ASTRONOMICAL REGULATORS

AND

OBSERVATORY TIME INSTALLATIONS

●

TOGETHER WITH A BRIEF ESSAY ON THE

FREE PENDULUM

AND THE GENERAL PRINCIPLES OF THE

SYNCHRONOME SYSTEM

ON WHICH IT IS BASED

●

THE SYNCHRONOME COMPANY LTD.

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Printed in England for the Synchronome Co. Ltd.

THE SYNCHRONOME

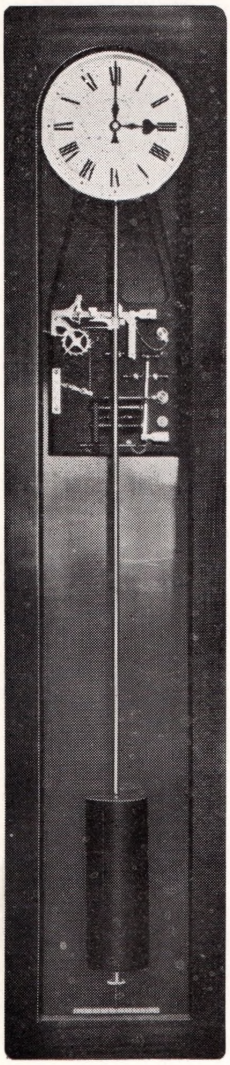

Fig. 1

STANDARD

ELECTRICAL

CONTROLLING PENDULUM

OR

MASTER CLOCK

●

AN ELECTRICAL

TIME TRANSMITTER

USED TO OPERATE

CIRCUITS OF

ELECTRICAL IMPULSE DIALS

●

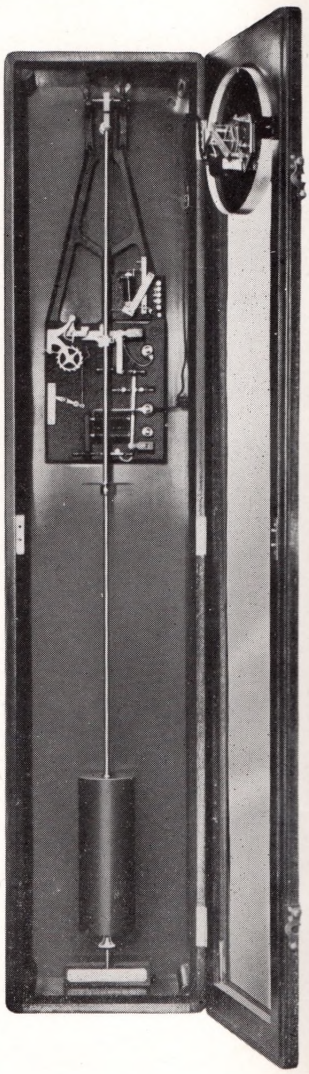

Fig. 1a

OBSERVATORY TIME INSTALLATIONS

THE SYNCHRONOME SYSTEM

In order that the method of operation of the Synchronome "Shortt" Free Pendulum Astronomical Regulators described in the second half of this pamphlet may be properly understood, it is necessary first to describe briefly the general principles of the SYNCHRONOME SYSTEM, whose standard time transmitter with seconds pendulum is shown in Figs. I and Ia, and is used as a "Slave".

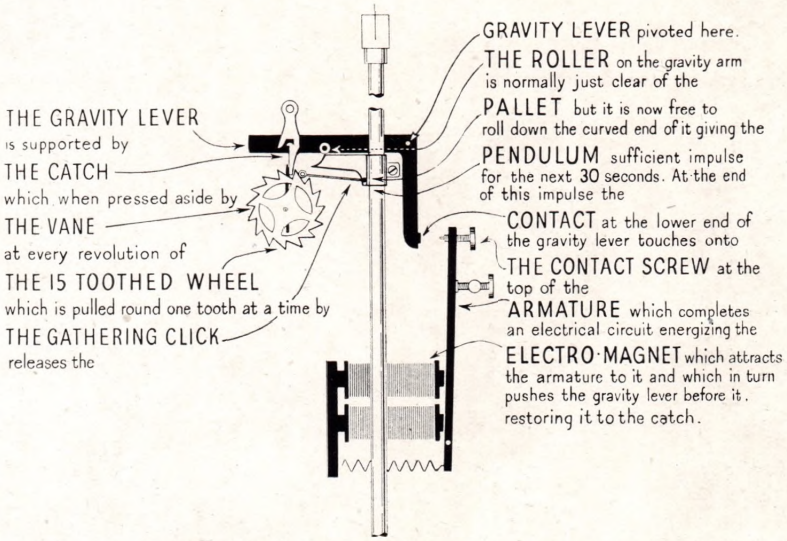

Fig. 2

THE FUNDAMENTAL UNITS

The unit of time measurement is the pendulum. It is combined with a switch, the unit of remote control, and the method of their reciprocal automatic operation is known as the Synchronome "Remontoire". The switch consists of two moving parts : the right-angled lever, and the vertical armature A, both shown in black in Fig. 2, which is self-explanatory.

At the moment of release the sloped face of the bracket or pallet has just *not* passed under the roller (from left to right) and the pendulum has just *not* reached its mid position. Thus the impulse is given while the pendulum is passing through its zero or central position, and the pendulum is quite free at the ends of its swing. The escapement is therefore not only detached but operates at zero and thus fulfils the horologist's ideal. The shape of the pallet has been determined mathematically, so that the impulse commences very gradually, increases to its maximum at zero and then decreases in an identical manner.

IMPULSE OF THE PENDULUM

The electrical contact, occuring at each half-minute precisely, is perfectly clean in the make and break. The gravity lever moves into contact at the speed of the moving pendulum and the opening is performed by momentum. It is the only contact in the system and owing to the fact that the whole of the energy required to keep the pendulum swinging is transmitted through the contact surfaces, there is no question about its reliability.

THE CONTACT

A Main wheel
B Electro-magnet
C Armature
D Armature lever
E Driving click
F Driving spring
G Backstop lever
H Momentum stop
I Stroke limit stop

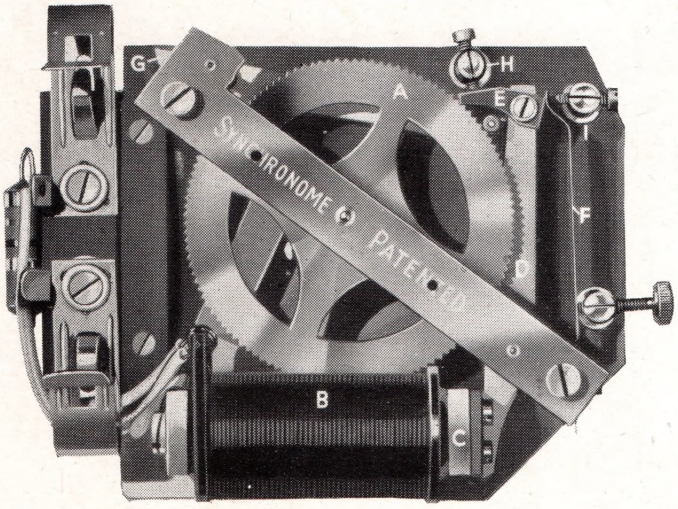

Fig. 3

Under normal circumstances the switch operates and the circuit is broken before the current has reached its maximum value so that a drop in the battery voltage merely results in a reduction in the rate of growth of the current and the reduced voltage is compensated by an *increase in the duration* of the contact. In consequence a very considerable voltage drop can take place before the magnet refuses to throw up the lever. When that happens the circuit

COMPENSATORY ACTION

remains closed until the pendulum on its return swing comes to the assistance of the magnet. The duration of the contact is therefore increased thus giving a visible and audible warning of the impending failure of the batteries. The pendulum will usually continue to operate under battery warning conditions for some days and only ceases to do so when the current has fallen so low that the magnet plays practically no part in the lifting of the lever, and ultimately if it is allowed to stop, the contact is held open, consequently the battery is prevented from committing suicide.

BATTERY WARNING

The unit above described serves as a never-failing automatic transmitter for the operation of electrical impulse dials. Thanks to its perfection, dial movements of ideal simplicity as illustrated in Fig. 3 can be used with confidence that they will keep in step.

From the movement as illustrated, it will be understood that the electromagnet B receives an impulse every half-minute which attracts the armature C and by means of the lever D enables the click E to drop one tooth down the wheel A. The spring F then propels the wheel A and the minute-hand attached to it one half-minute. The stops H and I are so arranged that the wheel is locked at every point in the cycle of operations, yet is capable of being freed at any moment by merely lifting the backstop lever by depressing its tail G.

DIAL MOVEMENTS

The Synchronome Switch is so designed that its minimum operating current is greater than the minimum operating current of any dial or other instrument in the circuit, and, as all the operating magnets are in series, the circuit has considerable self-induction and the current takes some hundredths of a second to attain its full value. Consequently it is impossible for the switch to operate without supplying sufficient energy to the dials or other instruments to propel them.

SUFFICIENT CURRENT ASSURED

In conclusion it should be stated that the history of the Synchronome System on which the Free Pendulum is based is the story of a consistent endeavour to obtain reliable electric contacts from clock mechanisms or their pendulums without taking energy from either.

THE HISTORY OF THE SYSTEM

The first of a long series of patents was taken out in 1895 and the Synchronome Company was then established by Mr. F. Hope-Jones, who read a Paper in description of the new system before the British Horological Institute in that year. Numerous lectures followed and the scientific world has bestowed many honours upon the system including Medals of the Royal Society of Arts, the British Horological Institute and the Franklin Institute of Philadelphia.

Electric time service has been established as a recognized branch of the Electrical Engineering Profession ; and British practice, as based upon its principles is generally admitted to be superior to the electric clock systems of any other country.

THE FREE PENDULUM

It will have been noticed in the foregoing description that the pendulum of the standard instrument is charged with the duty of rotating the count wheel one tooth every two seconds and with the release of the impulse lever once every half-minute, and although these operations are performed while the pendulum is swinging through its central position they rob it of energy. Whilst this energy is inconsiderable in quantity, it is nevertheless more than equal to that required to overcome the air friction of the bob. If only these two duties could be done for it, then we could truthfully call it a free pendulum, subject to no interference whatever excepting only that which is inevitable and inherent in the act of impelling it.

ENERGY REQUIRED TO COUNT AND RELEASE

For nearly two centuries it was taken for granted that nothing but the pendulum itself could unlock its maintaining force by releasing an escapement, because it alone knew the precise time and phase at which the impulse should be given. It seemed so impossible to do without it that no one even asked for a substitute. After all we can hardly blame clockmakers for not inventing an escapement which does not escape.

The problem was solved by the employment of two pendulums, one for time-keeping only which we will call the Master or FREE PENDULUM, and the other in a clock which we will call the SLAVE, since it releases the maintaining force for it. To enable the Slave to perform this escapement function for the Free Pendulum, the two must keep perfectly together—they must be synchronized. As a result of the invention of Mr. W. H. Shortt, M.Inst.C.E., two of the clocks such as we have described can be electrically linked together. His "Hit-or-Miss" synchronizer for the Free Pendulum enables the Free Pendulum to impose its timekeeping upon the Slave. The ability of the Free Pendulum to transmit a synchronizing signal without expending any energy—actually without being conscious that it has done anything at all—is due to a peculiar virtue of the system above described, the signal being derived from the fall of the gravity lever *after* it has given its impulse to the pendulum.

THE WORK GIVEN TO THE SLAVE

The arrangement and interconnection of the two clocks is seen in Fig. 4. It shows on the left the master pendulum which, because it has nothing to do but to measure time, is called the FREE PENDULUM. It shows on the right the SLAVE clock, so called because it does all the work of time-counting as distinct from measuring and releasing.

The Free Pendulum P carries a small wheel J. At every fifteenth swing to the left (at thirty-second intervals), the jewel R on the gravity lever G_1, released by the magnet E in the circuit of the Slave, falls on the wheel giving it an impulse. As the jewel falls off the wheel the end of the lever G_1 releases the Synchronome Remontoire G_2 which resets the lever G_1 by the pin S and plane T and operates the synchronizing electro-magnet H.

SCHEME OF OPERATION

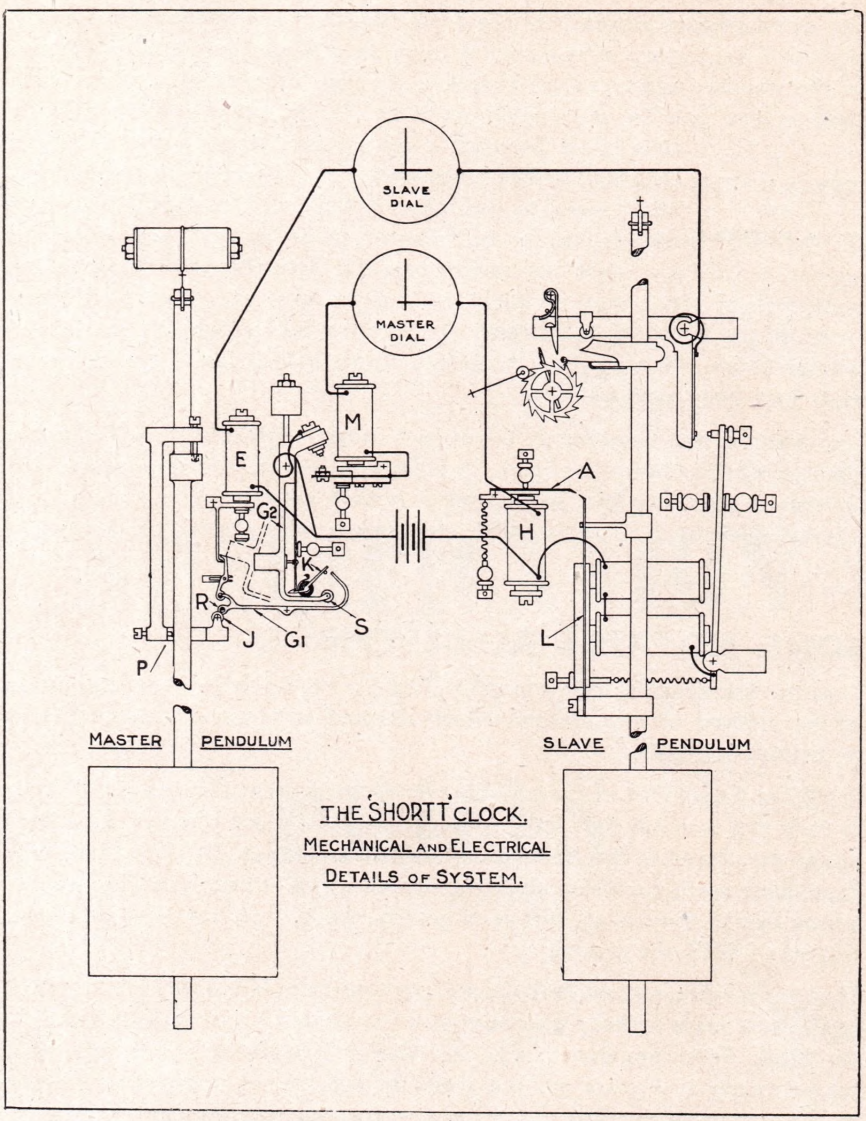

Fig. 4

The Slave Pendulum carries a vertical leaf spring on its left-hand side and the magnet H draws down a horizontal lever into its path, if it is slow, and on top of it, if it is correct or fast, which it never is, because the Slave Pendulum is rated to lose about six seconds a day or 1/480th second per half-minute. The action of the synchronizer advances its phase by approximately double this amount when the lever of the electro-magnet H engages. Consequently the synchronizing action to the Slave Pendulum usually occurs at alternate half-minutes, and that is why it is called "Hit-and-Miss". Perfect phase synchronization of the Slave Pendulum to the Free Pendulum is thus secured.

THE HIT-AND-MISS SYNCHRONIZER

DESCRIPTION OF THE FREE P'ENDULUM

THE CASE

The Free Pendulum is mounted in a cylindrical copper case, sealed at the top by a glass bell jar and at the bottom by a disc of heavy plate glass. The ends of the copper tube are flanged over substantial gun-metal rings and ground flat enabling the sealing joints to to be made direct between the copper and the glass with a thin layer of special sealing grease. The gun-metal rings are provided with fixing lugs by which the case is bolted to the wall. This should be a foundation wall in the basement or a concrete pillar let into the ground, free from the vibration of the building, and faced flat.

When sealed up, the case is exhausted to an internal pressure of 20 mm., suitable gauges being fitted in the case including a sensitive oil gauge which reveals the smallest leak. It is on record that one of these instruments ran for ten years without showing any signs of air leakage.

For suitable pumps see page 15.

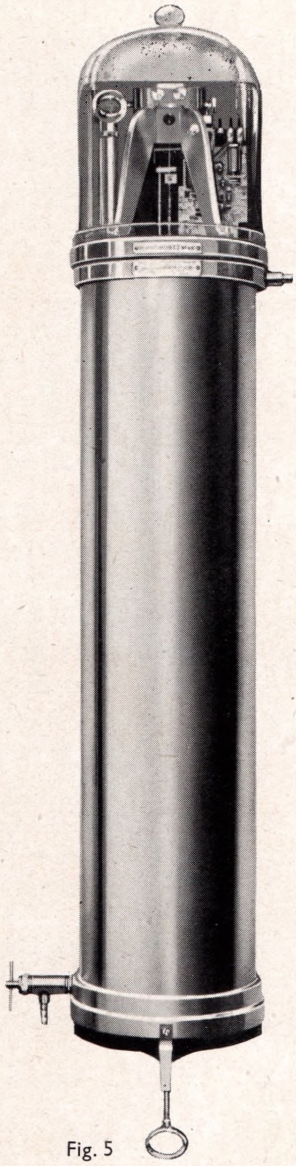

Fig. 5

Dimensions of copper cylinder :

Length - 38½ ins. (130·8 cm.)
Diameter - 9 ins. (22·85 cm.)

(Allow headroom for withdrawing pendulum)

The extraordinary accuracy of the Free Pendulum caused some embarrassment to Astronomers in ascertaining its error and stating it with confidence. As the standard against which a clock is checked is the rotation of the earth upon its axis, and the star transits by which this rotation is determined, a time chart becomes a comparison between the clock and the stars. Before the advent of the Free Pendulum, the differences were, in the main, debited to the clock; the transit observations were assumed to be correct, and would be represented by a straight horizontal base-line. The Astronomers' growing realization of the errors of individual observations and the instrumental errors of the telescope had already led them to take groups of transits and average them. Nevertheless, a perfect clock, before January 1925, could easily have been maligned.

A REVOLUTION IN TIME-KEEPING

This method was reversed at Greenwich, when their first Free Pendulum was installed in November 1924. In six weeks its rate was determined and forecast as a smooth line, so that when it took up its duty as the standard sidereal clock, on January 1st, 1925, the transits were plotted on either side of it.

SOME NOTABLE ACHIEVEMENTS

Thus the first notable achievement of the Free Pendulum caused a revolution in the method of time determination adopted at Greenwich Observatory on January 1st, 1925.

In 1927 at Greenwich, nutation was revealed though the maximum difference in daily rate was less than 0·002 of a second and the definition of Time itself had to be altered in the *Nautical Almanac* to include it. In 1929, three Free Pendulums were recorded against a quartz crystal clock, revealing a lunar period due to the diurnal change of gravity, though the maximum difference was only 0·0002 of a second.

The Free Pendulum at the Paris Observatory ran from August 1934 to July 1936, nearly two years without discoverable error (Montré une règulantè quasi—par faite). Free Pendulum No. 11 installed at Greenwich in February 1926, ran for nearly nine years without stopping, and No. 14, installed at Warsaw in 1927, ran until the Observatory was wrecked during the 1939-45 war.

On the following pages will be found detailed specifications of the Free Pendulum, Slave Pendulums, and the electrical impulse dials and accessories.

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THE PENDULUM

The pendulum rod is of fixed length rated to beat seconds, Mean Solar Time or Sidereal, in the latitude in which it is to be used. It is made of Stabilized Invar. The bob is also of Invar and weighs 14 lbs., supported on its centre, the support being pinned to the rod.

The Pendulum is fully compensated, the co-efficient of every rod and all its component parts being tested by the National Physical Laboratory at Teddington. Nevertheless, it is desirable that the temperature of the clock chamber should be kept constant by means of thermostatically controlled heaters with a fan to operate when they are cut off, to prevent stratification of the air.

A beat plate is provided at the bottom of the rod for reading the arc. Our standard method is to read it through a reflecting mirror on a fine line zero which enables one to read within one minute of arc. An alternative method is to use a reflecting microscope by which the arc can be checked to within four seconds direct on a micrometer scale and finer by interpolation. The extra price for reflecting microscope with its micrometer traverse and diamond engraved beat plate will be quoted on application.

THE MOVEMENT

The movement is of the finest workmanship. Its moving parts are fitted with sapphire jewel holes and end-stones.

Imparting an impulse to a pendulum is, technically, an interference, but it is reduced to a minimum in this instrument. The impulse is given once every half-minute and consists of gravity pressure upon a finely-pivoted wheel on the pendulum, resulting from the fall of a lever weighing 0·35 grams for a distance of 2·5 millimetres. This interference is confined to 0·001 part of the time measured.

SLAVE CLOCKS

TYPE A

A Free Pendulum requires a Slave clock to work in conjunction with it in order to release its gravity arm every half-minute. It may be erected in any convenient room on the ground floor. It consists of a standard Synchronome controlling pendulum of the highest quality as shown on page 2 fitted with "Hit-and-Miss" synchronizer as illustrated (*Fig.* 6) in the margin and an extra dial in circuit with the Free Pendulum's remontoire. The operation of the two dials at an interval of 0·8 sec. shows that the instruments are working correctly. A small silvered dial will be seen concentric with the 15-toothed wheel to indicate even-numbered seconds.

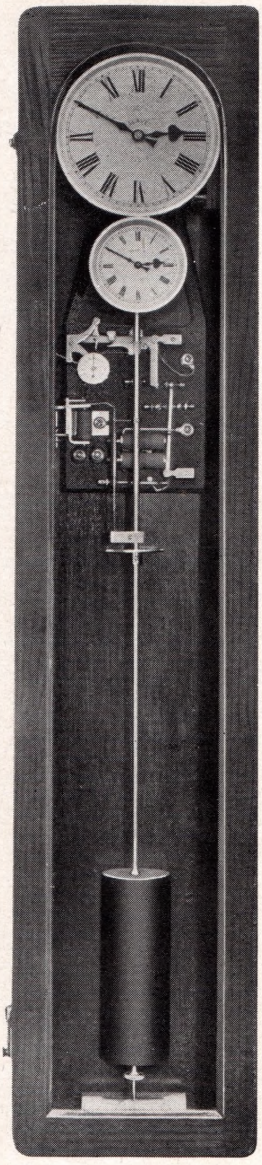

Fig. 6

SLAVE CLOCKS

TYPE AS

This clock is similar to Type A described on page 12, but is also provided with an "Inertia" type switch for transmitting electrical impulses every second with great precision. These impulses are useful for many purposes including chronograph comparisons, operating seconds impulse dials as illustrated (Fig. 10), etc., etc.

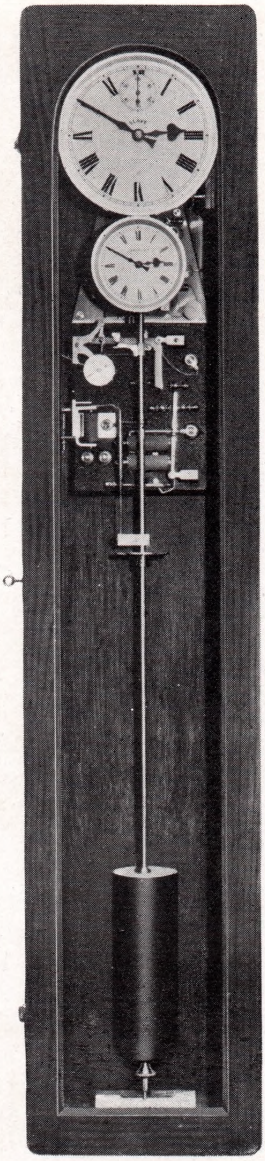

Fig. 7

The cases of Types A and AS are of polished hardwood and their overall dimensions are :

Length	-	51 ins. (129·5 cm.)
Width of trunk		10½ ins. (26·6 cm.)
Depth	-	6 ins. (15·25 cm.)

SLAVE CLOCKS

TYPE B

This clock is mounted in a carved polished mahogany case with a 10-inches diameter "Regulator" type dial showing seconds and hours in inset circles with the minute hand sweeping the full diameter of the dial. Below are two dials set in an oblong panel showing the time indicated by the Free Pendulum and Slave half-minute switches.

This clock is of the seconds impulse type, operated by a subsidiary Synchronome switch with jewelled movement and is therefore a transmitter of seconds as well as half-minute impulses. The seconds contacts in no way affect the Free Pendulum, even indirectly.

The Free Pendulum and its B type Slave are used as standard clocks in many Observatories, both for Sidereal and Mean Solar Time.

Additional apparatus is supplied for the automatic transmission of time signals of the six-dot seconds, Onogo and Rhythmic types.

The overall dimensions of the polished mahogany case with plate-glass front are :

Length	-	55½ ins. (134·7 cm.)
Width	-	13¼ ins. (33·6 cm.)
Depth	-	7¼ ins. (18·4 cm.)

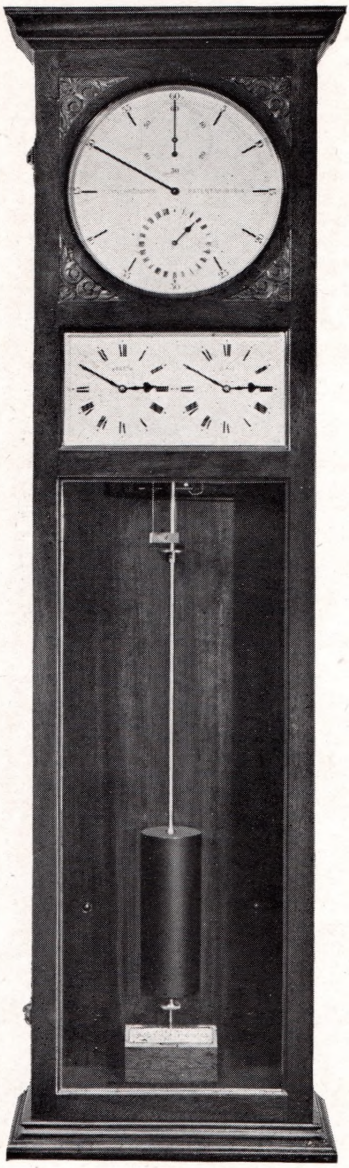

Fig. 8

ACCESSORIES

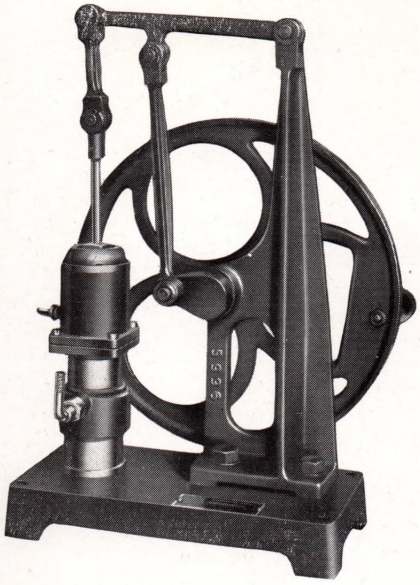

Fig. 9

THE ROTARY "GERYK" TYPE PUMP

Hand-operated reducing the pressure in the Free Pendulum case down to the required amount —20 millimetres in 8 minutes. A can of special oil is supplied with the pump.

Accessories supplied with the pump are as follows :—

4 ft. of rubber pressure tubing;
1 glass drying tube;
1 2-oz. bottle of Phosphorous Pentoxide.

SETS OF WEIGHTS ranging from 10 mg. to 10 grams, in wood block with forceps.

ELECTRICAL IMPULSE DIALS

Separate electrical impulse dials of half-minute periodicity, in polished mahogany cases, can be supplied in 8, 10, 12 and 18 ins. diameter. A full range of sizes and types will be found listed in Catalogue E.1. 48.

Electrical impulse dials of seconds periodicity, 10-ins. diameter regulator type, can also be supplied with inset seconds and hours silvered engraved dials in oak, mahogany or teak frame as Fig. 10.

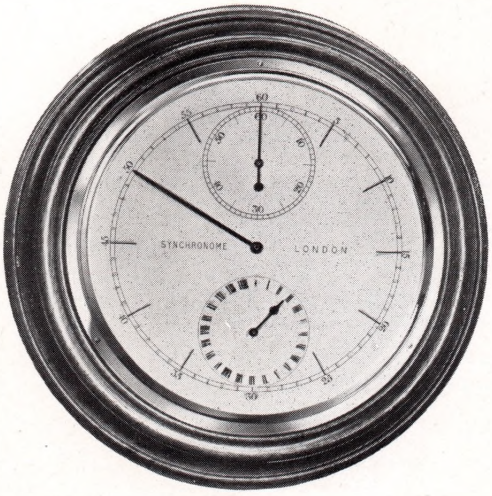

Fig. 10

THE MAGNETIC CORRECTOR

When a Mean Solar Time Free Pendulum and Slave Clock is used for transmitting time signals by Radio, or is used on Civil Time service, it is necessary in the former use of the clocks to ensure that the transmitter switch is correct for time just before transmission commences. It is also necessary to ensure that the clocks are periodically corrected in the latter case, that is to say—although the Free Pendulum is capable of keeping a very constant rate, within a few thousandths of a second per day—it may not have a zero rate, and it becomes necessary to put it to correct time before transmission.

The Magnetic Corrector provides the means of applying this correction to both Free Pendulum and Slave, and in either direction, fast or slow, by the exact amount required.

The lower end of each pendulum is fitted with a permanent ring magnet. Under the ring magnet, and fitted to the case, are a pair of solenoid coils.

To apply correction, current is passed through the coils to produce like poles to the magnet for slowing, and unlike poles for quickening, the swing of the pendulum.

The winding of the coils, the gap between the magnet and coils, and the amount of current passed through the coils, all combine to alter the rate of the pendulum by a known amount.

A Control Panel is also supplied which may be fitted at any convenient position, not necessarily near the clocks to which the corrections are to be made. Incorporated in the Control Panel is a dead beat moving coil Ammeter and the necessary switches and resistances, the whole being carefully calibrated and set at our works for the following correction values :—

To advance or retard 0·01 seconds per minute.
,, ,, ,, ,, 0·02 ,, ,, ,,
,, ,, ,, ,, 0·03 ,, ,, ,,

The operator switches on two switches—one for direction, i.e., advance or retard, the other for the amount of correction he wishes to use, 0·01, 0·02, or 0·03.

The ammeter is a centre zero type, one half of the scale being marked slowing and the other quickening. In operation the pointer will read :—

0·1 amp. on the slowing side for 0·01 seconds per minute retard,
0·2 amp. slowing for 0·02 seconds, and
0·3 amp. slowing for 0·03 seconds.

It will show 0·1 amp. quickening when switched to 0·01 second per minute advance, 0·2 amp. quickening for 0·02 seconds and 0·3 amp. for 0·03 seconds.

With these combinations it is quite easy to correct the clocks by the amount required. Magnetic correctors may be fitted to any pendulum clock under the control of the Free Pendulum.

When it is desired to magnetically correct a transmitting clock which is not under the control of the Free Pendulum and will, therefore, have a comparatively large change of rate, correction values are increased to 0·1 and 0·2 seconds per minute.

ELECTRICAL CONTACTS

Electrical contacts of any duration or periodicity, in multiples of a half-minute or of a second respectively, arranged according to any programme, can be operated from the clock system for chronograph recording or other purposes without the Free Pendulum being affected, even indirectly.

SPECIFICATION
AND
PRICES