing the hands of clocks to zero on the transmission of a suitable signal.

One of the earliest inventions is that by Alexander Bain in 1843, the principle of which is shown in Fig. 93.

*A* is a pin projecting from behind the minute hand *B*, which is only lightly spring tight on its arbor. *C* is a vee piece fixed to the armature of an electro-magnet, and normally resting in the lower position. On the reception of the synchronizing signal, the magnet raises the vee piece to the upper position, shown by the full lines, and in doing so catches the pin in the hand, and draws it to the centre of the vee which corresponds to the hour position.

Another early system is that of Lund, shown in Fig. 94.

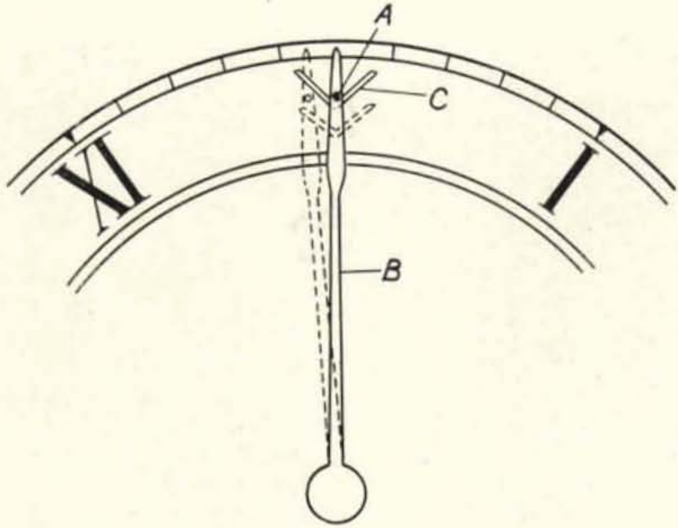


FIG. 93. BAIN'S SYNCHRONIZING SYSTEM (1843)

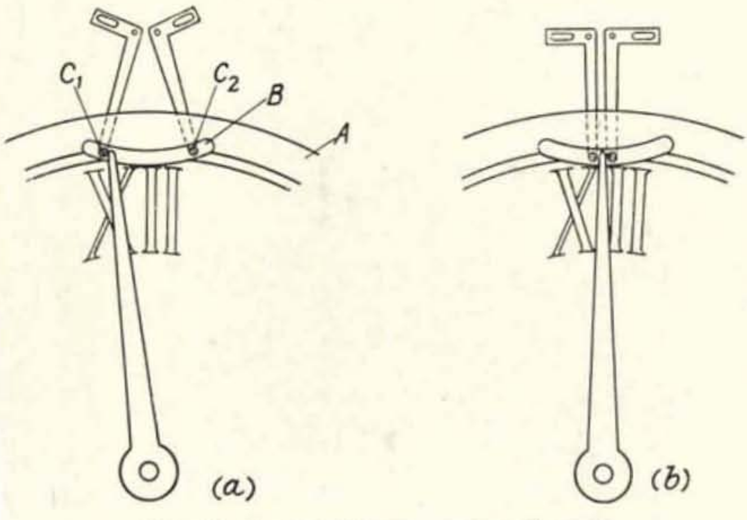


FIG. 94. LUND'S SYNCHRONIZING SYSTEM

In the dial $A$ is a slot $B$ through which projects two pins $C_1$ $C_2$ each mounted on a lever and connected by a link motion to the armature of an electro-magnet (not shown) in such a manner that the movement of the armature due to the reception of the time signal causes the pins to be drawn together, as shown in illustration (*b*). Should the long hand be late, it is drawn forward by pin $C_1$, and if it is in advance of the zero position it is brought back by pin $C_2$.

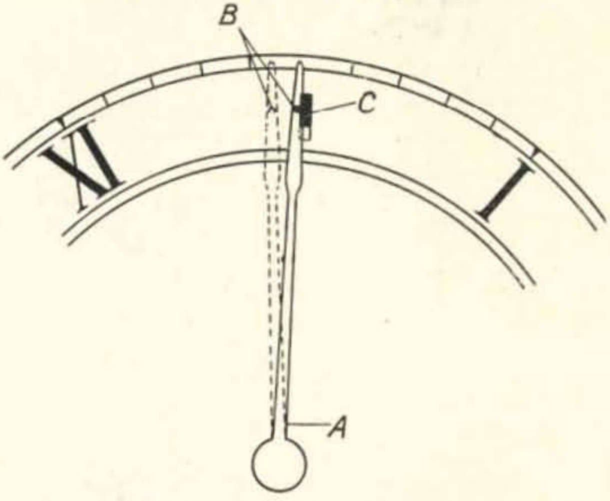


FIG. 95. RITCHIE'S EARLY SYNCHRONIZER

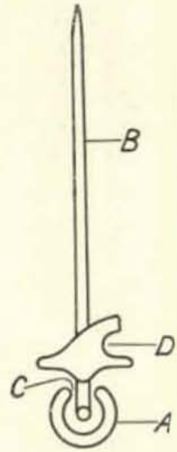


FIG. 96. STANDARD TIME CO'S SYNCHRONIZING SYSTEM

This system is sometimes known as the "finger and thumb" method—a very apt description.

Yet another early system is that of Ritchie, illustrated in Fig. 95.

$A$ is the minute hand, $B$ a pin fixed to it, $C$ a block projecting from the dial, and arranged to be drawn downwards by an electro-magnet. The forward motion of the minute hand is arrested by the pin engaging with the block when in its normal or upper position. The clock is arranged to gain slightly, and the hand is stopped at zero until the reception of the signal whence it starts exactly at the hour.

This system has two disadvantages: (1) no provision is made or correction of a possible loss, (2) if the signal fails to arrive ,t the hour, the clock is stopped. The system of synchroniza-ion adopted by the Standard Time Company is a modification f the Bains "V" method, as will be seen from Fig. 96.

*A* is a tube to which the minute hand *B* is fixed, and having

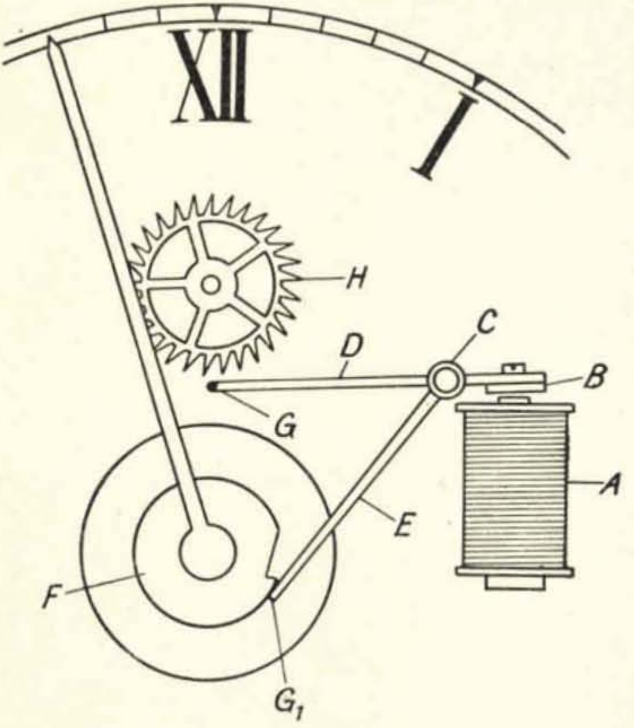


FIG. 97. RITCHIE'S IMPROVED SYSTEM

ı open side *C*. *D* is an extension of the armature of an electro-agnet, which when the magnet is energized is drawn down to engagement with the opening in the tube, and so compels e minute hand to assume a vertical position.

Fig. 97 shows an improved system of synchronization due Ritchie of Edinburgh.

The clock to be operated on is caused to gain slightly—the ıount being immaterial, and can vary from 1 second to 40 minutes per week. The minute hand will, therefore, arrive at the hour more or less too early, and the aim is then to arrest its progress until the arrival of the synchronizing signal. The electro-magnet *A* is excited 15 seconds before each hour by a master clock, and attracts armature *B* pivoted at *C* to which are attached levers *D* and *E*. *F* is a disc mounted on the minute hand spindle, and prevents the stop *G* engaging with the 'scape wheel *H* until the minute hand arrives at the 60th division of the dial when a notch in the periphery of the disc *F* corresponding to that division, allows the lever *E* to pass, and along with it the other arm *D*. The 'scape wheel remains stationary until the cessation of the current at the exact hour whence the magnet ceases to attract, the levers drop back to their normal position, and the clock restarts.

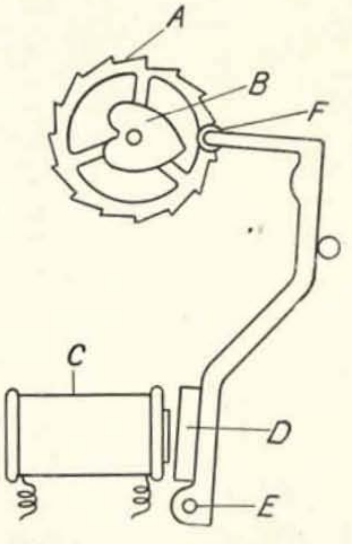

FIG. 98. HEART-SHAPED CAM SYNCHRONIZER

The advantages claimed for this system are its simplicity, small current required for operation, the hand need not fit loosely in its arbor, and failure of the synchronizing current will not stop the clock.

One other method of forcible correction requires mention. It is particularly applicable to the count wheels of electric impulse transmitters, and is shown in Fig. 98.

*A* is the usual 15-tooth wheel of the impulse transmitter, and *B* a heart-shaped cam mounted on the same spindle. *C* is an electro-magnet connected to the time signal circuit. *D* is an armature pivoted at *E* and having at its other extremity a roller *F*. When the signal is received the roller makes contact with the cam, and turns it either forward or backward according as to whether the clock is slow or fast, until the roller rests in the vee of the heart.

The driving and back stop pawls are, of course, automatically disconnected from the count wheel during this operation to enable the wheel to turn as required. This mechanism is not shown in the illustration.

The disadvantages of all methods of forcible correction is that no attempt is made to apply a permanent correction. For example, a clock which has a regular loss of one minute daily will need to have this made up every day until the regulation is improved.

The systems of gradual correction now to be described aim at keeping the time-keeping correct within fine limits by automatic regulation of the swing of the pendulum.

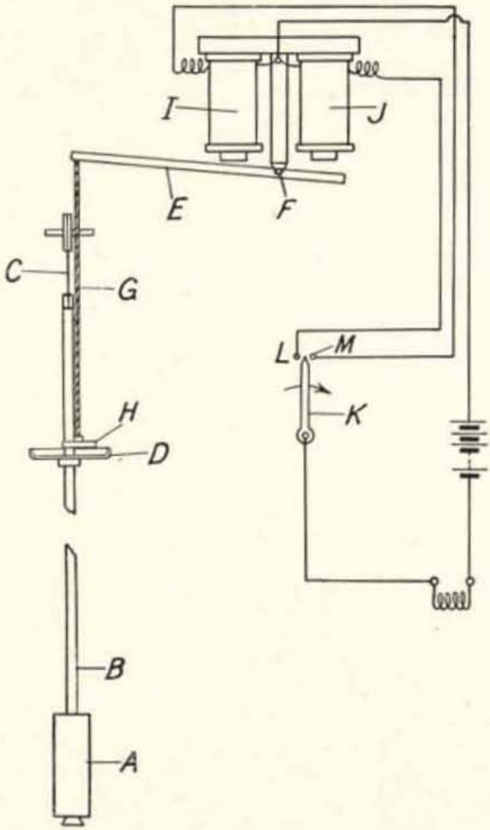

FIG. 99. SEE-SAW METHOD OF GRADUAL CORRECTION

## Methods of Gradual Correction

The basic principle of all methods of gradual correction of clocks is to add a small weight above the pendulum, thereby shortening its effective length, if the clock is slow when the synchronizing signal is received, and to take it away if the clock is "fast." The pendulum is normally regulated so that it loses slightly in the twenty-four hours without the auxiliary weight.

Fig. 99 shows how this is accomplished. *A* is the pendulum bob, *B* the pendulum rod suspended at *C*. *D* is a tray for weights fixed to the pendulum rod. *E* is an iron armature pivoted at *F*, and joined to its end is a silk cord *G* supporting a weight *H*. *I* and *J* are electro-magnets such that when *I* is energized the weight is lifted off the pendulum, and when *J* is energized it is dropped on to the tray. *K* is an arm fitted to the minute hand of one of the secondary dials in such a manner that it engages with contact *L* if the clock is slow, and with contact *M* if fast, thereby energizing the appropriate magnet.

In addition to the fast and slow contacts shown, an additional contact is fitted so that the contact can only become effective for the minute preceding and following the time of the Observatory signal, thereby preventing any stray signals from interfering with the control. Any false currents which may come during the two minutes when the control circuit is effective can only delay the operation of the correcting control for that day.

## Workmen's Time Recorders

An important application of synchronization is in connection with the electrical operation of Time Recorders, as used in factories to record the time at which employees start and cease work, etc.

It is particularly necessary that these clocks correspond with the general factory time, but there are several considerations against replacing the mechanical movement with which they are usually fitted with an electric drive.

1. The recorders incorporate considerably more mechanism than an ordinary clock, and interference with the movement is not liked either by the maker of the instrument or by the owner.

2. More driving power is required than with an ordinary clock, and this is a somewhat variable factor, as the type or mechanism may become stiff or clogged from time to time.

3. Any stoppage of the recording clocks due to breakdown of the electric clock circuit would seriously upset the system of costing and payment of wages.

For these reasons the time recorders are usually left as independent units, wound weekly, and a scheme of synchronization applied to keep them in step with the general clocks. In this case the synchronizing signals comprise the half-minute impulses of the time circuit instead of a signal from an outside source, as in the systems previously mentioned.

In one method of synchronizing, the pendulum of the clockwork is removed, and an electric escapement fitted which, operated every half-minute from the time circuit, allows the clock train to run on in half-minute intervals. This method does not fulfil the conditions (1) and (2) above, but is used to some extent, and is, therefore, worthy of mention. In the case of some types of recorder it is the only possible system.

A popular and interesting method of time recorder synchronization which reduces interference to a minimum is the "Reflex" system of Gent & Co. of Leicester, now to be described.

The Reflex control apparatus consists of two main parts,

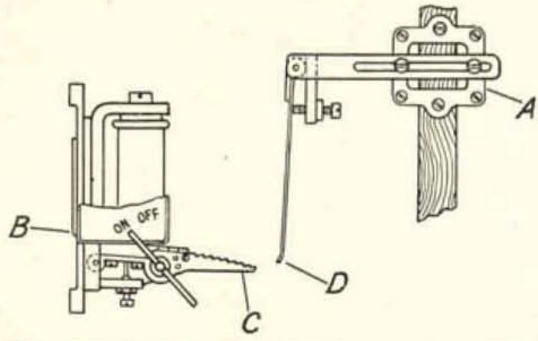


FIG. 100. GENT'S "REFLEX" SYSTEM OF TIME RECORDER CONTROL

(1) the vibrator, $D$ and $A$, Fig. 100, which is merely clipped to the pendulum rod, and (2) the stator $B$ and $C$ in the figure, which is screwed to the woodwork or body of the recorder. The clock is given a losing rate of two to two and a half minutes a day, and the pendulum must be such that it swings an even number of beats per minute. Thus, supposing the pendulum seen in the figure beats 88 per minute, at every half-minute it will be performing its 44th swing, and being slow will yet be swinging to the left when the rack $C$ is lifted by a half-minute impulse of the time circuit passing through an electromagnet on stator $B$. The free end of the vibrator $D$ will engage one of the teeth of the rack, sustaining the latter by its pressure to the left. The spring is deflected, which action terminates that particular beat sooner, and moreover, the

spring in giving back the energy stored in it, sends the pendulum to the right more quickly, thus removing its loss. The Reflex action will control a losing rate up to 5 or 6 minutes a day.

The on and off switch shown is necessary because the rate of the pendulum will have been altered by the addition of the vibrator, and also the clock must be given a definite losing rate by screwing down the rating nut, before the apparatus will operate satisfactorily.

When the clock shows itself to be regularly losing two to

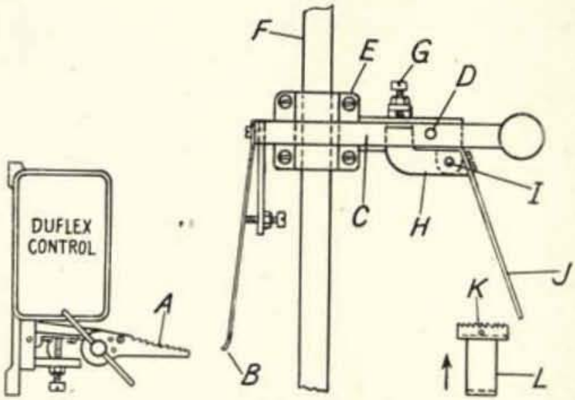


FIG. 101. GENT'S "DUFLEX" CONTROL

four minutes in twenty-four hours, the Reflex switch can be turned to the "on" position.

## Synchronization of Mechanical Turret Clocks

The Reflex system can be applied to synchronize an existing mechanical turret clock with an impulse time circuit, but as it stands it is not entirely suitable for this purpose, because a definite losing rate is demanded. If for any reason the clock control circuit is broken and not repaired immediately, the loss quickly accumulates, and, further, the Reflex system is incapable of dealing with a gaining clock. To overcome these difficulties, the "Duflex" system has been devised for turret clock control.

In this case the pendulum is regulated to keep its best time, and as long as there is no error, no controlling action takes place. If the pendulum tends to lose it is speeded up, and if fast is retarded. The action is best understood by reference to Fig. 101.

When the pendulum is found to be late by the half-minute time impulse, the vibrator spring *B* will be moving to the left over the rack *A* which will be lifting, and one of its teeth will engage with the point of the vibrator spring so terminating the stroke early and giving the pendulum an impulse to the right, in the manner already described for the Reflex system. If the pendulum is correct as the impulse is received it will be at the end of its swing to the left and momentarily stationary. The rising rack will then touch it and recede without giving it an impulse.

If the pendulum is fast, it will be travelling to the right, and the rising rack *A* will lift spring *B* which is attached to bar *C* pivotally mounted at *D* upon bracket *E* fixed to the pendulum rod *F*. This lifts screw *G* of bracket *H* also mounted on bar *C*, pivoted at *I*, causing the blade *J* to rotate clockwise, and engage with the teeth *K* of rack *L*. This rack is depressed against the pressure of a spring or weight, giving the pendulum work to do before it reaches zero, and consequently slowing it. When the pendulum passes zero the rack rises, and provides an impulse after zero, the tendency of which is also to slow the pendulum. On the return swing these motions are repeated, and the four slowing actions continue as long as the pendulum remains fast. Normally, of course, the actions take place at infrequent intervals, but a clock can be controlled by this means.

## CHAPTER IX

### TURRET CLOCKS AND CHIMING GEARS

Practically all electric clock installations of any size incorporate one or more public, or turret clocks as they are generally called, and these usually present a certain amount of difficulty owing to the various exacting conditions which have to be met.

In the first place the dials and hands are very much larger than any indoor clock—the largest yet made has a 26 ft. diameter dial and a minute hand 15 ft. 6 in. long—so that considerable driving power is required. Further, it is generally impracticable to put a glass cover on the dial of an outside clock owing to the reflection of the sun's rays, and consequently the hands are exposed to, and must work in face of, all climatic conditions. The clock must go on, and keep time, in the fiercest gale or when the hands are carrying a load of snow.

It goes without saying that public clocks must be first-class time-keepers. In the City of London, as mentioned in the previous chapter, one of the conditions upon which clocks are permitted to be erected projecting over the public way is that the same shall be kept synchronized with Greenwich mean time by means of a wire from the Post Office or other approved method, and a company exists which supplies time signals for this purpose.

More often than not, in addition to indicating time, turret clocks are required to strike the hours and chime the quarters, this being, of course, done electrically in the case of electric clocks, but it entails more or less complicated motor-driven gear as the ordinary electrical time impulses are quite unsuited to work of this nature. Where it is desired to preserve the architectural features of a building, the striking and chiming may be relied upon to give the time and no dials are provided.

It is standard practice to illuminate the dials of modern public clocks, so that they tell time by night as well as by day. The usual method is to form the dial of white opal class mounted on an open framework, and illuminate it from behind, the hands and the figures then standing out boldly in black. A modern tendency is to illuminate the hands and figures themselves. The even illumination of the old-fashioned weight-driven striking and chiming gear was often difficult by reason of the cumbersome machinery installed in the clock chamber. Electrically-driven clocks have a decided advantage in this respect, as their driving unit is comparatively small.

In this connection it may be mentioned that clock rooms are often small, and considerable ingenuity has to be exercised in installing and erecting. A large room is, of course, preferable as not only does it permit of adequate space for the lay-out, but maintenance is made much easier, and not so liable to be neglected as is often the case where "the works" are difficult of access.

Turret clocks are often provided with four dials. These can be driven either from separate movements or from one only, depending on the size of the clock and local conditions. Sometimes it is more convenient to locate the movement in a chamber away from the dials, the hands being driven by suitable shafting. In such a case the outside hands cannot be seen, and a pilot dial must be provided on the movement. It is, of course, also necessary to be able to set easily the hands of the clock from the clock room.

The advantages of electric turret clocks are numerous. They provide accurate time, and can be synchronized with any other public or other clocks connected to the same system. If considered desirable they can be synchronized daily with time signals sent out from Greenwich Observatory. This is not usually necessary, as a reliable time-keeper only requires occasional checking, and the signals broadcast by the British Broadcasting Corporation can be utilized with considerable saving in expense.

They require no winding and little maintenance. The winding of a large turret clock which has striking and chiming gear in addition to the going train is a job which requires frequent attention, accompanied by much physical toil. The advantage of the small movement in allowing the dial to be illuminated has been referred to. It requires little additional equipment to make time impulses themselves switch on the tower lights at the correct hour—alteration in the lighting up time being compensated for. Similarly, control of chiming gear such as switching it out of circuit after a certain hour in the evening is easily arranged. The small size of the electrical movement often permits a clock to be placed in a position which would otherwise be impossible. A striking example of this is shown in Fig. 102.

The clock tower, carrying also a mammoth barometer and thermometer, is in reality a factory chimney, and any clock chamber was, therefore, out of the question. The clock dials (three in all) are 6 ft. in diameter, and each movement is actually fitted in a space scooped out of the solid brickwork, the only means of access being to remove the centre panel of the dials which carry the hands and their movements.

The cleaning of the dials of turret clocks is a frequent necessity, particularly in cities, and in old-fashioned clocks entails considerable trouble and expense, besides a certain amount of danger. It was essentially a job for the steeplejack.

Fig. 103 shows the turret clock of Holborn Hall "having its face washed." The movement is fixed to the centre panel of the dial, which is hinged, and is swung inwards, permitting cleaning of the figures, etc., to be carried out from the inside of the clock tower; instead of scaffolding having to be erected for the purpose. The economy of such a method is apparent without further elaboration.

Most of the remarks above apply to the purely electrical clocks. Electricity is also applied to turret clocks in two other ways as follows.

(*a*) Existing clocks weight driven, with pendulums, which are electrically wound.

(*b*) Weight-driven clocks which are required to be kept in synchronism with other clocks or with Greenwich time signals, but continue to work independently if the synchronizing system breaks down.

Electric winding is usually done by a small electric motor operated from the supply mains, and takes place at short intervals so that the weights fall only a short distance between winds. This gives a valuable advantage that space does not have to be provided in the towers of such clocks for the drop of weights. The cost of electric winding is negligible. The winding gear itself is not expensive, and its cost will rapidly be recovered by the saving in winding time. The application of an electric winding mechanism to an existing weight-driven clock affords considerable economy, although, of course, the

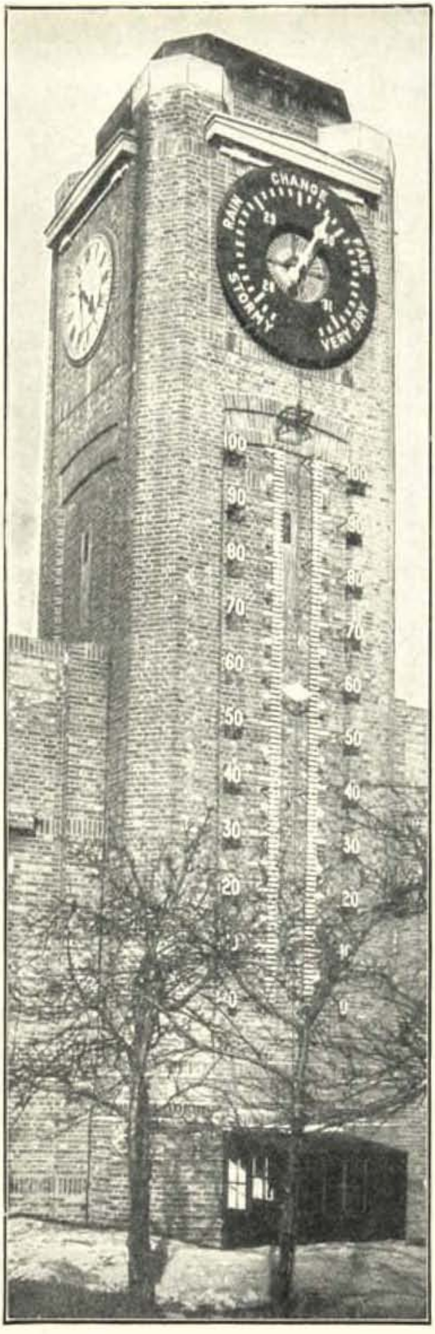


Fig. 102. A Chimney Clock Tower

accuracy or otherwise of the time-keeping is not effected. The amount of labour to keep a large mechanical clock running depends on its size, but twice weekly winding is quite common, and even then hard work.

The winding of the world-famous "BIG BEN" clock at Westminster used to take two men a whole day twice weekly. It is now done by an electric motor.

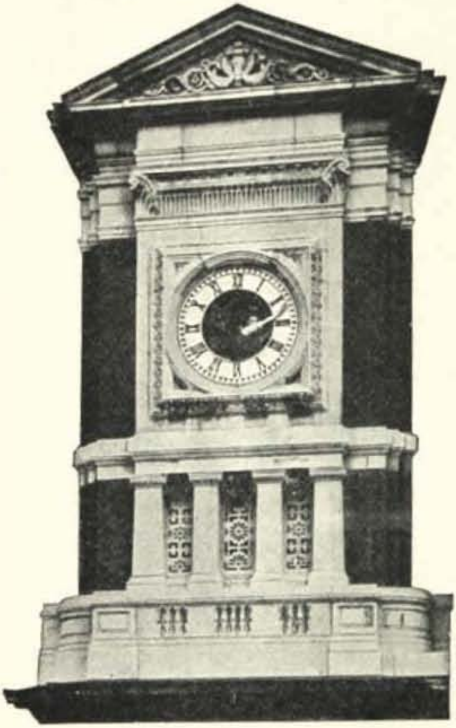

FIG. 103. WASHING FACE OF HOLBORN HALL CLOCK

Having regard to the advantages of electric clocks set out above, the reader may be tempted to inquire in passing why such an important clock as "BIG BEN" is still actuated by weight and pendulum. The reason is that it was designed by the late Lord Grimthorpe, who was recognized as the world's foremost authority on clock construction, and whose book *Clocks, Watches, and Bells* is a classic. It is natural, therefore, that the Westminster clock should be retained in its original form as a national memorial to his genius. Incidentally it has the reputation of being the finest mechanical time-keeper in the world.

The great advantage of adapting a public clock whose time-keeping may or may not be good, so that it is periodically synchronized with standard time signals, is self-evident. The synchronization may either be done by signals sent out from Greenwich Observatory over the G.P.O. telegraph wires, or from a local time circuit. The apparatus required to enable this to be done is quite simple, and should the synchronizing fail for any reason, such as the blowing down of overhead wires, the clock will carry on keeping its own time.

Where a number of public clocks in different parts of a


FIG. 104. THE WORLD'S LARGEST CLOCK

town are to be connected to a time circuit, the cost of underground cables is usually considerable. Overhead wires are much cheaper. Most of the public clocks at Chesterfield (England) are synchronized in this manner, the master clock being located in one of the Corporation offices, and the various clock towers, including the parish church with its famous crooked spire, are connected up with the overhead telephone wires. The clocks themselves are not electric, and, therefore, if the overhead wires are carried away by snow or any other cause the time system is not radically upset, and repairs can be affected at any convenient time.

Before passing to a description of the various turret clock systems, a few typical clock installations of this type will be

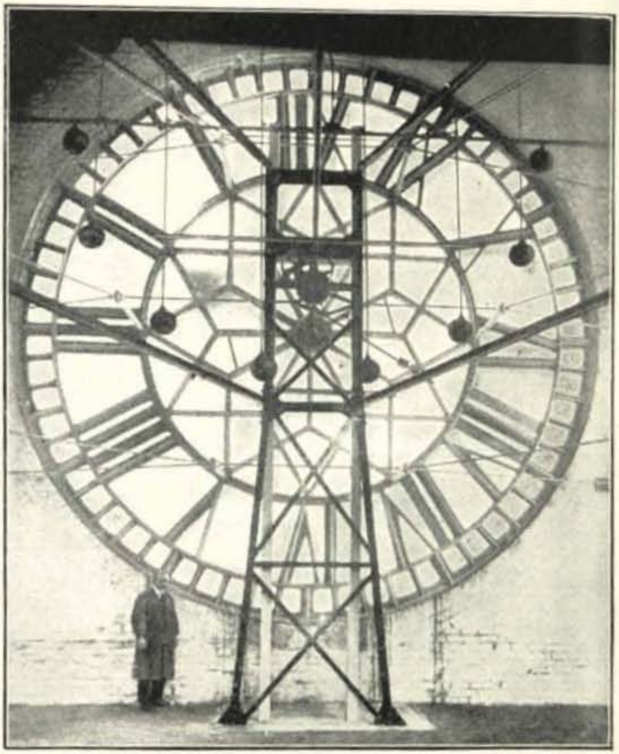

FIG. 105. ONE OF THE DIALS OF THE SINGER CLOCK

illustrated in order that the reader may have some idea of their magnitude. Fig. 104 shows the largest electric clock in the world, at the Singer works, Glasgow. It has four faces, each 26 ft. in diameter, and is operated by the Pul-syn-etic system of Gent & Co. Fig. 105 shows one of the dials of the Singer clock. The eight reflectors seen are for illuminating the dial. The height of the tower is 240 ft., and the length of the

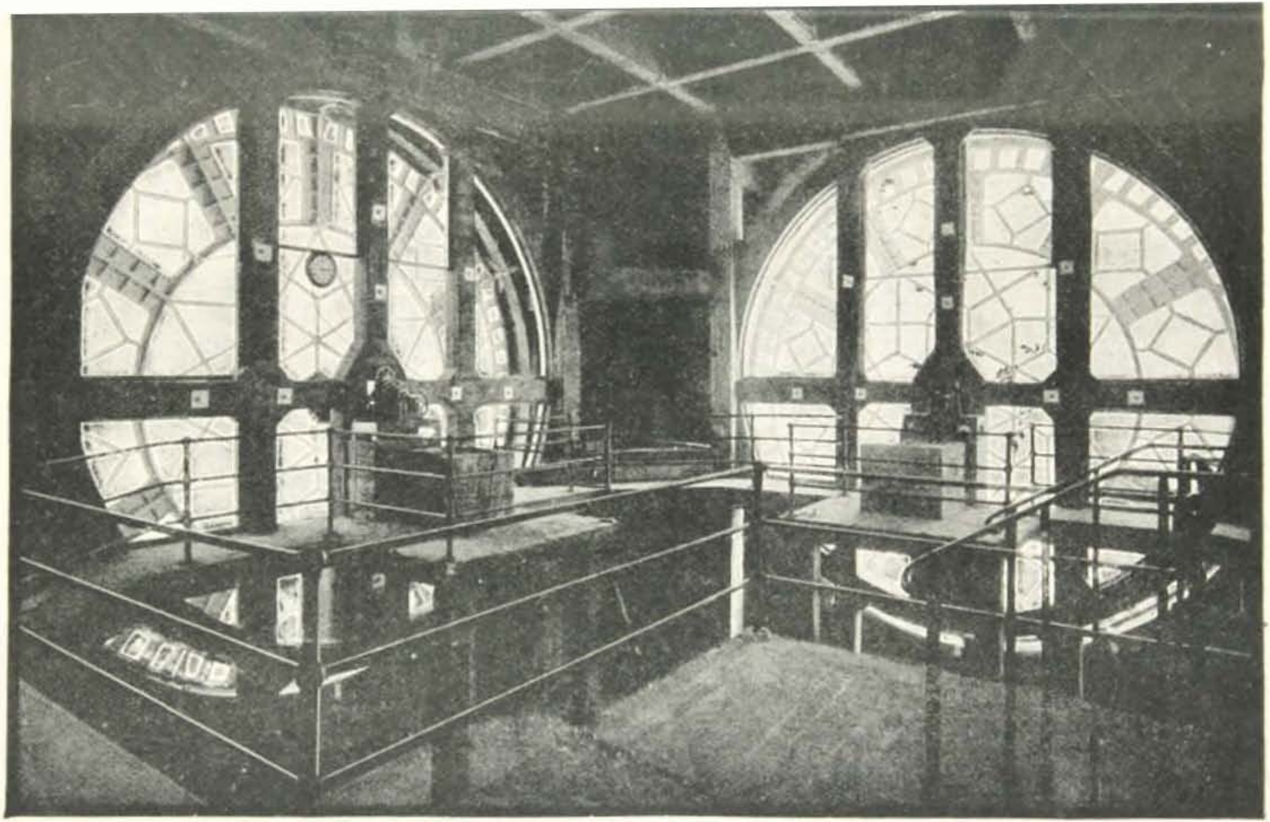

Fig. 106. Interior Clock Chamber, Royal Liver Building, Liverpool

hour hands 9 ft. 6 in. each, and that of the minute hands 15 ft. 7 in. each.

Fig. 106 gives an interior view of the clock chamber of the Royal Liver Building, Liverpool, and shows two of the four dials—each of which is operated by a separate driving movement, all connected with a master clock fixed on the ground floor which is synchronized with signals from Greenwich. The 12 in. office clock shown over the left dial in the picture gives some idea of the proportion. The diameter of the dials is 25 ft., and the clock keeps time with an accuracy of approximately two seconds per week. It was erected in 1911.

**The Pul-syn-etic System**

Messrs. Gent & Co. have devoted considerable attention to the question of turret clocks, and have three alternative systems which are employed as circumstances require.

1. The standard impulse clock movement, described in detail in Chapter IV. This is only recommended for small to medium sized clocks, having glazed faces.

2. The "Waiting Train" system by which the hands are driven by a motor pendulum but timed by impulses from the master clock. This system is always used for large or other dials having exposed hands.

3. The Duflex system for synchronizing existing turret clock pendulums.

The Waiting Train System. As mentioned above, the basic idea of this system is that the clock hands are driven by what is known as a motor pendulum—that is, a pendulum whose duty it is to drive, rather than to control. The pendulum is kept in motion by electro-magnetic impulses, and the apparatus is so arranged that the number of driving impulses in a given time is regulated by the load on the clock hands. If need be, thirty times the normal power can be developed. Thus, however severe the climatic conditions the clock cannot be stopped.

The pendulum is proportioned so that the ratchet wheel, with which it engages, and to which the hands are connected, makes one revolution in about 27 seconds. This completed, the driving pawl is held up until a releasing impulse arrives at the 30th second, from the master clock—hence the name "waiting train." Any variation in the swing of the pendulum itself makes no difference to the time-keeping of the clock. The fact that the hands travel through a half-minute in a few seconds less than the correct time and then stop, is not noticeable. It is considered preferable to the hands moving forward

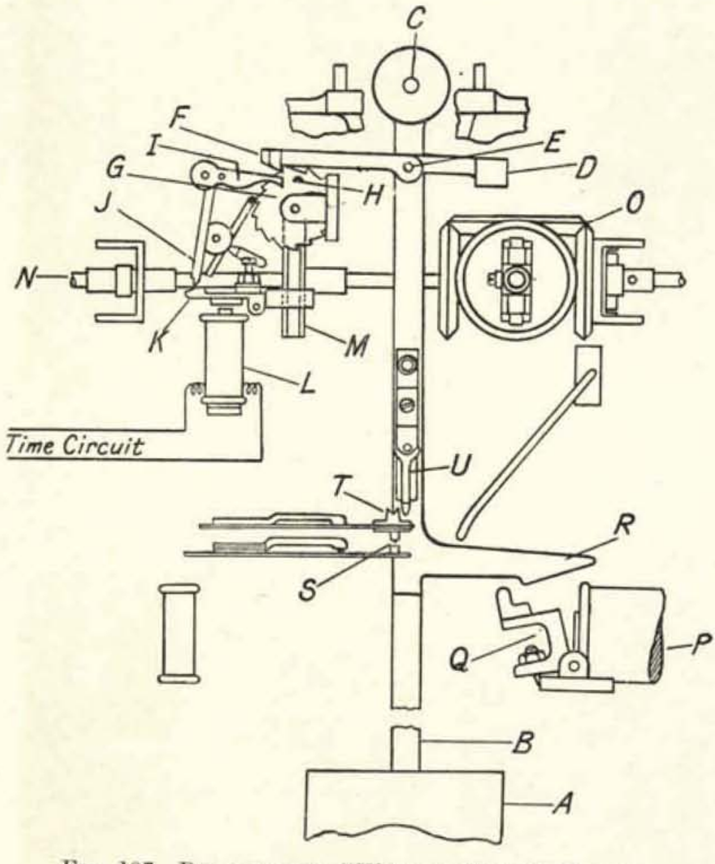


FIG. 107. PUL-SYN-ETIC "WAITING TRAIN" TURRET CLOCK MOVEMENT

in half-minute jumps, as in a large clock with long hands this sudden movement forward must necessarily impose considerable strain on the mechanism.

Fig. 107 shows a waiting train movement, and an illustration of the working parts is given in Fig. 108.

Referring to the former, *A* is the pendulum bob, *B* the pendulum rod pivoted on ball bearings at *C*. On the pendulum rod is a gathering lever *D* pivoted at *E* carrying the driving pawl *F* which engages with the ratchet wheel *G* carrying it

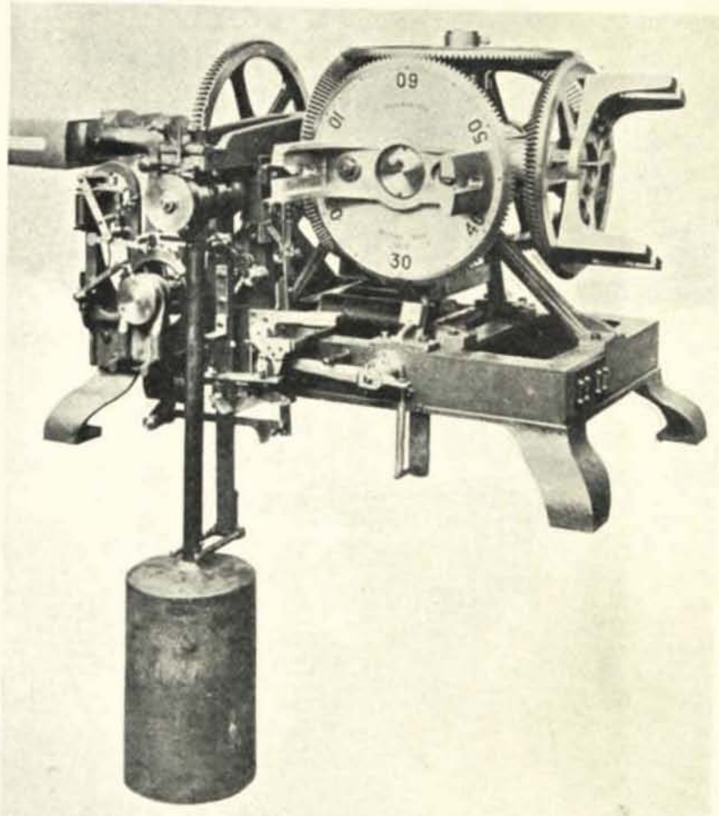


FIG. 108. PUL-SYN-ETIC "WAITING TRAIN" MOVEMENT

forward one tooth for every complete swing of the pendulum. On the ratchet wheel is a pin *H* which as it comes round engages with masking pawl *I*, which in turn lifts the gathering pawl clear of the ratchet and the pendulum swings idly. When lever *I* is lifted, the tail end *J* is held by detent *K* attached to the armature of the electro-magnet *L*, which is in series with the master clock as shown.

Thus the drive cannot commence again until the time impulse is received by *L*, thereby releasing levers *J*, *I*, and *D*. On the ratchet wheel is a worm which meshes with gear wheel *M* on one of the hand spindles *N*.

The drive for the hands of the other dials is taken from the crown gear *O* through suitable couplings and rods. Where there is only one dial the waiting train movement is usually close behind it. Where there are four dials the movement is located near the centre of the clock chamber.

One of the crown wheels has a small dial marked on it to assist in setting the hands, and for the same purpose a small handle is supplied on the ratchet wheel spindle. Both of these features are omitted from Fig. 107, but clearly seen in Fig. 108.

The pendulum is kept in motion by impulses of current in magnet *P* attracting armature *Q* which pushes to the right the projection *R* attached to the pendulum rod. The driving magnet can either be energized from primary batteries or accumulators, or from the electricity supply mains.

The number of impulses per minute is controlled by the arc of swing of the pendulum. *S* is a switch, normally open, the upper contact of which carries a notched block *T*. On the pendulum is a toggle *U*, which is normally drawn past the notched block. There comes a time, however, when the arc of the pendulum diminishes such that it is insufficient to draw the toggle right over the block, and its end drops into the notch. The pendulum now swings back and, due to the wedging action of the toggle in the notch, depresses the contact blade, and energizes the driving magnet. It will be readily apparent that with a heavy load on the hands, due to wind or snow, the swing of the pendulum will diminish quicker than in normal working, and thus there will be more driving impulses.

The current consumption of the power magnet varies from ·4 to ·5 amperes, according to the size of the movement.

The pendulum is usually enclosed in a wooden casing to minimize interference from draughts, etc.

Fig. 109 shows a complete waiting train installation, and is self-explanatory.

The construction of the waiting train movement is very robust. The frame is of cast iron and the arbors, or spindles, are of toughened steel running in gun-metal bushes, which a detachable to enable parts to be removed for cleaning, et without disturbing the remainder. The gears are of hammer gun-metal accurately machine cut. The contacts of the mot pendulum are of heavy gold-silver alloy, and are shunted l a resistance to prevent sparking.

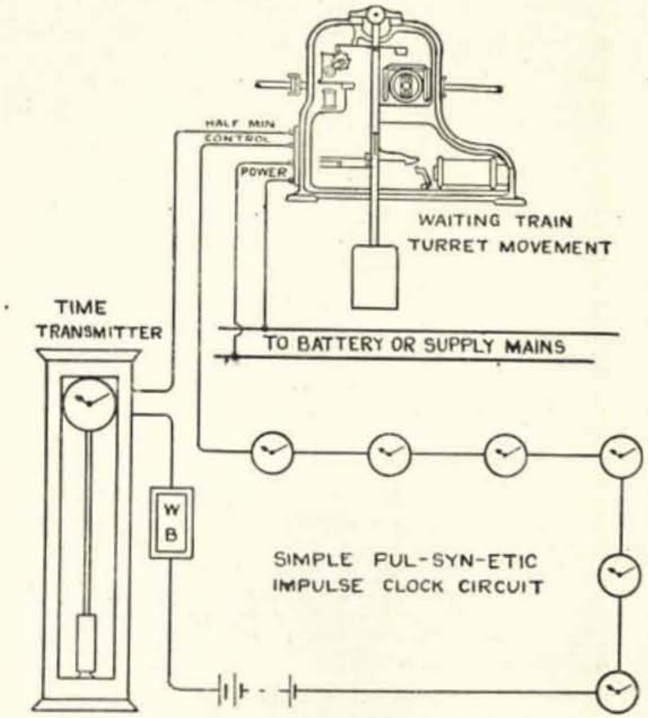


FIG. 109. "WAITING TRAIN" CIRCUIT

Five standard sizes of waiting train movement are made the largest capable of driving four dials 28 ft. in diameter.

THE DUFLEX SYSTEM. The Duflex system is designed t control the heavy pendulums of existing mechanical clocks i such a manner that though the clockwork continues to func tion as an independent unit, it is subject to correcting impulse from a master time circuit. Should the correcting impulse fai to arrive for any reason, the clock continues at its own rat until matters are put right. This system has been fully described in Chapter VIII on Synchronized Clocks.

### The Synchronome System

Several examples of synchronome turret clocks have been illustrated. The movement employed is similar to that used

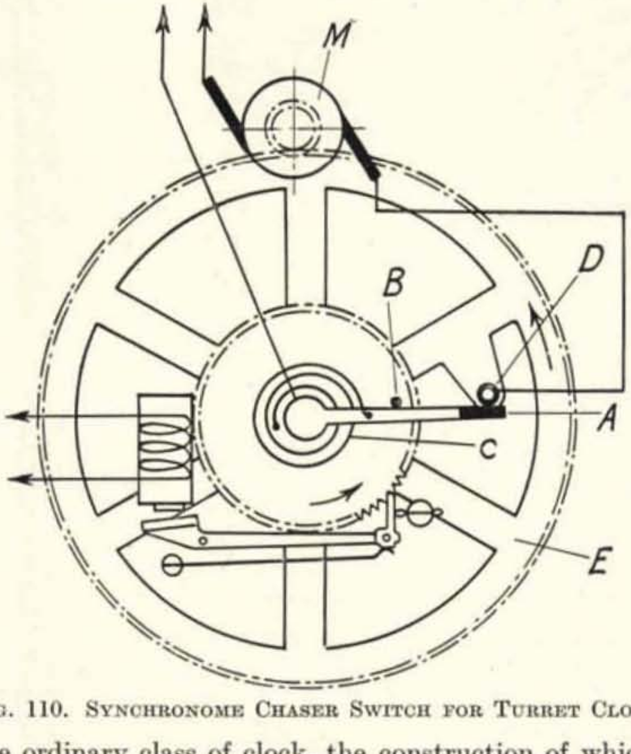


FIG. 110. SYNCHRONOME CHASER SWITCH FOR TURRET CLOCKS

in the ordinary class of clock, the construction of which has been described in detail in Chapter IV. It is, of course, made more robust in construction, but the principle remains the same, and the turret clocks will operate in series with the other clocks in the same circuit.

The Synchronome turret clock movement is made in six sizes, the largest being suitable for dials up to 10 ft. in diameter. Above this size a small rotary electro-motor is used, continuously or almost continuously running, being controlled by a chaser switch, the principle of which is illustrated in Fig. 110.

The arm $A$ concentric with an impulse dial movement of half-minute periodicity is normally held against stop $B$ by helical spring $C$, and against the contact pillar $D$ on the large wheel $E$, to which the clock hands are connected. This latter completes the circuit of a power supply through the rotary motor $M$, with the result that, if the large wheel $E$ gains on

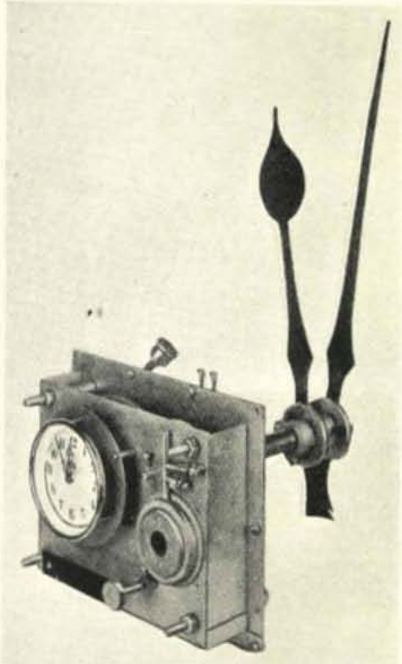

FIG. 111. LARGE SYNCHRONOUS MOTOR TURRET CLOCK MOVEMENT (EVERETT EDGCUMBE)

the dial movement, a break will occur at $D$, and $A$ will continually chase it. If the power supply is cut off, the dial movement stores its half minutes into spring $C$, and the rotary motor will have an uninterrupted run until it has restored the turret clock hands to time. In actual practice, of course, steps are taken to make a clean and rapid make-and-break at contact $D$. A mercury switch is often used.

**Synchronous Turret Clocks**

The synchronous or mains driven clock is in its infancy as far as this country is concerned, and has not yet been applied to any extent to turret clocks. There is no limit whatever to the size and power which can be obtained from synchronous motors, thus driving of turret clock motion work presents no

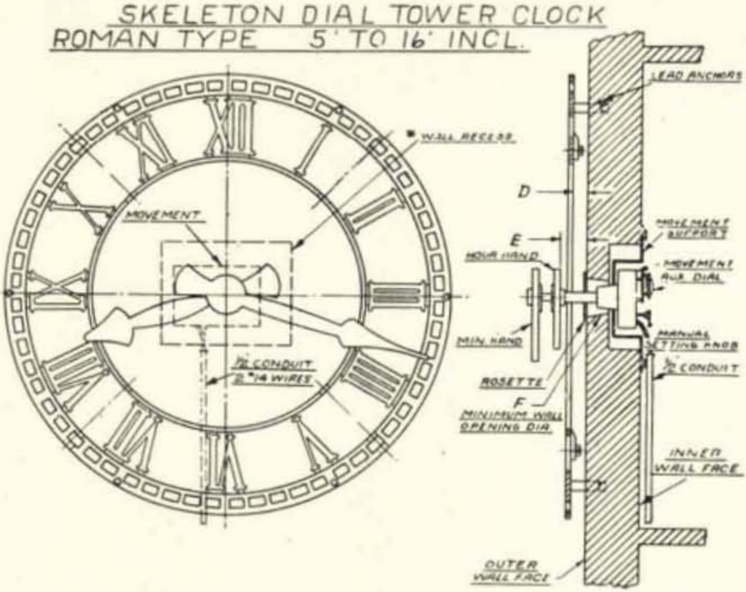


FIG. 112. FITTING SYNCHRONOUS TURRET CLOCK MOVEMENT

difficulty. The one driving motor if sufficiently powerful should suffice for both time-keeping and chiming.

A synchronous turret clock is cheaper than any other form. Like all other synchronous clocks, its time-keeping depends on the continuity of electricity supply and the accuracy with which its frequency is controlled. For semi-public clocks, e.g. those outside shops and factories where attention could be quickly given if need be, the synchronous clock is generally preferable to a mechanical clock.

Fig. 111 shows a large synchronous movement suitable for dials up to 16 ft. in diameter. It will be noticed that there is

a tell-tale dial at the back which greatly facilitates settin
This particular movement is driven by a Warren motor.

Fig. 112 shows the method of fitting to the wall, and
self-explanatory. Fig. 113 represents a movement suitable f

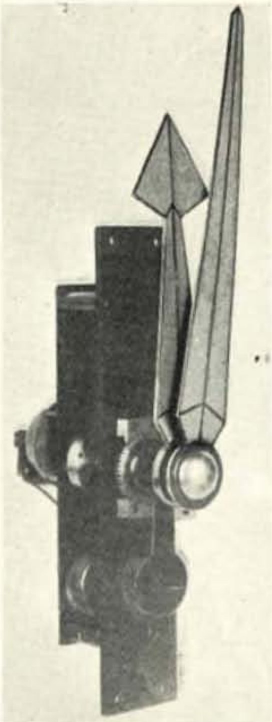

FIG. 113. SMALLER TYPE OF SYNCHRONOUS TURRET CLOCK MOVEMENT

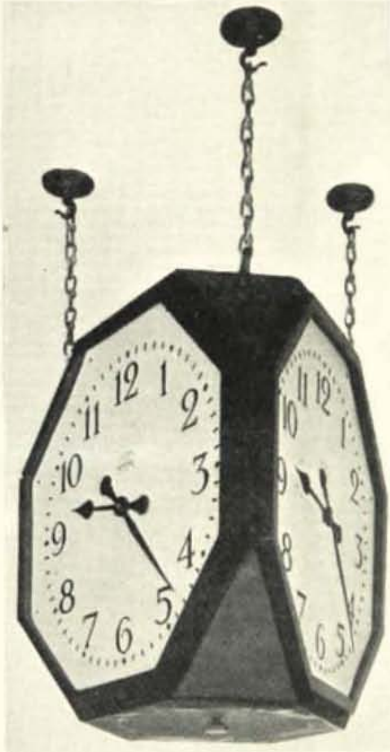

FIG. 114. SYNCHRONOUS PUBLIC CLOCK
18 in. dial

smaller dials, and Fig. 114 a typical three-faced public clock
having 18 in. dials.

## Turret Clock Construction

The requirements of turret clocks have already been dealt
with in the introductory portion of this chapter.

The principal features which call for consideration in the design, construction, and installation of a turret clock are that it must tell time accurately under all conditions of weather and temperature, and must be easily seen both by day and night. Further, externally the clock must blend harmoniously with other architectural features of the building, and internally probably have to fit in with other building considerations.

### Movement

The clock movement must have sufficient power to drive the hands and to trip any chiming or striking gear attached, under the most severe weather conditions. It must be able to carry a load of snow on the hands for days on end if necessary, and must be unaffected by atmospheric conditions. Clock rooms are often damp, particularly in the case of chiming clocks, and danger of rust must be guarded against. For this reason gun-metal wheels are employed wherever possible, and all steel parts, not actually working surfaces, are painted. All spindles are, of course, of steel, and the bearing bushes in which they run are generally of gun-metal. Provision for oiling all bearings is made, and automatic or semi-automatic oiling can be used with advantage.

### Turret Clock Mounting

A rigid mounting for the clock movement is essential, particularly in any movement employing a pendulum. No definite instructions can be laid down on this subject, however, as much depends on the circumstances—such as the number, size, and type of the dials, the movement used, and the general construction of the tower and disposition of other apparatus in the room.

A stone bracket built into the wall of the tower provides the most rigid mounting, but it is not generally possible to do this when the movement is to be mounted behind an illuminated dial. Such an arrangement also makes maintenance difficult. A system which is much used is to mount the movement on substantial iron girders, built into the tower. The mechanism can then be mounted in almost any convenient place in the tower without sacrificing rigidity.

Mounting the clockwork on wooden joists or on a stool fixed to a wooden floor is not recommended owing to the possibility of shrinkage and movement. The rigidity of the mounting of the movements in the clock chambers illustrated earlier in the chapter will be apparent.

**Dials**

Two considerations enter into the design or selection of a dial for a turret clock, viz. its height above the ground, and

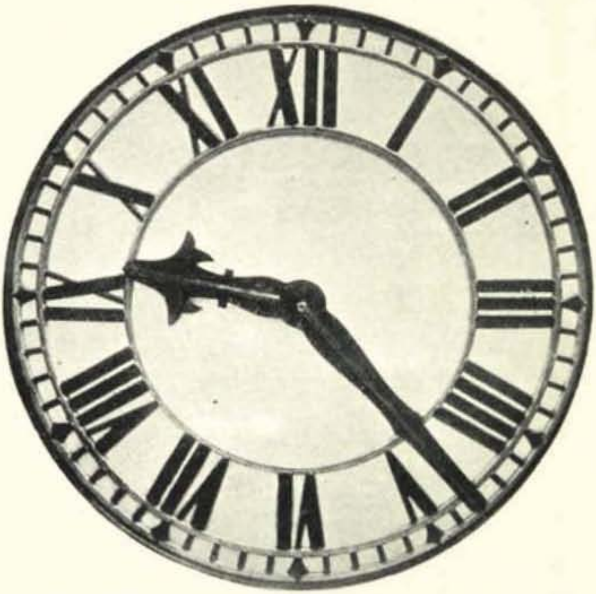

FIG. 115. ILLUMINATED TURRET CLOCK DIAL
*(John Smith & Sons, Derby)*

whether it is to be illuminated or not. Naturally the higher the clock is mounted, the smaller it will appear to the observer. If it is too small, time will be difficult to read.

It may be mentioned in passing that an observer always takes time from the position of the hands of the clock, and numerals can be, and often are, omitted from a dial without the public being aware of it, and as a matter of fact actually increasing the efficiency of the clock by reason of the increased clarity of the hands.

As regards the size of the dial a simple rule exists by which this may be readily determined. The diameter of the dial must not be less than one-tenth of the height of its centre from the ground. That is, a clock to be placed 100 ft. high will require a dial at least 10 ft. in diameter. This rule is followed very closely in turret clock practice.

Dials which are not to be illuminated can be conveniently formed by painting on the brick or stonework of the tower

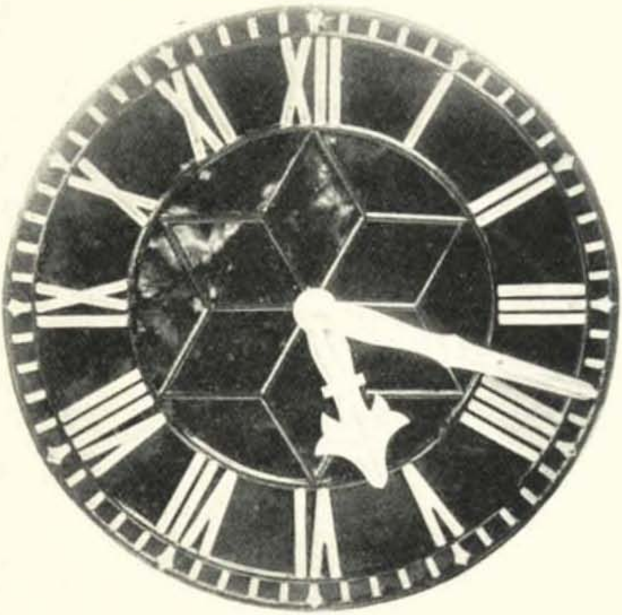

FIG. 116. DIAL FOR LIGHT BACKGROUNDS
*(John Smith & Sons, Derby)*

itself, otherwise they are usually made of sheet copper, or of cast iron or gun-metal framework, backed with copper sheets. Dials intended to be illuminated by electric light from the rear are generally made in the form of a cast-iron or gun-metal sketeton dial having the framework backed with white opal glass. Larger sized dials have an additional star framework in the centre to give extra support.

Fig. 115 shows a dial for an illuminated turret clock. Very large dials are generally made in four or more sections and bolted together on site.

Fig. 116 shows a similar dial backed with sheets of copper which, with the framework painted black, blue, or Indian red, and the figures, minutes, and hands gilded, makes a fine dial, largely used for church towers where the background is of fairly light colour.

### Hands

In older clocks, sheet copper was invariably used for the hands, and although this material is still used to a great extent, it has largely given place to aluminium in the case of electric clocks. The hands are always ribbed lengthwise, as can be easily seen in the illustrations, to add to their strength, and large hands are always balanced.

### Illumination of Dials

Illumination of the dial is effected by one or more lamps at the back mounted in suitable reflectors, and the lighting is generally arranged to be switched on automatically by a controller connected in the time circuit. If desired, it can be arranged for the illumination to switch off, say, at midnight, and come on again in the early hours of the morning during the winter months.

Fig. 117 illustrates an automatic switch for this purpose made by Gent & Co., Ltd., The switch itself consists generally of a metal fork on the end of an arm, arranged to dip into two vessels containing mercury, thus completing the lighting circuit. Alternatively, simple mercury tube contacts may be used if current is not excessive. The latter type is seen in the illustration.

The movement progresses in half-minute impulses, and at the given time the contacts close by means of the cam clearly shown in the illustration, and open again at a later hour by another cam. The time cams are adjustable by hand, so that changes may be made to suit the gradual changes of the seasons, and as the gear does not require winding these changes may be made fortnightly or at other convenient intervals. This may also be arranged to be accomplished automatically.

Another form of light control which is likely to be used in the future is the photoelectric cell, which is put outside the dial. This cell generates an E.M.F. according to the light falling on it, and it can be readily arranged for a relay to be operated when the light falls below a certain value, thus switching on the clock illumination.

An advertising sign is frequently attached to the turret clocks of stores, etc.

A modern tendency is for the figures and hands of the clock to be themselves illuminated. This is done by lining them with

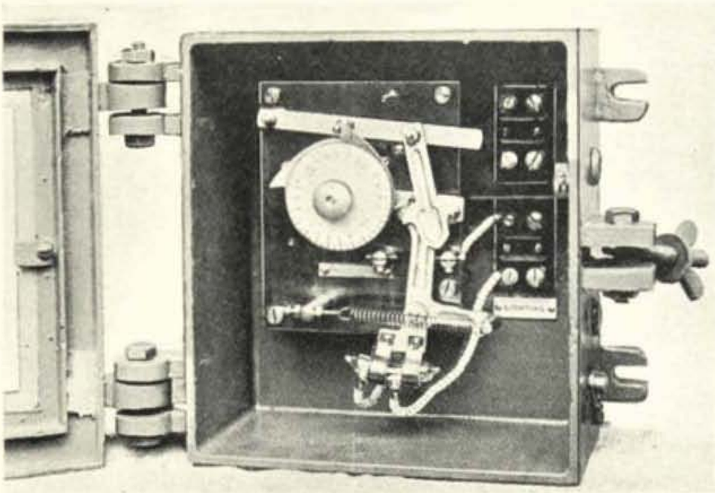

FIG. 117. GENT & CO. SWITCH FOR AUTOMATICALLY ILLUMINATING CLOCK DIALS

Neon tubes which light up with a coloured effect when a current passes through them. When this method is adopted it is necessary to fit two slip rings on each hand spindle to lead the current in and out of the hands. A striking example of this class of clock can be seen at St. Giles Circus, Tottenham Court Road, London. This clock has several other features of interest, and the following is a brief description of its construction, supplied by the Magneta Time Company, who were responsible for the clock portion of the sign.

The length of the minute hand from the centre is 6 ft. 9 in., and the hour hand 4 ft. 7 in. The clock mechanism consists of heavy motion work with ball-bearings where necessary, also the copper slip ring for carrying the high tension for illuminating the Neon tube. To this motion work there is a double angle drive consisting of a vertical driving rod approximately 10 ft. long at the lower end of which 10-in. right-angle bevels are used to couple up to a horizontal driving rod 12 ft. long. At the end of this rod is another angle bevel connecting to a horizontal rod at right angles. This rod is approximately 3 ft. long, and is coupled to the main shaft of the differential driving mechanism. This differential driving mechanism is

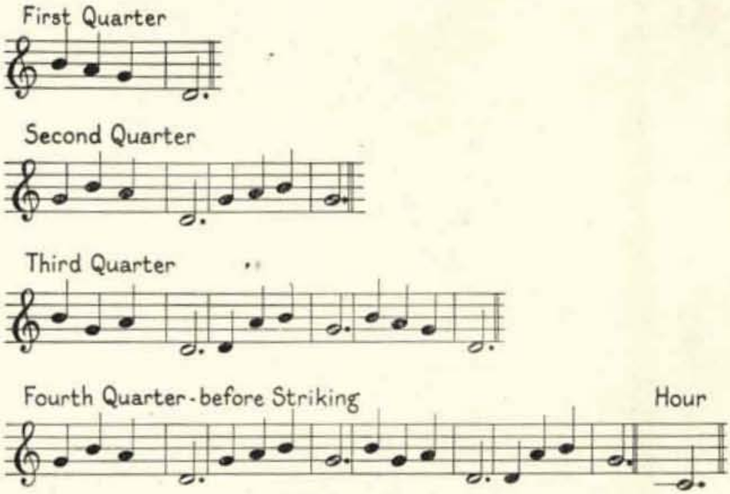


FIG. 118. "WESTMINSTER" CHIMES

operated by the master clock, which in turn is synchronized hourly by the Standard Time Co.'s Greenwich mean time synchronizing service. The differential movement consists of a 1/25th horse-power motor, which is automatically switched in and out every half-minute. There are two features in this movement, one the time feature, and one the power feature.

The impulse from the master clock drives the first member of the differential which may be termed the time member, and closes the mercury contact which switches on the motor. This motor is worm-geared to the second member of the differential. This is the power member which drives the hands forward each half-minute. Immediately the power member has caught up to the time member the current is switched off. The motor consequently only runs for a very short period each half-minute. In the event of a fault in the current supply the clock stops, but the time member of the differential continues

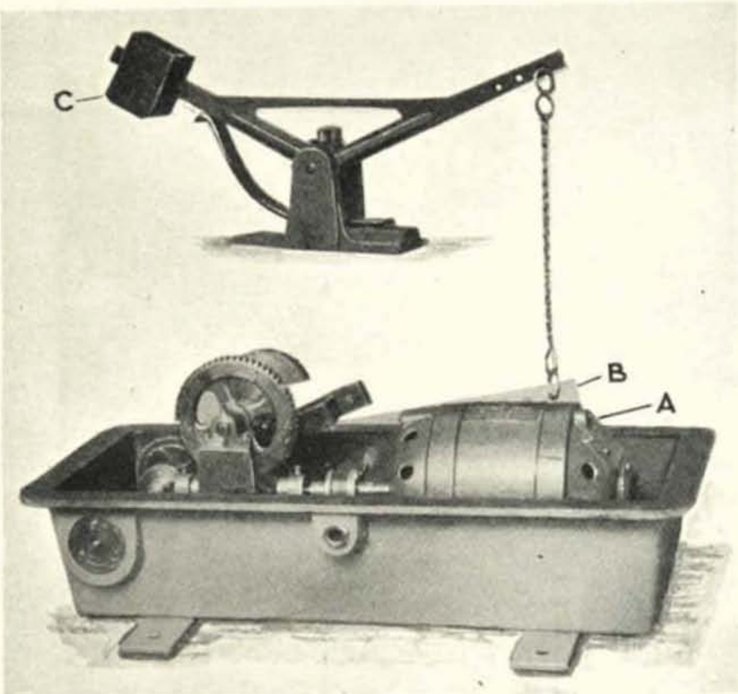


FIG. 119. SIMPLE BELL-TOLLING MECHANISM
*(Gent & Co.)*

to operate leaving the mercury contact permanently closed, so that immediately the current is restored the motor operates, and continues to do so until the power member has caught up to the time member. By this means the clock is automatically corrected after any interruption in the current supply. The hands of the clock do not actually jump forward each half-minute, as in the case of the impulse clocks, but are driven through locked gears, and move over a period of half a minute in about 5 seconds.

## Chiming Gears

Chiming and striking gears for electric clocks are generally

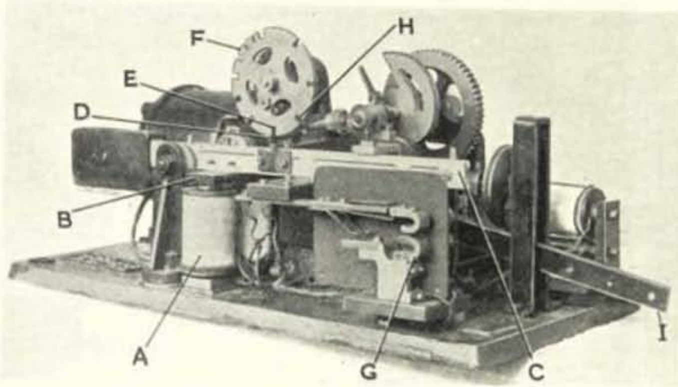


Fig. 120. Motor-driven Striking Gear
*(Gent & Co.)*

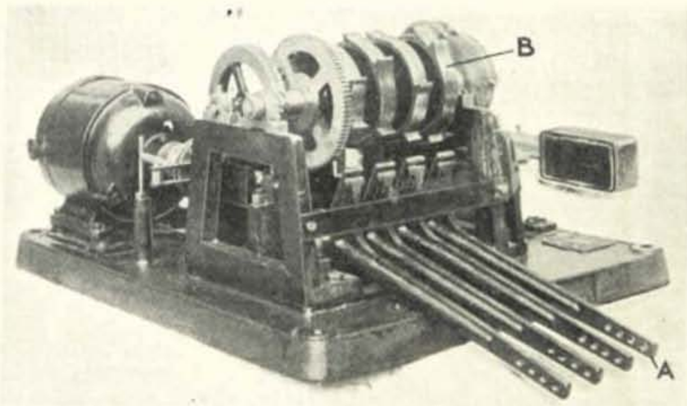


Fig. 121. Electrically-driven Chiming Gear for Turret Clock
*(Gent & Co.)*

entirely separate movements from the clock itself, and are usually driven by one or more electric motors.

The action of ringing the bells, which in the case of church chimes have to be arranged so that they can be rung manually when required, is purely mechanical. Some clocks are required to strike the hours only, but most public clocks chime each quarter.

There are several chimes in common use—the "ding dong" being the simplest and adaptable for two or three bells. Where four or more bells are available a wider selection is possible.

One of the best known chimes is the Cambridge, composed by Dr. Crotch in 1793 for Great St. Mary's Church, Cambridge, often called the Westminster Chime because it was employed by the late Lord Grimthorpe in the well-known clock at the Houses of Parliament, familiarly known as "BIG BEN." The musical notation of these chimes is shown in Fig. 118.

Fig. 119 shows a simple tolling mechanism, and serves to illustrate the general principle of the more complicated chiming and striking gears.

*A* is an electric motor driven from the mains or an accumulator and arranged to be switched on either by hand or by a time circuit impulse, according to circumstances; *B* is a lever which moves up and down through the action of a cam, raising the hammer by means of a wire connection, which then falls by its own weight and strikes the bell. A buffer spring lifts the hammer slightly to allow the bell to give forth its full volume of sound. This method of striking the bell by drop hammer is the best method, particularly in large sizes.

Fig. 120 shows a motor-driven striking gear, the principle of which is as follows. Exactly at the hour, the incoming time impulse energizes magnet *A* and attracts armature *B* fixed to lever *C*. This has two effects. Catch *D* is pulled out of slot *E* of "count wheel" *F*, and at the same time the switch *G* is closed, starting up the motor. The rotation continues until the catch *D* drops up into the next slot (*H*) of the count wheel. It will be noticed that the slots in this wheel are spaced at increasing distances, thus allowing the number of bell strokes to increase with the hours. The wire to the bell hammer is attached to lever *I*.

Fig. 121 shows a typical chiming gear for four bells. The levers *A* are actuated in correct sequences by the series of cams *B* which are rotated by the motor, the amount of rotation being dependent on whether the quarter, half, three-quarter, or hour is to be chimed. This is effected by a count wheel. The chimes are released by impulse from the standard time circuit.

# CHAPTER X

## MARINE CLOCKS

PRACTICALLY all modern ships are fitted throughout with an electric clock system. The conditions which have to be fulfilled in marine clock installations are somewhat different, and more exacting, than is the case with those for use on land. Any form of pendulum control is out of the question on board ship owing to the motion of the vessel, and all clocks need, therefore, to have a balance wheel escapement. Further, as a ship's longitude alters, so also does the local time, and it is, therefore, necessary to be able readily to advance and retard the clocks. When a ship sails eastward it is necessary to advance the clock hands, and when sailing westward to retard them. The clocks are usually corrected once daily, and provision must be made so that this can be done with as little trouble as possible from the master clock.

The clocks and wiring are subject to the deleterious effect of sea air, and provision has to be made in their manufacture to withstand such effects. Clocks fitted to warships must also be so robust as not to be damaged by the effect of gunfire.

Marine clocks are almost always of the impulse type, the master clock having a balance wheel instead of a pendulum. Sometimes the ships chronometer is also the master clock for the clock installation. Individually driven or electrically-wound clocks are rarely used because of the daily necessity of correction referred to above, and the fact that many of this particular class are pendulum clocks. The application of synchronous clocks to ships is not generally possible because the electricity supply is usually direct current, which is useless for this class of clock, and even if A.C. is available, it is not controlled, as there is no need for it in a self-contained generating plant.

A ship's electric clock installation, therefore, comprises the following four units, viz. (*a*) the master clock arranged to send out half-minute impulses, (*b*) the secondary dials, (*c*) the battery, and (*d*) the control panel from which the dials are advanced or retarded as required to correspond with local time. Power supply for ships' clocks is frequently taken from the lighting mains.

## The "Octo" Marine System

One of the best known systems of ships' clocks is that of T. & F. Mercer, of St. Albans, who are world famous for their marine chronometers.

In the Octo system the ship's navigating chronometer is

FIG. 122. "OCTO" HAND-OPERATED MASTER CONTROL PANEL

used as the master clock, contacts being fitted to enable an impulse to be sent out every half-minute. The contact gear can be fitted to any modern marine chronometer without in the least affecting its time-keeping. The impulse sent out by the chronometer actuates a relay in the control panel, which in turn operates the entire circuit of ships' clocks.

Two types of control panel are manufactured, styled hand operated and automatic. The hand-operated panel is shown in Fig. 122.

In addition to the clock dial there are two push buttons—located in the lower corners.

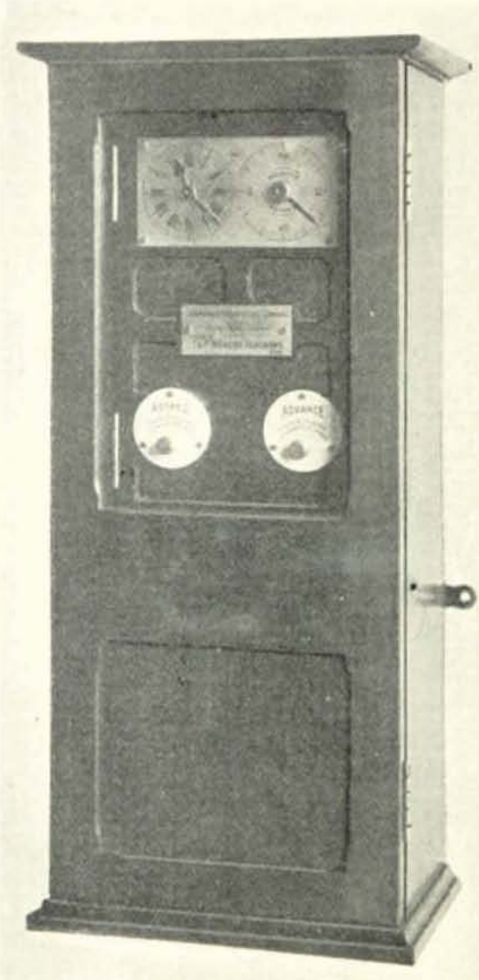

FIG. 123. "OCTO" AUTOMATIC CONTROL PANEL

To advance the ship's clocks the "Advance" button is depressed once for each half-minute of advance required. To retard the clocks the "Retard" button is pressed right home, and the hands of the pilot dial set back the required amount, and the button is released. Then only the pilot dial is actuated by the chronometer until it agrees with the rest of the installation, which is then automatically put in circuit again.

The "Automatic" control panel is illustrated in Fig. 123, and is similar in operation except that the advancing is carried

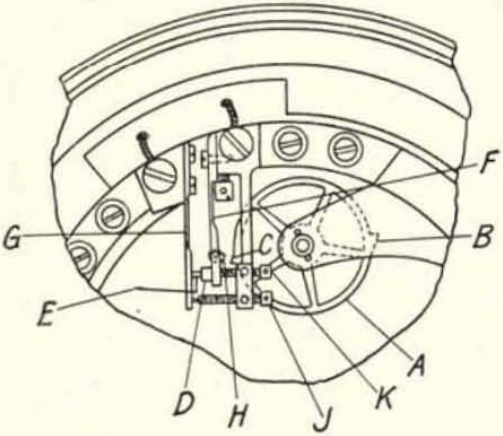


FIG. 124. CHRONOMETER CONTACT, "OCTO" SYSTEM

out automatically, it being only necessary to set the hands of the pilot dial forward the required amount, then to depress the "Advance" push button, when the entire system of clocks will advance automatically to the time set by the pilot dial.

Two types of secondary dial movement are available—the standard and the special silent pattern. The standard movement is recommended in all but special cases, as it is more robust, and is practically inaudible under ordinary conditions.

Special attention has been given to the prevention of corrosion by sea air. All the spindles, clock screws, etc., are of stainless steel, and the springs are specially treated.

The same size of movement is used in all ships' clocks, and watertight cases are supplied where necessary.

Fig. 124 illustrates the manner in which the half-minute impulses are taken from the chronometer.

The wheel $A$ makes one revolution per minute, and has on its periphery two projections $B$ and $C$. $D$ and $E$ are platinum contacts mounted on springs $F$ and $G$ respectively, and normally "open." As the wheel rotates, one of the projections wipes against catch $H$ on spring $F$, and raises the platinum

FIG. 125. "PUL-SYN-ETIC" MARINE TRANSMITTER

points into contact, thereby completing the circuit to the clock operating relay. Parts $B$, $C$, and $H$ are shaped so as to give a quick break. The normal current to be broken is only ·1 ampere. The contacts are adjusted by means of screws $J$ and $K$.

**The Pul-syn-etic Marine System.**

The principal differences between the Pul-syn-etic impulse clocks for marine use and those for land use, as described in Chapter IV, are—

1. The transmitter is operated by a balance wheel, the ordinary pendulum-driven master clock being obviously impossible.

2. The clock fittings are made more robust so as to enable them to be operated from the ship's electric supply main

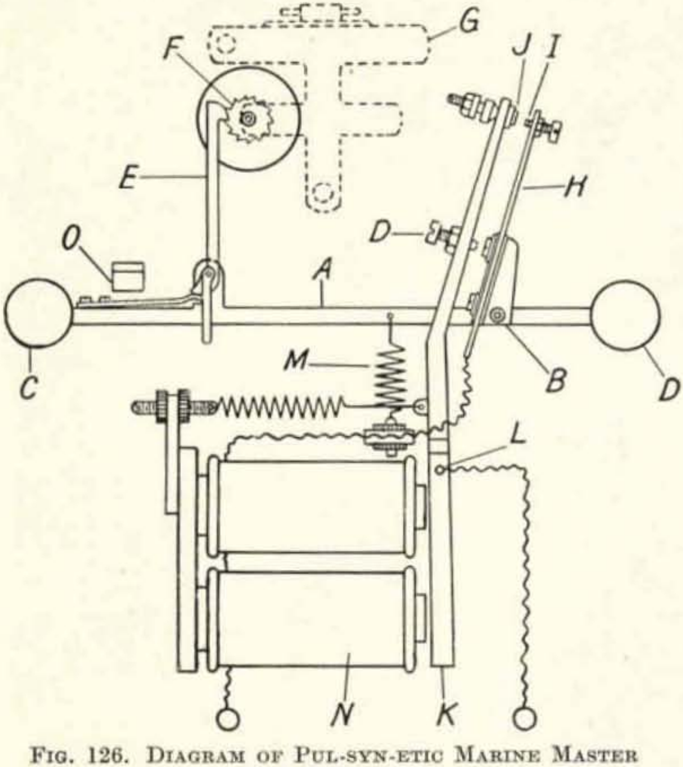


FIG. 126. DIAGRAM OF PUL-SYN-ETIC MARINE MASTER TRANSMITTER

through a potentiometer. For this reason the operating current of marine dials is standardized at ·38 ampere instead of ·22 ampere of the land type.

3. The transmitter is fitted with an automatic advance and retard mechanism.

Fig. 125 shows a Pul-syn-etic marine transmitter.

In the left-hand compartment is the half-minute impulse mechanism mounted on a cast-iron base, and controlled by a jewelled lever escapement with chronometer balance. The right-hand compartment contains the automatic advance and retard mechanism, while the pilot dial at the top indicates the time shown by the ship's clocks.

Fig. 126 shows the essential parts of the impulse mechanism. $A$ is the driving lever, pivoted at $B$ and provided with driving weight $C$, and balance weight $D$.

Attached to lever $A$ is the pawl $E$, which engages with the ratchet $F$ of the escapement mechanism $G$. On $A$ is also the

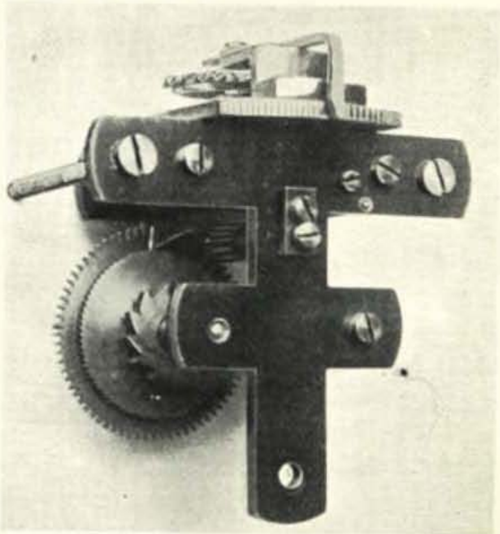

FIG. 127. ESCAPEMENT OF PUL-SYN-ETIC MARINE TRANSMITTER

contact plate $H$, whose contact $I$ is in proximity to contact $J$ mounted on armature $K$ pivoted at $L$.

The sequence of operation is as follows. Due to the pulling effect of gravity and of the spring $M$, and restrained by the action of the escapement, lever $A$ gradually falls. When it gets "down" contact is made between $I$ and $J$, electro-magnet $N$ is energized, and attracts armature $K$, thereby throwing lever $A$ up and causing the pawl $E$ to haul on to the next tooth of the ratchet wheel $F$, and then the cycle is repeated.

The upward travel of $A$ is limited by the stop $O$, made of felt to deaden the sound. The downward travel is limited by the adjustment of the contacts. The escapement is so set that the lever takes just thirty seconds to fall. The secondary dials are connected in series with the contacts and electro-magnet, thus the hands advance one half-minute every time contact is made.

The function of screw $D$ is to act as a fulcrum as lever $A$ is thrown up, thus causing contacts $I$ and $J$ to separate rapidly, making a clean break. Owing to its importance and delicacy

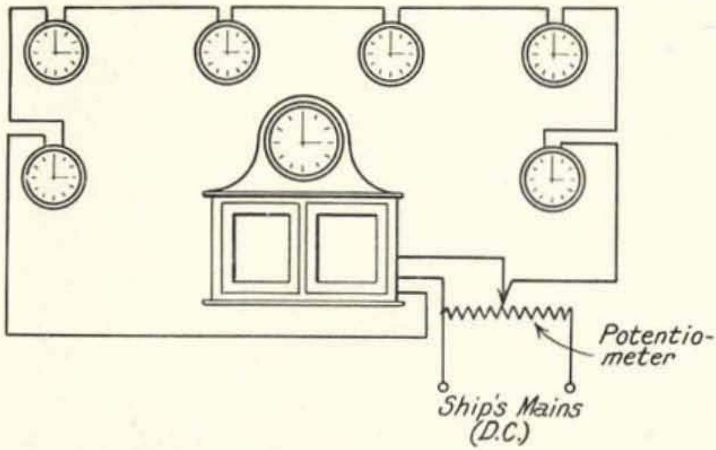


FIG. 128. OPERATING ELECTRIC CLOCKS FROM SHIP'S MAINS

the escapement movement is made detachable, enabling a spare to be readily inserted should any trouble arise. Fig. 127 shows the escapement fitting.

The automatic advance and retard is operated as follows. To advance the clocks, the pointer on the setting dial (Fig. 125) is turned to the figure indicating the requisite number of minutes. The "advance" lever is then pressed, and double this number of contacts is automatically made (i.e. one contact for each half-minute) in rapid succession, and the pilot dial and the impulse clocks are thus set to the required time.

To retard the ship's clocks it is only necessary to set the pointer to the desired number of minutes, press the "retard" lever, when all the dials will remain "held" until the desired number of minutes have passed, when the clocks throughout the ship will automatically restart.

When the "advance" mechanism operates, the pawl *E* (Fig. 126) is thrown back, the escapement stops, and a fan moves quickly instead of the balance wheel. When the "retard" mechanism is operated, pawl *E* still hauls the escapement, but the impulse clocks are cut out of circuit, and their place taken by an equivalent resistance. The transmitter then

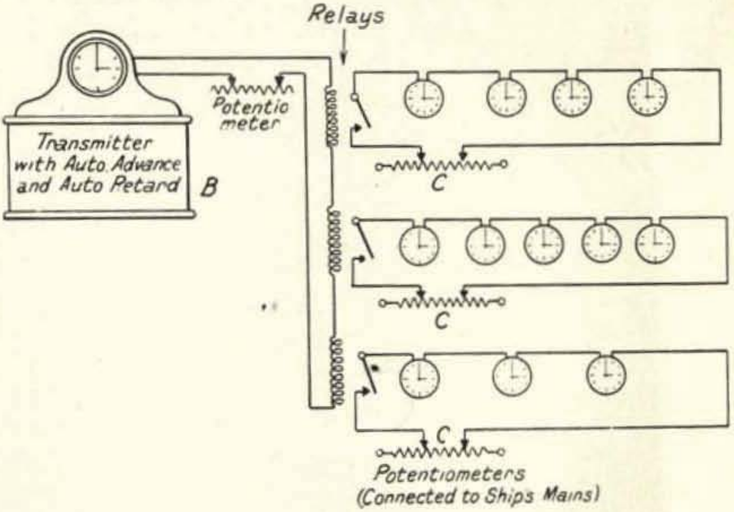


FIG. 129. SHIP'S CLOCKS IN GROUPS, ALL OPERATED FROM MAIN ELECTRICITY SUPPLY

operates for the given number of half-minutes without driving either the pilot dial or the ship's clocks. A hand advance transmitter is also supplied where required.

The dial movements are similar in design and construction to those of the standard Pul-syn-etic system mentioned in Chapter IV, and require no further description.

Clocks made for insertion in panelling are fitted with two unobtrusive pin terminals by which clocks can be set to time by means of a dry cell in case adjustment is required owing to stoppage or interference with the system. Watertight clocks in cast-iron cases are fitted in exposed positions, engine rooms, etc.

Current for operating the clocks may be derived from the ship's electric light mains, dry batteries, or from accumulators.

FIG. 130. "PUL-SYN-ETIC" AUTOMATIC SHIP'S POSITION INDICATOR

The first is the most general. The voltage required by the clock system depends on the number of clocks in circuit, and is best reduced from the ship's mains by the potentiometer method shown in Fig. 128, the position of the slider being adjusted so that the current passing round the clock circuit is ·38 ampere.

Another system of wiring is shown in Fig. 129. Here the clocks are arranged in three or more groups, each group receiving its impulse from a relay actuated from the master transmitter *B*. The primary circuit and each group of dials has its own potentiometer *C*.

The advantages of this system is that a failure of one clock circuit only affects its own particular group of clocks, and does not upset the whole ship. In cases where dynamo current is sometimes cut off, accumulators must be used. These can be trickle charged from the ship's mains.

As indicating the uses to which the ship's time impulses can be put, Fig. 130 shows a Pul-syn-etic automatic ship's progress indicator.

The indicator is made in the form of a large, coloured relief map in a heavy, ornamental frame. The map covers the recognized route that the vessel is in the habit of taking, that illustrated relating to a ship sailing from England to Buenos Aires, touching at various ports of call. A model ship representing the liner is moved along the route by concealed electric clockwork, operated by the time system of the ship, and the rate of travel of the model is arranged proportionate to the actual speed of the vessel so that its position on the ocean can be seen by passengers at any time. By means of a simple switch moved at the commencement of the return journey, the model automatically reverses and indicates the return journey. Such an indicator is, of course, only possible where a liner follows a regular route. The driving mechanism is contained in the cabinet below the model.

# CHAPTER XI

## MISCELLANEOUS APPLICATIONS

In this chapter it is proposed to deal with some of the many uses to which electric time circuits can be put, apart from the actual indication of time. Some of these miscellaneous applications have already been described, as, for example, the ship's position indicator, illustrated in the previous chapter. Almost any process or apparatus where time is one of the guiding factors can be arranged for automatic operation.

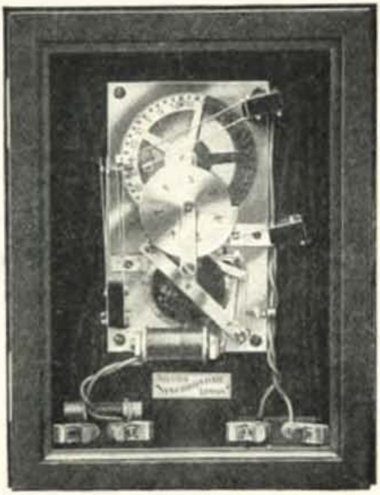

Fig. 131. Synchronome Bell Controller

The start and cease work signals of a factory may be arranged to be entirely controlled by the electric clock system.

Again calendars, which are really clocks showing days instead of hours may be readily adapted to be worked from the time circuit or from the A.C. mains.

The control of shop window lighting is another use to which the time circuits can be usefully employed. Modern business practice is to leave the shop window lights on for some hours after the closing hour, an automatic switch being provided for the purpose of switching off at a given time. The electrically-operated time switch does away with the trouble of winding the clock, and at the same time will take entire control of the lighting—both switching on and switching off, on early closing days and Sundays.

The apparatus for most of these special applications has to be designed to suit each individual set of circumstances, and it is, therefore, not proposed to enter into any great detail in the typical examples now to be described.

## Programme Controls

This is by far the largest application of electrical time principles outside of actual time indication. Almost every business, factory, and institution has a series of bell or whistle signals which lend themselves to automatic operating by electricity.

A typical Synchronome Bell Controller is illustrated in Fig. 131, and its principle of working is shown in Fig. 132.

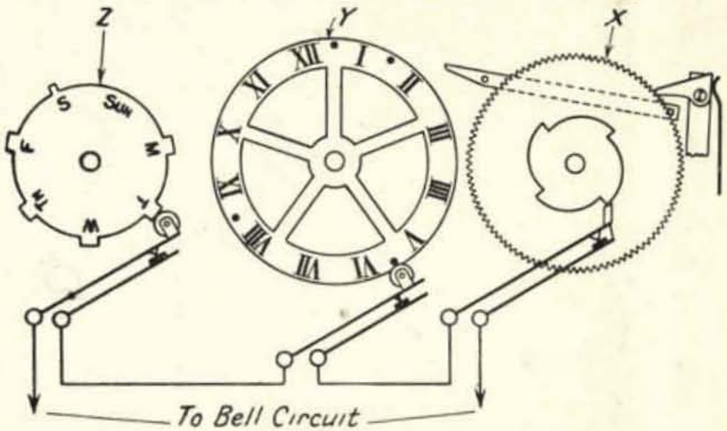


FIG. 132. DIAGRAMMATIC REPRESENTATION OF SYNCHRONOME BELL CONTROLLER

The wheel $X$ is rotated once per hour by impulses from the time circuit in exactly the same manner as the minute hands of the secondary clocks in the same circuit. Wheel $Y$ is geared to rotate once in twelve hours, and wheel $Z$ once a week. A pair of contact springs engages with each of these wheels $X$, $Y$, and $Z$, and since all are in series the bell or other circuit which it is desired to operate, will not be completed unless all contacts are closed simultaneously.

In the example shown, wheel $X$ makes contact for half a minute every fifteen minutes, but nothing will happen unless some particular fifteen minutes is selected by wheel $Y$. Then if wheel $Z$ is making contact, as it does during working hours, opening it every night, on Saturday afternoons and Sunday,

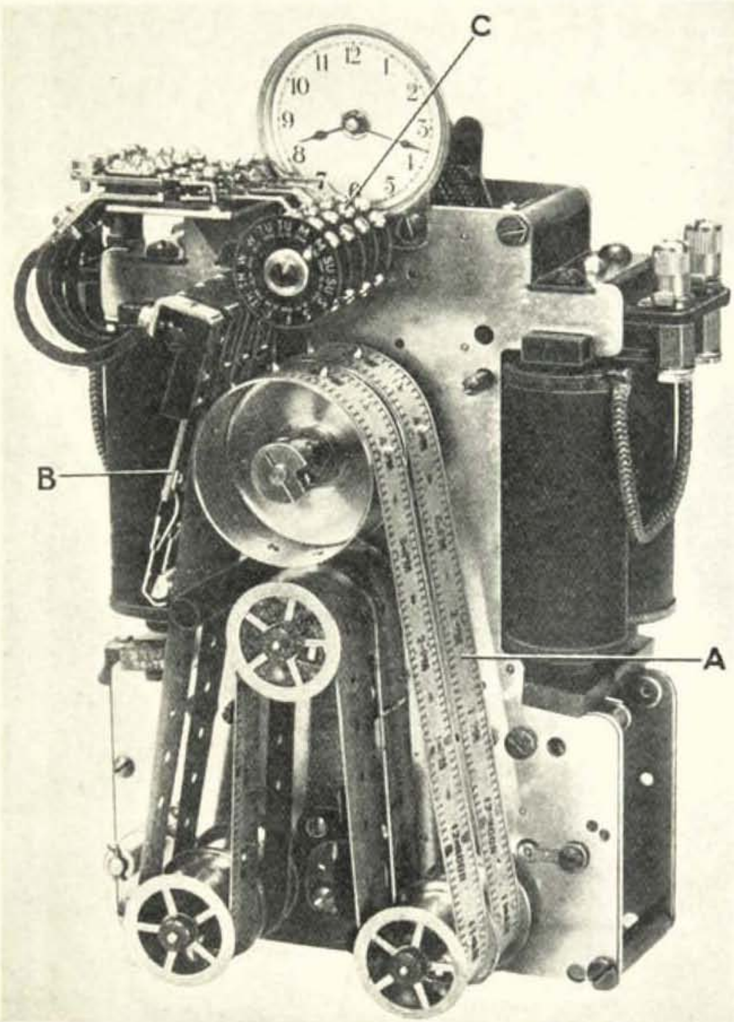


FIG. 133. STROMBERG PROGRAMME CONTROLLER
(*Magneta Time Co.*)

the secondary circuit will be completed and the bells will ring for half a minute. The programme can be varied at will within the limits of the instrument by inserting pins in wheel *Y* in appropriate positions. The setting in the diagram shows the bells ringing at 5.30 p.m. on Tuesday. The controller

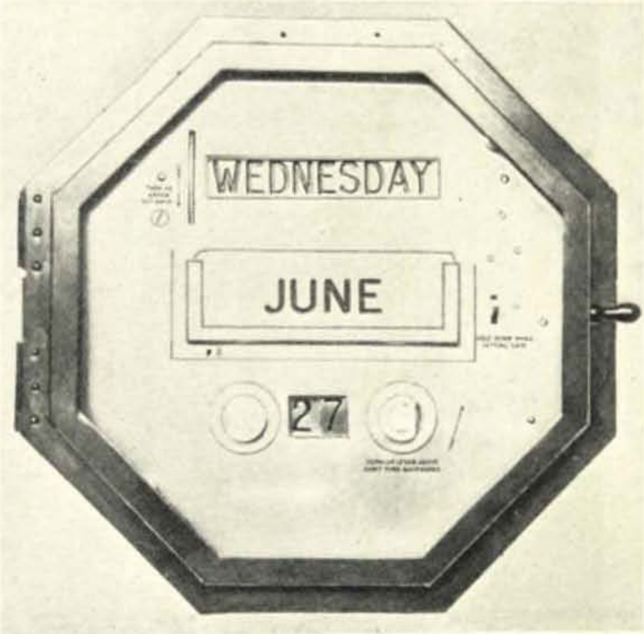


FIG. 134. "PUL-SYN-ETIC" ELECTRIC CALENDAR

can be arranged to suit any desired programme, and to give any desired length of ring. In some instances the control contacts can be fitted to a clock dial.

Another form of programme controller is the Stromberg instrument illustrated in Fig. 133. The principal component of this apparatus is the tape *A* made of a specially prepared celluloid material, which passes over the pulleys shown, and is moved progressively forward either by half-minute or minute impulses from a master clock, or by a synchronous motor.

The degrees of the tape are marked with divisions of time, and holes are punched in the tape at any point where it is desired to operate any signal or other instrument. When such a perforation passes under one of the contact fingers *B*, the circuit is completed. A further selector *C* enables the signals to become inoperative on certain days of the week as required. To change a schedule of signals it is only necessary to substitute a new tape, punched for the new schedule—the work of a few minutes.

**The Electric Calendar**

The electric calendar illustrated in Fig. 134 represents another interesting and useful application of the electrical time circuit impulses.

The mechanism is advanced step by step, and at midnight both the date and the day are automatically changed. The names of the month are changed by hand.

# CHAPTER XII

## CHOOSING AN ELECTRIC CLOCK

HAVING now described in some detail the various types of clocks on the market, we are in a position to review the merits of each, and to discuss the factors governing the choice of an electric clock for a given purpose.

There are three considerations, viz. cost, the accuracy and reliability of time-keeping required, and the system of electricity supply available.

### Commercial Installations

For institutions, railway stations, factories, etc., where accurate time is of supreme importance, the impulse clock system takes first place. It is comparatively cheap in capital cost, as only one master transmitter is wanted no matter how many dials are connected in circuit. The cost of installation can be very low, as an elaborate system of wiring, such as is necessary with mains-driven clocks, is not required. The cost of running and maintenance is negligible, and there is the additional advantage of being able to couple in existing clocks, workmen's time recorders, and also automatically operate any desired programme of signals. The mechanism of both the master clock and secondary dial is very simple, and there is little to go wrong. Their time-keeping is superior to any form of mechanical clock, and if extreme accuracy is demanded only a simple addition is necessary to enable the master clock to be periodically synchronized by time signals sent out from Greenwich Observatory. Generally this latter refinement is quite unnecessary. It is a very simple matter to check the master clock from time to time against the time signals now so frequently broadcast.

Objection is sometimes raised to impulse clock systems on account of the fact that the hands move forward in half-minute jumps. Where a steady forward motion is necessary, this can be arranged with all makes of clocks.

Another point in favour of the impulse clock system is the negligence нег-ли-дженс. небрежность, невнимательн



fact that all dials can be altered from winter to summer time, and *vice versa*, by manipulation of the master clock. This is of considerable importance in large installations, particularly in hotels.

The only competitor of the impulse clock for the uses under consideration is the synchronous motor clock. This can, of course, only be used where time-controlled frequency alternating current is available. The principal disadvantage is the fact that the accuracy of its time-keeping is entirely in the hands of the power station authorities.

If the supply fails, the clocks stop, and except in the case of self-starting clocks, each individual clock must be restarted and reset on the resumption of the supply. If the supply people fail to keep the frequency accurately under control the time-keeping suffers, and the user has little redress.

As regards cost of installation, synchronous clocks are connected to the ordinary lighting or power circuits, and do not, therefore, require special wiring. In capital cost of dials there is little to choose between the two systems. Cost of running is an item to be reckoned with in large installations. Five hundred synchronous motor clocks, each taking one watt, will consume one unit of electricity every two hours. With electricity at 1d. per unit this represents one shilling a day—a considerable item of expense in the course of a year. The cost of current of the impulse clock is negligible. The life of an impulse clock is likely to be longer than that of a synchronous motor clock owing to the smaller number of moving parts. Synchronous motor clocks are not so readily adaptable to the operation of time recorders, etc., as are impulse clocks.

## Domestic Clocks

For domestic use conditions are not so exacting, and a wider choice can be given. For large residences the impulse clock system with its advantages as set out in the previous section can be advantageously employed, but for smaller houses the high cost of the master clock for the few dials necessary, together with the special wiring, makes the system prohibitive.

Where time-controlled alternating current is available the synchronous motor clock is the best proposition for domestic time-keeping. Accurate time within a few seconds of Greenwich is assured, and all the clocks indicate alike. An occasional failure of the electricity supply is not likely to cause serious inconvenience.

The synchronous motor clock is cheap to buy, and five clocks can be run for 200 hours or more for one electrical unit —say, 3s. 6d. per annum. To obtain satisfactory service the clocks must be permanently wired to the supply mains. This, however, is not costly, and should not amount to more than a few shillings per clock.

If a mains-operated clock is wanted, and alternating current is not available, the only choice left is the electrically-wound clock. This is in reality only a spring clock with an electric winding motor attached. The time-keeping, therefore, depends only on the clockwork, and is not likely to be better than a spring clock. The majority of such clocks on the market which the author has seen are all well made and good time-keepers, but are expensive, because one really buys both a clock and an electric motor. The cost of current is negligible as the motor is only switched on for a few moments at long intervals. Special wiring can usually be dispensed with, the clock being connected to an existing plug point. Disconnection during the use of any other piece of apparatus will not affect the clock, as the spring enables it to carry on for a long period, and it will fully wind as soon as the plug is replaced.

The most economical domestic clock is undoubtedly the self-contained battery-driven clock such as described in Chapter V. These clocks require no wiring whatever, and cost little to run—a battery costing a shilling or so will last two or three years. They are cheap to buy, and when once regulated and set they keep very good time. Generally, their time-keeping compares more than favourably with spring-driven clocks of similar price. This type of clock possesses a pendulum and retains a "tick" which appears to be a point in its favour.

## Synchronized Clocks

There remains the case as to what can be done with the existing mechanical clock whose mechanism is in good order, but whose time-keeping is perhaps not up to present-day standards. There are two ways in which such a clock can be electrified. It can be fitted with an electric winding motor, and can be synchronized either by impulses from an existing time circuit or by synchronizing signals from Greenwich Observatory, sent over the G.P.O. telegraph lines, or if in London by the Standard Time Company's synchronizing service. In the event of the failure of the synchronizing signal, the clock simply goes on at its own rate.

As far as the winding motor is concerned, this will not affect the time-keeping, but it will effect considerable saving in labour. The winding motor may be automatic or manually controlled. In the former case the winding is done automatically at regular intervals. In the latter case it is still necessary for a man regularly to visit the clock tower, but all he has to do is to switch on the winding motor.

### Public Clocks

The conditions which have to be fulfilled by a public clock worthy of the name are very exacting.

1. It must give Greenwich time correct to within a few seconds.

2. It must keep time under all sorts of conditions—even when the hands are heavily loaded with snow.

3. It must never stop.

Further, it must generally be arranged to chime quarters and strike at the hour.

There are two cases which require consideration, viz. a new clock, and electrification of existing clocks to give improved time-keeping. As far as new clocks are concerned, an adaptation of the impulse system is the only reliable scheme, and fulfils all the conditions set down above.

Where, as is generally the case, the public clock is erected over a group of offices, it simply forms one unit of the office time system, and although its hands may be driven by a separate motor or other mechanism, the actual time-keeping is controlled by the master clock in the building below, which in turn may be synchronized with signals from Greenwich Observatory. Even when no time circuit exists, the installation of a special master transmitter to control the one turret clock does not add much to the total cost, and is to be recommended in preference to a mechanical clock with its tedious winding and possible vagaries of time-keeping.

Synchronous public clocks are used to some extent, but the same objection holds that the clock is at the mercy of the electricity supply, which *may* fail, and they cannot be recommended where absolutely accurate and reliable time-keeping is required.

There is no difficulty in providing a synchronous motor to develop as much power as required. The synchronous motor turret clock has the merit of cheapness compared with the cost of a corresponding electric impulse clock or a mechanical clock.

**Privately Owned Outside Clocks**

For semi-public clocks, i.e. outside shops and in the windows, in cinemas, etc., synchronous motor clocks are ideal. Here the accuracy of time-keeping is not quite as important as in the case of the large turret clock. An occasional stoppage is not important, as the shopkeeper is on the spot to set the clock going as soon as the power comes on again. These slight risks would more than compensate for the advantage of having all the public clocks in a street indicating the same time, and that only a few seconds from Greenwich mean time. The differences in time exhibited by various mechanical clocks in the same street is too well-known to require further mention.

# CHAPTER XIII

## INSTALLATION AND MAINTENANCE

As with any other piece of apparatus, to get the best results an electric clock must be carefully installed and properly maintained. The amount of work and care that must be taken in installing depends to a great extent on the type of clock. For instance, the self-contained battery-driven type simply requires its battery to be attached and its pendulum released when it is ready for use. Synchronous motor and electrically-wound clocks require wiring to the mains in a similar manner to any other piece of electrical apparatus.

Impulse clocks, because of their greater accuracy and the fact that their circuit is independent of any existing electricity supply wiring, and the superior accuracy of performance which is required from them, demand the greatest amount of attention in installation and after care, and it is with this type of clock that the present chapter is principally concerned. Much of the information, however, applies equally to all types of electric clock, and special notes regarding other types have been inserted where necessary.

It should be carefully noted that it is impossible in a work of this description to give details of installation which cover any and every type of clock, and any manufacturer's instruction should be carefully read and rigidly adhered to.

### Clock Circuits

The principles of the electric circuit have already been dealt with in Chapter II. It is now proposed to give a few typical wiring diagrams of clock circuits.

Fig. 135 shows the simplest type of impulse clock circuit. Here all the dials are in series and the current to operate is derived from a battery of primary cells or accumulators. The voltage of this battery is governed by the number of dials in circuit, and differs with various makes of clock. As a rough approximation, one cell per dial can be allowed, and the voltage across each dial is then the same as the voltage of one cell of the battery.

The battery warning device is also connected in series, and gives a visible signal of a weakening battery some days before total failure occurs. It will be observed that in the series system shown there is only one wire running round the building, making a complete circuit linking up each dial in turn.

As has been seen in Chapter IV, some clocks generate their own energy and no battery is necessary. Other makers put a

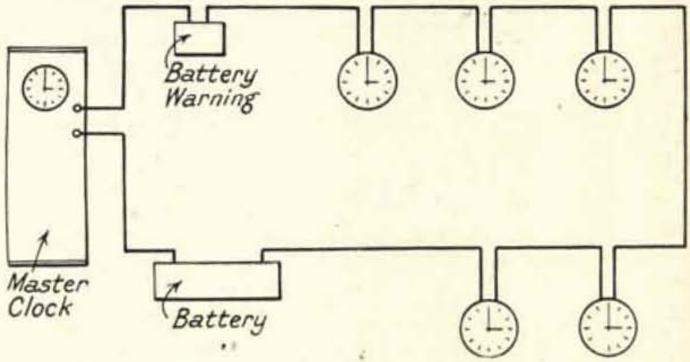


FIG. 135. SIMPLE IMPULSE CLOCK CIRCUIT

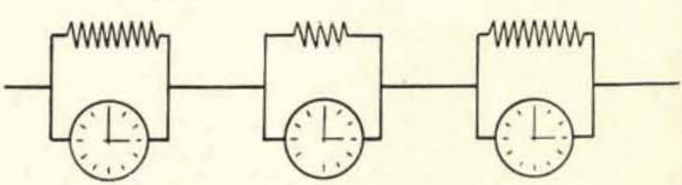

FIG. 136. DIALS IN SERIES BUT SHUNTED BY RESISTANCES

resistance in parallel with each dial, the ohmic value depending on the size of the dial movement, in which case each group of dial and resistance is connected in series with the next, as shown in Fig. 136.

Synchronous motor and other clocks worked from service mains are wired in parallel, as shown in Fig. 137, and in consequence have the full voltage across their terminals. Their insulation and wiring must, therefore, be capable of withstanding this pressure. The mains wires shown in the diagram are, of course, the existing lighting circuit wires in the house.

Impulse clocks may be worked off the supply mains, but this is not generally recommended, as there is less liability of breakdown with the lower (battery) voltage, beside which the clocks operate more satisfactorily and the cost of installation is lower.

Fig. 138, however, illustrates a method of working from direct current mains.

*D* is a resistance connected across the mains and permanently taking a small current. The voltage drop across any

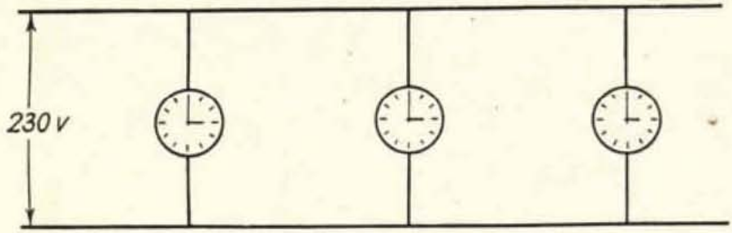


FIG. 137. CLOCKS CONNECTED IN PARALLEL ACROSS MAINS

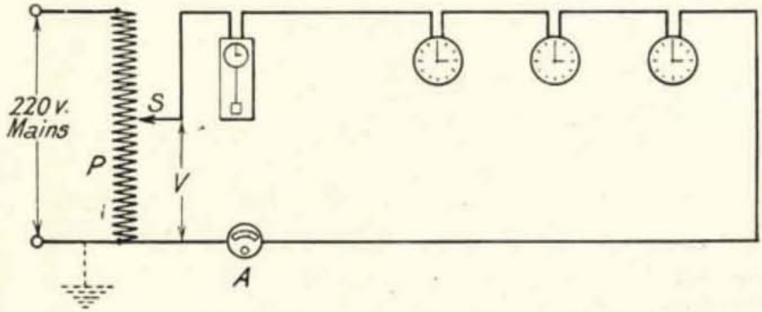


FIG. 138. OPERATION OF IMPULSE CLOCKS DIRECT FROM D.C. MAINS

section of it is exactly proportional to its resistance. That is, if the total length of the coil is 6 in., and the main voltage 600, there will be a drop of 100 volts for every inch. The one terminal of the clock circuit is connected to one end of the resistance, and the other end is connected to the slider *S*, the position of which is so adjusted that the voltage *V* is equivalent to the required battery voltage, or, in other words, the current indicated by ammeter *A* represents the normal working current of the dials. When a resistance is used in this manner, it is called a potentiometer.

It should be noted that one side of all commercial electric supply mains is connected to earth, as shown by the dotted lines, and a person touching any live part of the clock movement is liable to receive a shock, even though the voltage as set by the potentiometer is low. For the same reason the insulation of clocks and wiring must be capable of withstanding the full mains voltage.

Fig. 139 represents a method of driving an installation from alternating current supply mains. Here the voltage of the

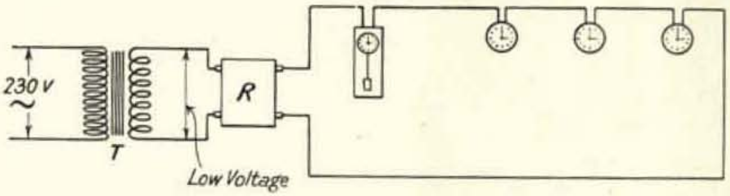


Fig. 139. Operation of Impulse Clocks from A.C. Mains

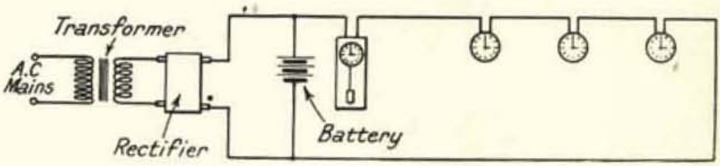


Fig. 140. Operation of Impulse Clocks by Accumulators Trickle-charged from A.C. Mains

mains is reduced to that required by the clocks by means of the transformer $T$. There is no connection between the two windings of the latter, and so there is no necessity to guard against insulation breakdown and shock as in the case of direct current mains mentioned above. It is, however, necessary to convert the low voltage alternating current to direct current to make it suitable for operating the clocks. This is done by an apparatus known as a rectifier shown at $R$. There are no moving or liquid parts in either the transformer or the rectifier, so they require no maintenance.

The disadvantage of mains operated systems is, that if the supply fails for any reason all the clocks stop. This can be overcome very simply and very successfully in the case of A.C. mains by adding an accumulator as shown in Fig. 140.

The clocks now operate from the battery as in an ordinary installation, the accumulators being constantly charged at a very low rate—technically known as trickle-charged—from the mains. In the event of the electricity supply being cut off for any reason, the battery will continue to run the clocks for several days, if necessary. Supply breakdowns are, of course, comparatively rare, and are generally only of short duration.

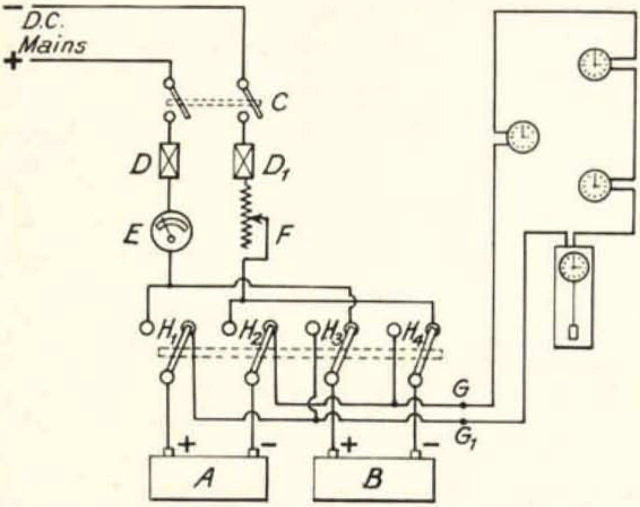


FIG. 141. OPERATION OF CLOCKS FROM D.C. MAINS USING TWO BATTERIES

Where alternating current supply is available, this trickle-charged battery method of operating the clock installation is undoubtedly the best to employ.

In the case of direct current mains a similar method is not desirable for the reason that the full pressure of the mains is impressed on the clock circuit. It is not possible to transform high voltage direct current to low voltage with totally inde-dendent windings, as is the case with the alternating current transformer. The best that can be done in the case of direct current supply is to employ two batteries or accumulators, so that one set is working the clocks while the other is being charged. Fig. 141 illustrates such an arrangement.

*A* and *B* are the batteries. *C* is the main D.C. switch, and $D$ $D_1$ the fuses. The ammeter *E* indicates the charging rate which is controlled by variable resistance *F*. Sometimes one or more lamps in series are used instead of a resistance. $G$ $G_1$ are the terminals of the clock circuit. $H_1$, $H_2$, $H_3$, $H_4$ are four two-way tumbler switches coupled to operate together. An inspection of the circuit will show that in the position shown, battery *A* is working the clocks, and battery *B* is on charge, when switch *C* is closed. Moving over switches *H* puts battery *A* on charge and *B* on the clocks. The change over from one battery to the other should be done between impulses, otherwise all the dials may loose half a minute. Programme controls, synchronizers, relays, and similar devices are wired in series with the standard clock dials. The circuit to the bells, hooter, or other signals is entirely separate from the clock wiring, and is operated by a separate source of current.

Having discussed the various circuit arrangements, we will proceed to a consideration of the installation of the various units.

## Installation of the Master Clock

Before proceeding further it should be pointed out that although primarily referring to the master clocks of impulse systems, most of the following remarks apply equally to other clocks where it is possible to apply them. Generally, however, the other types are confined to domestic use, and considerations other than that of accurate time-keeping enter into the choice of site, etc. Synchronous motor clocks are in a class by themselves, as their time-keeping depends entirely on an outside agency, and they will work under almost any conditions.

One of the essentials of accurate and regular time-keeping of a master clock is that it must be rigidly fixed and level. The pendulum alone often weighs 16 lb. or so, thus there is considerable weight to support. Where possible, the master clock should be mounted against a thick masonry wall which is free from all vibration. The wall chosen should preferably be in the lower part of the building, a basement wall being ideal. A wood partition should on no account be employed. The room should be one which is dry, and free from dust and injurious vapours, and the clock should not be subjected to extremes of temperature, or draughts. The clock should be fixed so that the centre of the dial is approximately at eye level. This allows the mechanism to be inspected and adjusted with a minimum of trouble.

All makers supply some device to indicate when the clock is vertical, such as a mark on the top and bottom of the case. A plumb line is held against the upper mark and the case moved until the bob comes in line with the lower mark. In fixing a clock the best method is to securely fasten two or three wooden battens about 9½ in. wide to the wall, and mount the clock case on these. Put in one fixing screw first, level the case, and put in the remainder of the screws.

Clocks are invariably delivered with the pendulum, and sometimes other parts detached, and the makers instructions in the fitting of these should be scrupulously followed.

## Battery Position

Some care is necessary in selecting a place for the battery, whether it be composed of accumulators, primary cells, or dry cells. The room should be cool and well ventilated. The cells themselves should be mounted on a shelf or cupboard, or in a box with a ventilated and easily removable lid. A battery mounted in a hot and dry position will require frequent attention owing to loss of electrolyte by evaporation. All terminals should be coated with vaseline to prevent corrosion, and great care should be taken to make all connections tight.

In the case of accumulators charged from service mains a rubber floor mat should be provided adjacent to the battery and charging board to prevent accidental electric shock. The battery warning indicator if provided, need not necessarily be near the battery. It should be placed somewhere in the building where its warning will be quickly noticed. It may be mentioned in passing that a bad contact between cells of the battery may cause the warning to operate, even if the cells are fully charged.

## Clock Mounting

Owing to the variety of size, shape, and patterns of clock dials available there is little that can be said. The fixing in any case is quite straightforward. Due to the small size of the movement and the fact that no further attention is necessary after installation, it is often possible to put an electric clock where it would be impossible to place a mechanical one.

Clocks for use in damp or steamy atmospheres should be mounted in cast-iron or bakelite casings. Where the noise of the ordinary movement is objected to, a silent movement should be fitted. Portable clocks, either battery-driven or electrically-wound, should be kept as far as possible in a position free from extremes of temperature. Too often the domestic clock stands on the mantel shelf, and is heated from the fire during the day, and subjected to an extremely low temperature during the night hours. There seems little possibility of these conditions being altered at present, and designers of the clocks and those responsible for the installation and maintenance have to make the best of circumstances.

## Wiring Systems

From the purely electrical point of view, clock circuits are of the simplest possible character. The current, too, is invariably very small, and only a small size of cable is required, so that at first sight it would seem that there is little to warrant consideration here. The subject of wiring is nevertheless important. In addition to carrying the current to operate our clocks, the wiring must be insulated so as to prevent leakage and short circuits; it must be protected to withstand ordinary wear and tear, and if it is in any way connected to a public supply of electricity, it must comply with the regulations and pass the tests of the supply authority concerned.

It has already been mentioned that more often than not impulse clocks are operated from comparatively low voltage batteries, whereas synchronous motor and electrically-wound clocks are always driven from the supply mains. Thus a system of wiring may be quite suitable for a low voltage system but quite impossible for mains-operated clocks. We will now consider the various wiring systems in use.

Copper wire is invariably used for wiring. Small cables have a single conductor, while larger cables have several such wires stranded together, and flexible cable is made up of a large number of very fine wires bound together. Cables may be insulated with cotton, rubber, paper, paraffin wax—a combination of several being used according to requirements. Bare copper wire is never used except for outdoor lines.

The simplest form of wiring, which is only applicable in some cases, is to use single bell wire without further protection, securing it as necessary with insulated staples.

This comprises a tinned copper conductor, No. 18 s.w.g., insulated with rubber sleeving and two layers of cotton, and

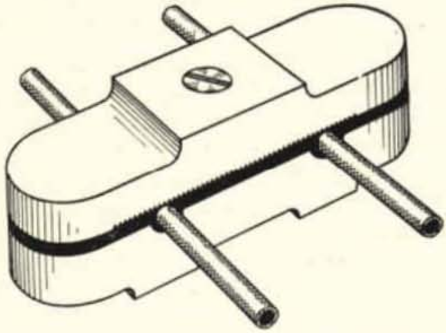

FIG. 142. V.I.R. CABLE CARRIED IN PORCELAIN CLEAT

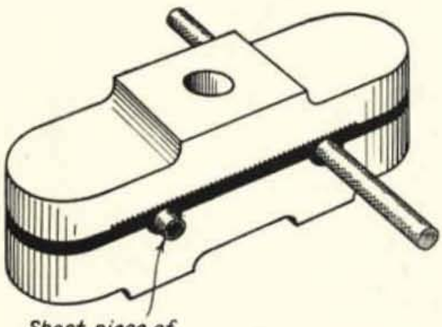


FIG. 143. SINGLE CABLE CARRIED IN CLEAT

impregnated with paraffin wax. It is cheap and easily run, and is unobtrusive, but liable to be damaged. It is generally suitable for small installations in private houses. It should not be used in damp situations.

A similar but more reliable method is to use electric lighting cable, size 3/036 in. Besides being a heavier conductor and, therefore, not so likely to break, it has considerably more strength of insulation. It is insulated with several layers of vulcanized india-rubber, which is a good insulator, does not absorb moisture from the atmosphere, and is waterproof when new, and will remain so for a number of years, in favourable

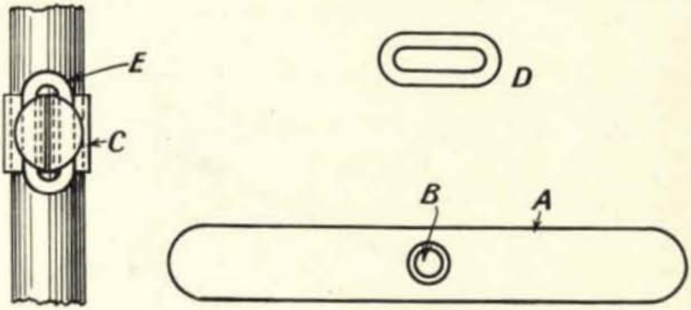


FIG. 144. CABLE CLIP, HENLEY WIRING SYSTEM

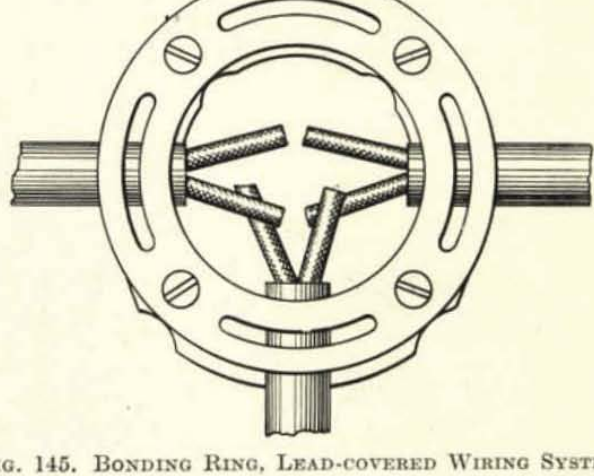

FIG. 145. BONDING RING, LEAD-COVERED WIRING SYSTEM

situations. It is further protected with a layer of tape and a serving of waxed braiding. It can be obtained coloured black or red, which is often an advantage as it permits easy identification of cables. It can be used in almost all situations where it is not likely to suffer severe mechanical damage, and can either be fixed by insulated staples directly against the walls or joists, or can be carried on porcelain cleats in the manner shown in Fig. 142.

If, as is usually the case, only one cable runs from clock to clock, a short length of similar cable should be put in each unoccupied side of the cleat to keep the top level, as shown in Fig. 143. Flexible lighting cord should never be used for permanent wiring.

These unprotected wiring systems must only be used on low voltage installations, not exceeding, say, 50 volts. For pressures above this, or in cases where more mechanical protection is desired, one of the following systems may be used.

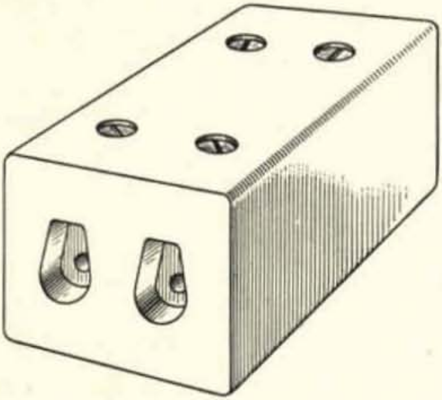

FIG. 146. PORCELAIN CONNECTOR

These are suitable for high voltages, and from this point onwards the information is applicable to both impulse and mains-driven clocks.

The simplest mains wiring system is that employing a conductor which is sheathed in a tube of lead alloy. It is obtainable having one, two, or three conductors. This class of wiring possesses the merit of being quickly run, requires little space, and is inconspicuous when fixed. The lead covering affords fair mechanical protection to the conductors, but is not, of course, proof against piercing by nails. Several lead-covered wiring systems are on the market, and each has its own method of securing the wiring and effecting joints and tappings. It is essential that the lead covering of the completed installation be electrically continuous, thus, where the sheath is cut away, as, for example, when a joint or connection is made, it is necessary to join the finish of the covering of one run of tube to the start of the next one. The casing is connected to earth in one or more places. If for any reason the casing becomes "alive" the fuses will then blow and prevent further trouble.

Fig. 144 shows how the cable is secured to walls, etc., in the

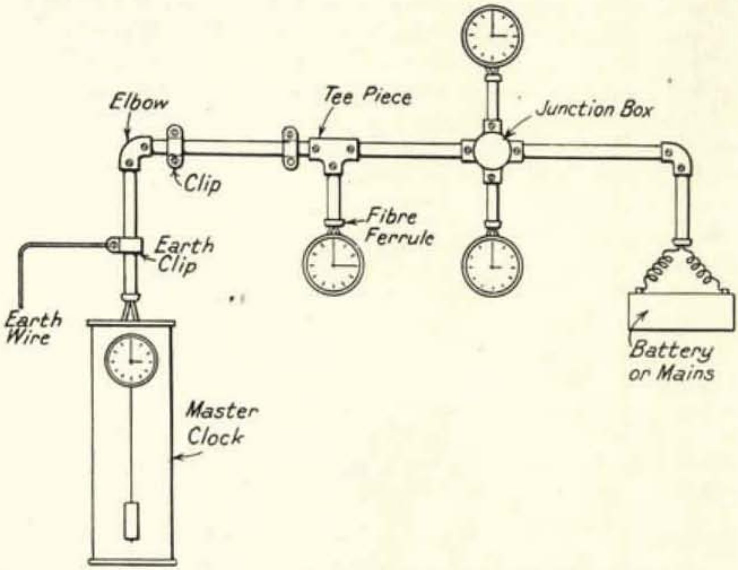


FIG. 147. CLOCK INSTALLATION WIRED IN CONDUIT

Henley wiring system. The clip *A* is first fixed by means of a screw or nail inserted through hole *B*. The cable is then rested upon it and the sides of the clip bent up as shown at *C*. Loop *D* is then threaded on to the bent up ends, pressed right down, and the ends bent back as shown at *E*.

Fig. 145 shows a bonding ring securing three cables. The box on which it is mounted is not shown. The joints in the wiring are subsequently made by small porcelain connectors, such as shown in Fig. 146.

The most reliable method of wiring and the one which should always be used in high-class work, is the Conduit system, in which the cable is drawn into steel tubing. This is naturally more expensive than the systems previously described, and unless put in during the erection of buildings is liable to be rather unsightly, although in factories this is not a serious objection.

For the wiring of clocks using a single 1/·048 diameter cable (i.e. a cable, the conductor of which comprises one conductor only ·048 in. diameter) ½ in. conduit is satisfactory, but where two or three cables of this size have to pass through one tube it is preferable to use ⅝ in. diameter tubing.

Various fittings are available such as bends, tees, and junction boxes to facilitate erection and wiring. There are two varieties of conduit—"screwed" and "grip fix." The former type is the better but is more expensive. In this system the lengths of tube are screwed into the joint boxes, bends, etc. In the cheaper method the piping is secured by grub screws. It is essential that electrical continuity be preserved throughout the length of the tubing, which is connected to earth. Conduit is supplied in lengths of 10 to 15 ft., and is cut up as required. For straight runs of greater length than this it is necessary to insert a coupling piece. In carrying out an installation of clocks in conduit the tubing is first erected completely, but not secured to the walls. The cable is then drawn in as required, this being done one section at a time, and a fish wire used to draw the cable through. When the wires are complete the tubing can be fixed in position and all the grub screws tightened.

Fig. 147 shows a simple clock installation carried out in conduit.

Where wiring has to be run across open spaces the bare cable can be used fixed to porcelain insulators in a similar manner to telephone wires, but it is generally advisable to use insulated wire, to obviate risk of the wires swinging together and causing short circuits.

## Wiring of Synchronous Clocks

Owing to its popularity the synchronous clock requires special mention. To be of any use as time-keepers these clocks must be permanently wired to the mains, an expense to which the average purchaser of a cheap clock is not inclined to go.

Power points are not so plentiful in the modern house as to enable one in each room to be monopolized for working the clock. Further, the fuses in the power circuit are usually about 15 or 30 ampere, and a clock developing a fault would be badly damaged before a heavy fuse like this could clear it.

The simplest way of wiring is to connect the clock to the live side of one of the power points, and insert a very fine fuse between it and the clock. George H. Scholes & Co., Ltd., of Manchester, have produced the little accessory shown in the illustration, Fig. 148, known as the WYLEX FUSED CLOCK CONNECTOR. It consists of a bakelite casing in which are two ½ ampere fuses. A lead is taken from the supply to one section of the device, the lead to the clock being taken from the other.

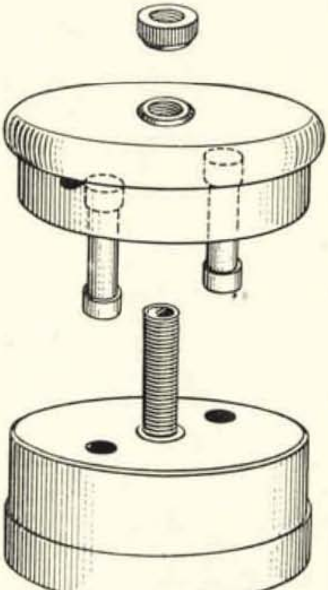

FIG. 148. "WYLEX" FUSED CLOCK CONNECTOR

Joints in wires should always be soldered using only resin as a flux. The use of any other flux is liable to give trouble sooner or later owing to electrolytic action in the presence of moisture.

## The Maintenance of Primary Batteries

LECLANCHÉ CELLS. The Leclanché cell when fully charged gives an E.M.F. of 1·5 volts per cell. The size generally recommended for a clock installation is the "heavy duty" or three-pint size. The Leclanché cell is capable of supplying current intermittently for a long period per charge, and given a suitable position a battery should last for twelve months or two years.

The construction of the cell has already been described. As delivered, the porous pot is received with the carbon plate and surrounding mixture of carbon and manganese peroxide sealed in position. This material does not require renewing throughout the life of the battery. To set the battery in operation, the porous pots and zinc rods are placed in the glass jars.

The cells are connected in series, so that the wire from each zinc rod is secured under the terminal nut of the carbon on the adjacent cell.

To charge the cell about 4½ oz. of sal-ammoniac is placed in the bottom of each (3-pint) cell, and rain water added, to bring the level of the liquid about 2 in. from the top. The cells should never be filled right up, and great care must be taken not to spill the water on the tops of the jars, porous pots, or battery shelves, or "creeping" of the solution will take place. After charging, the tops of the outer jar, zinc rod, porous pot, carbon plate, and its terminal should be given a good coating of vaseline to prevent corrosion taking place. Great care must be taken that all terminals are tightly screwed down. This liability of the solution to "creep" over the sides of the cell is the one disadvantage of the Leclanché cell, and too much care cannot be taken to prevent it. Once creeping starts, it is very difficult to stop, and impossible to keep the battery shelf or cupboard clean and tidy, besides which the efficiency of the battery deteriorates.

RECHARGING THE LECLANCHÉ CELL. As mentioned above, the Leclanché battery may be expected to last two years or more. It is a good plan to inspect the battery once every three months, and to recharge, whether it appears to want it or not, every two years.

At the three months' inspection the general condition of the battery should be noted. Any cell showing signs of creeping should be taken out and overhauled. The voltage of each cell should be checked and any loss of electrolyte due to evaporation made good by addition of distilled or rain water. If the zinc rods appear to be of a deep black colour, it is an indication that the battery is being overworked, possibly through leakage. This can be detected by inserting a milliammeter in series with the battery. If the solution has a milky appearance it indicates that it is too weak, and more sal-ammoniac should be added. When completely recharging the battery proceed as follows. Dismantle all the cells and throw away all the old solution. Fill all the outer jars with clean water, and put about a tablespoonful of spirits of salts (hydrochloric acid) into each and allow to stand for several hours. Meanwhile, scrub the porous cells and zinc rods thoroughly to remove all adhering crystals. Any zincs badly worn should be discarded and replaced by new ones. Next, stand the porous cells in water to which has been added some spirits of salts. After standing, rinse out all the cells, drain surplus liquid from the porous pots (by inverting them), thoroughly clean all the terminals, reassemble the battery, and proceed to charge as directed above. The battery cupboard should meanwhile have been scrubbed out and allowed to dry.

To overhaul the battery as described above takes some little time, and necessarily puts the clocks out of action. It can generally be done during a week-end without causing inconvenience, but in cases where the clocks must be kept going the writer substitutes a radio high tension dry battery costing a few shillings. The charging of any other type of primary battery can be carried out in a similar manner, using the appropriate solutions. The golden rules of successful battery maintenance are regular attention and cleanliness.

Dry cells cannot, of course, be recharged. When they show signs of weakening ,they are discarded and replaced by new ones. A dry battery of the normal electric bell size and of good make can be expected to work a clock installation for three years or more without attention. It will fail earlier if housed in a warm place, owing to the drying up of its constituent chemicals. Replacement batteries should preferably be obtained from the manufacturers to ensure their freshness. Batteries obtained from local electricians have sometimes been in stock for a long period, and soon fail when put to work.

### Accumulator Charging and Maintenance

The correct charging and treatment of accumulators is very important. Even a little neglect will quickly ruin a good battery. Makers' instructions which differ slightly one from the other should be followed to the letter.

The first charge of an accumulator is very important, and should be carried out as follows. Fill each cell with dilute sulphuric acid 1·180 specific gravity, and charge for at least twenty-four hours *continuously* at two-thirds the normal charging rate, as stated by the makers. Pure brimstone sulphuric acid should only be used, and not the ordinary "commercial" variety, and for diluting it use distilled water. Acid ready diluted is obtainable, or it may be made up, checking the specific gravity with a hydrometer. Pour the acid *slowly* into the water, stirring continuously.

Certain types of accumulators are known as dry first charged, and only need the addition of electrolyte to make them ready for use. Even with these, however, a long initial charge does no harm.

Only direct current can be used for charging accumulators, and the positive pole of the supply must be connected to the

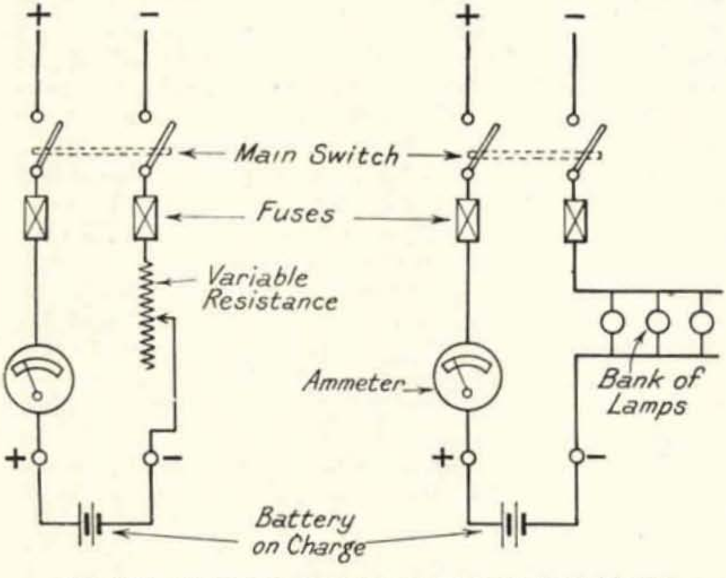


FIG. 149. CHARGING ACCUMULATORS FROM D.C. MAINS

positive terminal of the accumulator. Each cell when fully charged should have a voltage of 2·4. This quickly drops to about 2·0 when in service at which it remains steady until nearly discharged, when it drops to 1·8. Any attempt to discharge the battery below 1·8 volts per cell will cause irrepairable damage to the plates.

During charging the specific gravity of the electrolyte will rise to about 1·25. Ordinary charging should take about eight hours, the charging current varying with the size of the cell, and is always stated by the maker. Charging above the normal rate causes harmful heating and gassing. Charging is complete when the voltage and the specific gravity have attained steady values, and the plates are gassing freely.

During charging the vents of the cells must be removed, and no naked light brought near as the gases evolved are highly explosive.

Apart from the regular charging, accumulators require little maintenance to keep them in good order. The electrolyte should reach to about ¼ in. above the level of the plates. Loss of electrolyte should be made good by adding distilled water only—*not* acid—as it is only the water which evaporates. The accumulator should never be allowed to stand for any length of time in a discharged condition as sulphation of the plates will quickly set in and ruin them. Smear all the terminals with vaseline to prevent corrosion.

Fig. 149 shows two methods of charging accumulators from direct current mains. The current is regulated by the resistance of the number of lamps required to give the charging current recommended by the makers, as shown by the ammeter. When charging is done from A.C. mains it is necessary to include a transformer (to reduce the voltage), and a rectifier to convert to direct current, as has already been described in a previous section of this chapter.

### Clock Maintenance

The only attention required by clocks of all kinds is occasional lubrication of working parts. Newly-installed pendulum clocks also require regulating.

### Oiling

Only the finest clock oil should be used for lubricating. Ordinary oil is fatal. Even the correct oil should be used very sparingly. A piece of wire about 18 gauge, flattened at the end, forms the best oiler.

All pivots of the mechanism must be oiled, one drop only for each. The oiling should be carried out methodically so as not to miss any of the points requiring lubrication, and any dirt or fluff seen anywhere in the mechanism must be removed before oiling. Dirty oil should also be wiped away, using a clean duster free from fluff. In impulse clocks it is important *not* to oil the face of the pallet down which the impulse roller runs, as such oil is likely to retard the fall of the arm.

**Regulating**

Regulation of pendulum clocks is carried out in raising or lowering the bob by rotating the milled nut on which it rests. The rating nut is usually graduated. A movement of one division causes the clock to gain or lose one second per day according to the direction in which the nut is turned.

Another method of regulation, and one which should be used for all fine adjustments, as it does not involve stopping the clock, is to add a small weight to the pendulum. Adding the weight *above* the bob raises the centre of gravity, and so causes the pendulum to swing faster and the clock to gain. The addition of the weight *below* the bob lowers the centre of gravity, thus slowing the pendulum. Most high-class clocks are provided with a tray for the purpose of carrying these fine weights, but domestic clocks rely on the adjustment of the rating nuts. Accumulation of dust on the top of a pendulum is sometimes sufficient to cause a clock to gain.

Synchronous motor clocks cannot be regulated by the user, and all that can be done in the case of faulty time-keeping is to communicate with the electricity supply authority.

**Faults**

Owing to the number of makes of clocks available all having different constructions and working principles, it is impossible to give any definite information regarding the location of faults. The best advice that can be given to the reader is to make himself acquainted with every detail of the installation under his care, and in case of trouble, the cause of which is not immediately apparent, the makers should be communicated with at once. Do not attempt to adjust the mechanism unless certain of the cause of the breakdown. In the case of stoppage, ascertain that the battery or electricity supply has not failed. If this proves in order look for a breakage in the circuit, short-circuiting each dial and section of wiring in turn. If a break has occurred in the windings of a clock, short-circuiting its terminals will allow the rest to go on working. A faulty connection between cells sometimes causes trouble. The stoppage of synchronous motor clocks may be due to a break in the windings, or the blowing of a fuse in the house circuit; or a momentary drop in voltage such as caused by a "short" in some other circuit in the house may be sufficient to stop the clocks.

## CHAPTER XIV

### LATEST DEVELOPMENTS

SINCE the writing of the previous chapters, the development of electric clocks has proceeded apace—particularly with regard to the Synchronous Motor Type, and many makes are now available.

The principal developments have been in the direction of domestic striking and chiming movements, an example of each of which it is now proposed to describe. There have also been developed alarm clocks, bichronous clocks which have a spring movement to carry on, in case of supply failure, and new types of control clocks.

**The Synclock Striking Clock.** The principle underlying the design of this clock is as follows—

The hands are driven in the usual way by a Warren self-starting synchronous motor whose construction has been fully described in Chapter VI.

The motor in turning the hands also winds a small spring, which is released at the hour and half-hour to drive the striking mechanism.

Fig. 150 shows a complete movement in which $A$ is the driving motor, $B$ the spring barrel. The motor is coupled to the spring in such a manner that during twelve hours the number of revolutions made by the driving end of the spring is exactly equal to the revolutions of the driven end, so that the only work the motor is called upon to do is to store some energy during the small hours to be given up again as midday or midnight is approached.

The movement is ingeniously designed so that the setting of the hands also gives an initial wind to the spring.

A slipping device is fitted inside the spring case to prevent damage should the spring be accidentally over-wound.

Except for the small size of the spring, the design of the striking train follows usual practice.

$C$ is the star wheel which revolves when the train is released, and actuates the hammer lever spindle $D$. (The hammer and

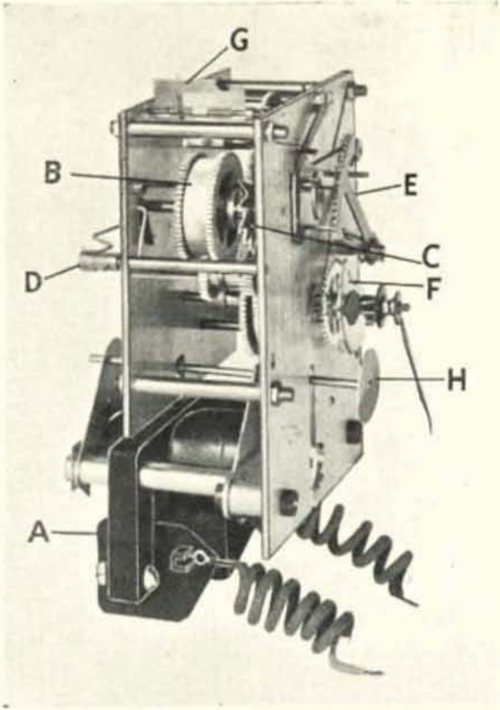


FIG. 150. THE "SYNCLOCK" STRIKING MOVEMENT

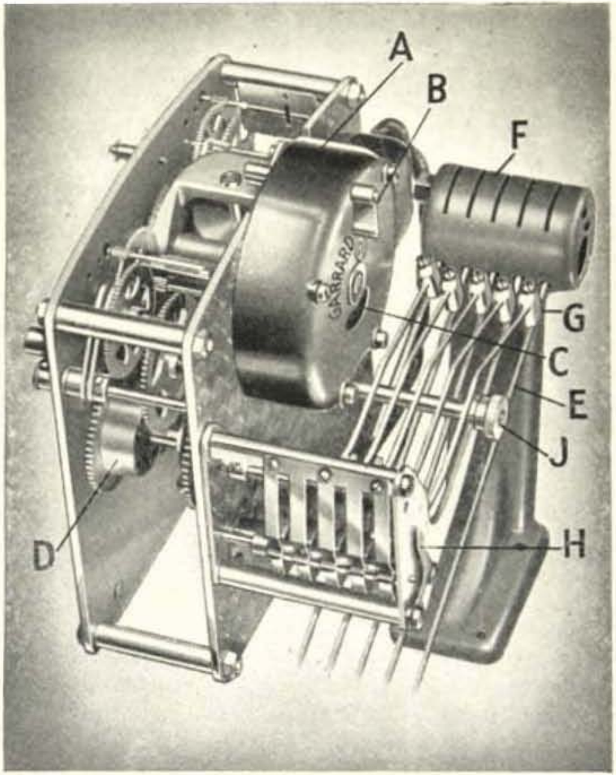


FIG. 151. MOTOR AND CHIMING ACTION OF THE GARRARD MAINS ELECTRIC CLOCK

gong are not shown.) *E* is the rack which, in conjunction with "snail" *F*, controls the number of strokes in striking, while the fly *G* controls the rate of striking.

*H* is a continuity indicator, and consists of a disc having two segments, one white and the other red.

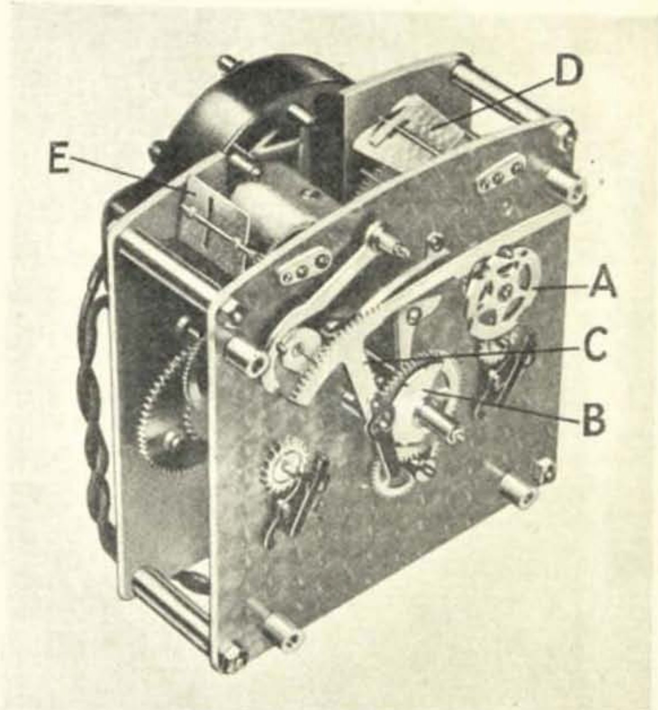


FIG. 152. MOVEMENT OF THE GARRARD ELECTRIC CHIME CLOCK

A slot in the dial enables half of this disc to be seen. Normally, only the white portion is visible, but in the event of a current failure the red portion comes into view.

**The Garrard Electric Chiming Clock.** The general design of the Garrard mains-driven chiming clock consists of a self-starting synchronous motor which drives the hands, and at the same time stores power in two small springs which are arranged to drive the chiming and striking trains when released at the appropriate times.

The motor is enclosed in a bakelite case.

The stator coil is circular in form, and is enclosed in two pressed steel housings, which are interleaved to produce alternate magnetic poles.

The rotor runs at 200 r.p.m., and is completely surrounded by the stator. The motor is arranged for hand starting.

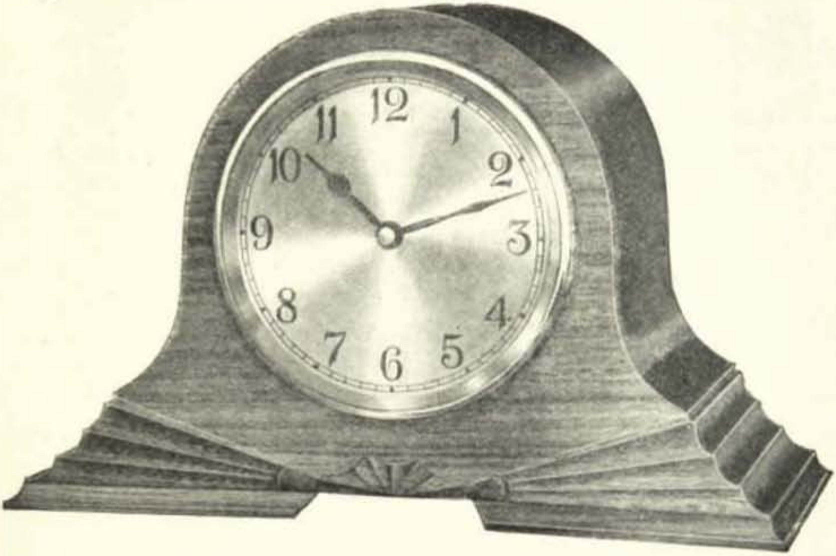

FIG. 153. GARRARD ELECTRIC CHIMING CLOCK

A sectored disc on the rotor spindle can be viewed through a slot in the rear of the motor casing to indicate that the clock is in motion.

The first two stages of speed reduction are through worm gears, after which the gears are of the usual clock type.

The general construction of the chiming and striking movements follows that of the Garrard spring chiming clock.

The setting of the hands is done from the rear, and a key is provided to give the chiming and striking springs an initial wind.

Referring to Fig. 151, *A* is the motor, *B* the starting lever, and *C* the slot for the indicator disc.

*D* is one of the two spring barrels.

Five chiming rods, *E* secured in the casting, *F* are provided.

The hammers *G* can be raised clear of the chiming rods by the lever *H*, so silencing the clock when required.

*J* is the hand-setting lever.

Referring now to Fig. 152 which gives a front view of the movement, *A* is the count wheel for the chimes, which operate every quarter of an hour.

*B* is the striking snail, against which the tail end of rack *C* drops when released by the "warn," the depth of drop of which governs the number of strokes.

*D* and *E* are the flies for the control of the chiming and striking speeds.

The clocks are supplied in a range of cases and arranged for Westminster Chimes.

A neat two-pin connector is fitted for attachment of the flexible connecting cord.

Fig. 153 gives an external view of the Garrard Electric Chiming Clock. The improved appearance due to there being no winding key holes is marked.

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