A NEW MARINE CHRONOMETER
THE CHRONOSTAT III LEROY

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To say that the need to know the time is the basis of every form of hydrographic activity is to state an obvious fact.

Certainly, hydrographers do not always need, except for certain operations in geodetic astronomy, to know the time with any great precision, but they always need to know the correct time in order, in all circumstances, to be able to time isolated, simultaneous or consecutive observations in an absolute and relative manner.

It is therefore necessary for them continually to refer to a time-piece and, as their work is carried out either at sea, on board a ship, or on land under unstable conditions, this time-piece must not only be mobile and self-contained, but also remain unaffected by the movement of the vessel at sea.

Thus, hydrographers find it essential to use marine chronometers.

That is why it seems useful to mention in these pages the recent introduction of the Mark III Leroy chronostat.

Historical note

The marine chronometer, which has been universally used by navigators for centuries, is a direct descendant of the magnificent inventions of the great clock makers of the 18th century, and in particular of Harrison, Pierre Leroy and Ferdinand Berthoud.

During the course of the following years until the last war, many great French clock makers : Bréguet, Dumas, Winnerl, Vissières to name only the most famous, made hundreds of efficient marine chronometers, of which many are still in use. But the events in France from 1940 to 1945 resulted, amongst other things, in a complete standstill in the making of marine chronometers. For this reason, when the renaissance of the French Navy brought a demand for chronometers, no French clock-maker was in a position to supply them. That is why, the procedure of buying after competitive selection, in accordance with the rules of the Navy, turned out to be purposeless.

Then the firm of Leroy, which had been supplying the Navy for more than 50 years, undertook the construction of a new type of time-piece, in which the movement was powered not by a spring but by an electrical source of energy, preferably a battery.

The realization of this became possible as a result of new discoveries in modern industry, but as clock-makers, the firm of Leroy wanted to keep as governor the cylindrical balance spring of the chronometer which had already been proved quite satisfactory, and the considerable modification of the power transmission to the balance wheel presented some problems in regulation which were difficult to solve.

It should be recognized that a quite remarkable result has been achieved in a relatively short time : this is the chronostat III.

Summarized theory of operation

The requirements which this new chronometer must satisfy, in order to be adopted by the Navy, are the following :

a) Adjustment — the chronostat must have means of adjustment comparable to those required in mechanical chronometers (thermal compensation, correct time-keeping up to the usual standards, and be relatively uninfluenced by tilting);

b) Duration and reliability of working — experience has shown that the only means of attaining this is rigorously to exclude any electric contact liable to deteriorate during use;

c) Autonomy — the chronostat must not depend on an exterior source of electric energy, subject to failure, and must remain easily controlable under all conditions, enclosed in its case of relatively restricted dimensions.

More than 40 years ago (1919) Messrs ABRAHAM and BLOCH achieved electronic power supply to a pendulum, without electrical contact.

But, on the one hand the process, applicable to an oscillating system of low amplitude, was quite unsuitable for a circular chronometer balance wheel powered by oscillations of high amplitude, and on the other hand the electrical power supply of the electronic part of the system, that is to say of the three-electrode tube, did not fulfil the necessary condition for the mobility of the instrument.

Since this already distant date when ABRAHAM and BLOCH realized their process of power supply to a pendulum, it has become possible, thanks to the many and diverse improvements made in various branches of industry, to maintain the oscillations of a balance wheel.

On the one hand, very small magnets of great and stable coercive force are easily found, and on the other hand diode and triode transistors, based on the semi-conductor crystal principle, enable electronic units to be produced which need only a very reduced electric power which could be supplied by a single battery.

The two requirements stated above are therefore fulfilled :

— there is no electrical contact for the maintenance of oscillation of the balance wheel; which ensures, on first approximation, reliable working;

— the chronostat is self-contained as the power-supplying battery and electronic equipment can easily be contained in the instrument's case. The requirements for regulation remained to be satisfied.

The axis of the balance wheel of the chronostat carries two small magnets, by means of supports, and a soft iron shunt — the whole unit oscillates together.

When the balance wheel is at the dead centre point, each of the magnets is facing the flat coil situated between magnet and shunt.

One of the coils is called release and the other maintenance. The circuits of the two coils are mounted as indicated on fig. 1.

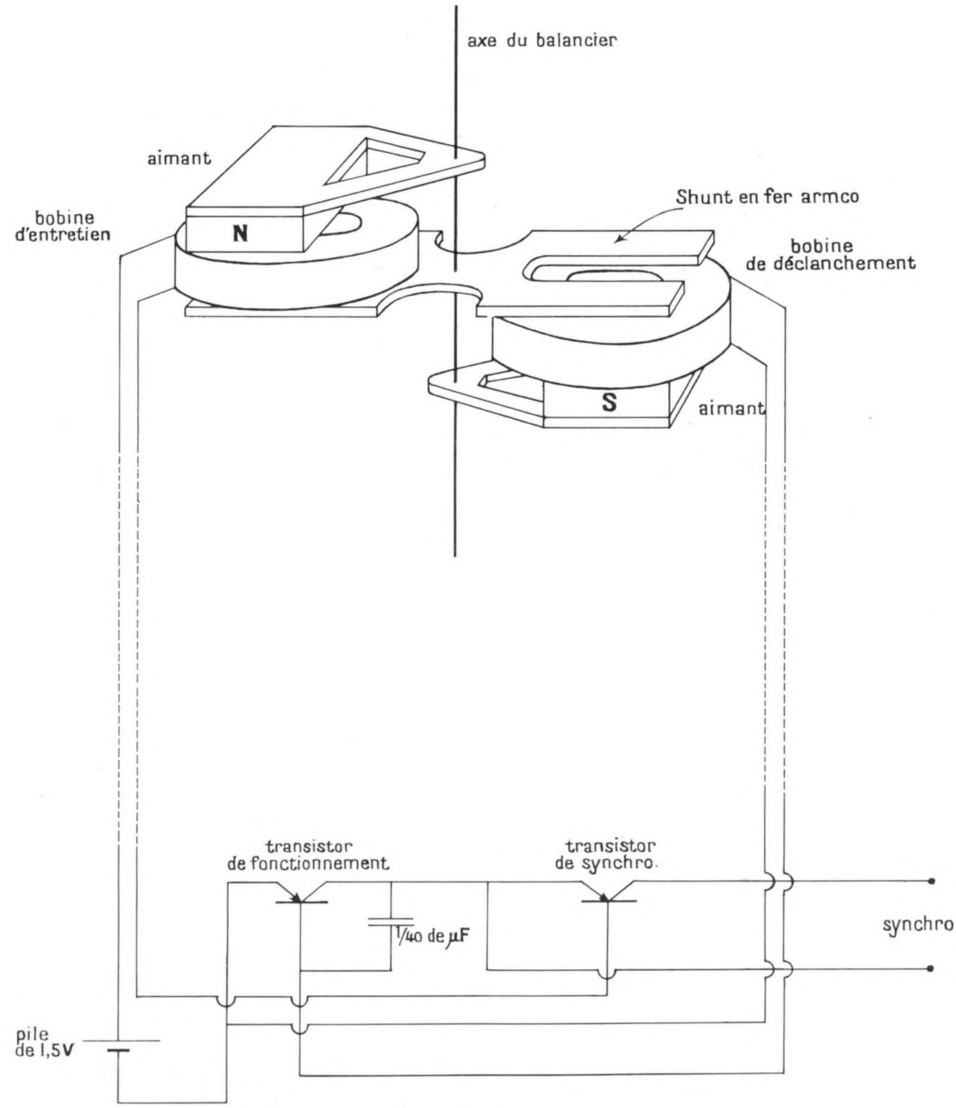

FIG. 1

When the equipment oscillates, the movement of one of the magnets in front of the release coil creates in the coil an electromotive force which produces a current. The impedance of the circuit of the release coil is regulated in such a way that the induced current only results in the gating of the transistor when it reaches almost its maximum.

The transistor, gated for a short time, then allows the passage of a current also very brief, supplied by the battery, in the maintenance coil.

It follows that the maintenance coil produces an electromagnetic field which acts on the second magnet, producing the effect of an electro-motor torque, still very brief, in the same direction as the movement and which restarts the balance wheel.

Thus the balance wheel magnet shunt unit oscillates partly under the action of its spring and partly under the action of an impulse received on each passage at the dead-centre point.

Figure 2 shows the simultaneousness of the movement of the balance wheel, of the induced current, of the current in the maintenance coil and of the electro-motor torque.

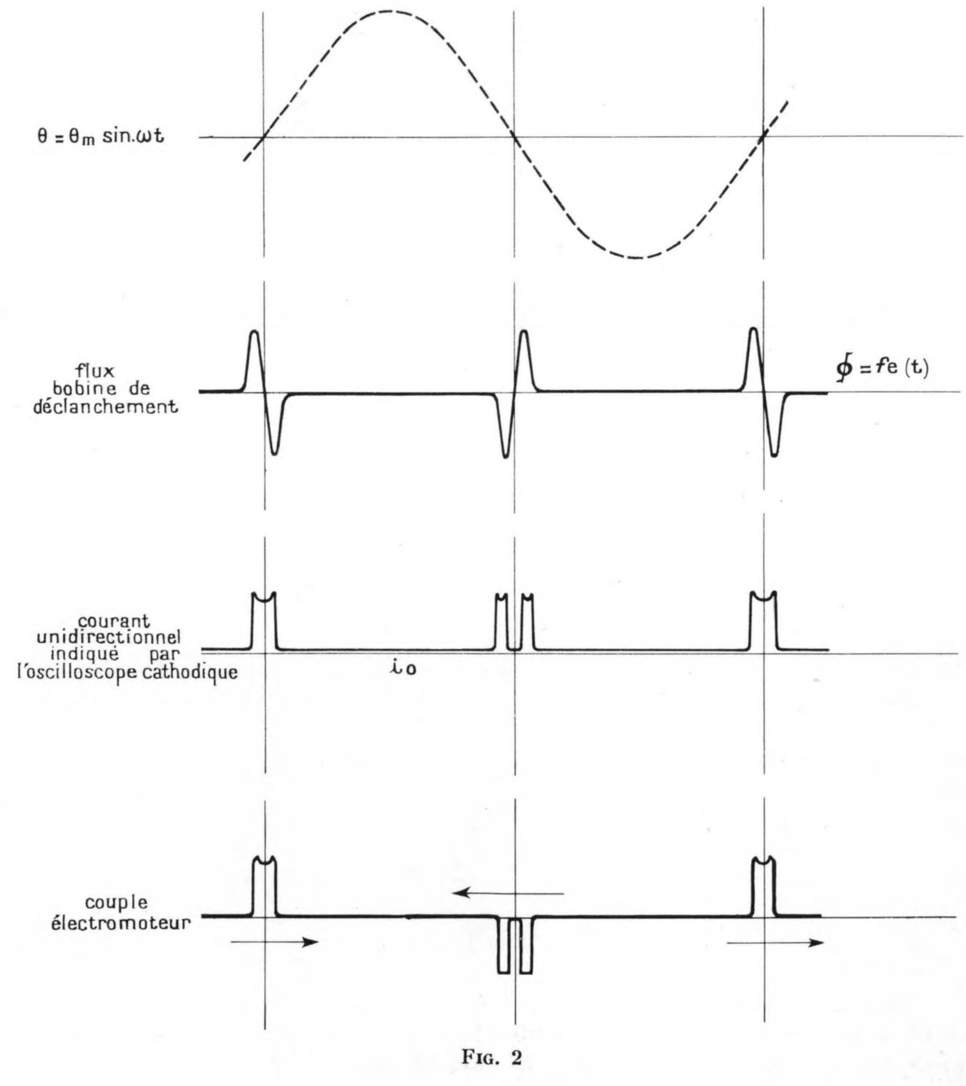

FIG. 2

There are two remarks to be made : the impulse ou alternate beats, is double, but these two impulses, divided symmetrically with regard to the passage to the dead-centre point, have an action equivalent to a single, centred impulse. Furthermore, a very weak current continually passes through the maintenance coil, but its action has no effect on the movement of the balance wheel, as the latter produces no electromagnetic force owing to the fact that between these impulses, the mobile lines of force do not cut the active conductors.

The governor unit is the balance wheel itself coupled to its spring. Regulation is rather delicate, as the thermal compensation must take into account not only modification of the inertia of the equipment due to the dilation of the supports of the magnets and the shunt.

The coil setting is also very delicate, as the motor torque must act at the exact moment when the balance wheel spring passes the dead-centre point, in order to produce the maintaining impulse under the same conditions as at the time of the working of the expansion escapement of Pierre Leroy : this is essential for the efficient regulating of the balance wheel, as far as isochronism is concerned.

Of course, the work had to be done by trial and error on the diameters of the balance wheel pivots taking into account at the same time their strength and the adjustment for the daily variation.

Finally, the control of the short duration of the maintaining impulse was obtained by working simultaneously on the impedance of the circuit of the release coil and on the resistance of the circuit of the maintenance coil.

It should be noted that these difficulties have been overcome and that the working of the chronostat as a time-piece is satisfactory, as pointed out at the end of the article.

Description of chronostat III

The regulator is a Guillaume balance wheel with four compensating weights connected as required to a cylindrical steel spring. This has proved its value over several decades and allows for extensive latitude in compensation. The balance wheel is of the quarter-second type, i.e. it makes two complete oscillations per second.

On the axis of the balance wheel are fixed, on the one hand, two arms of beryllium (a metal chosen because, in practice, it is not influenced by magnetism) which support the two magnets and, on the other hand, a shunt to close the magnetic circuits by concentrating the lines of force.

Two small flat coils of copper wire are fixed to the plate so that there is one between the shunt and one of the magnets, and the other between the shunt and the second magnet.

The features are the following :

- the magnets are Ticonal 600 (2/5/10 mm);
- the shunt is of iron — Armco;
- the weights of the magnet supports, of the magnet and of the shunt are balanced on the axis of the balance wheel;

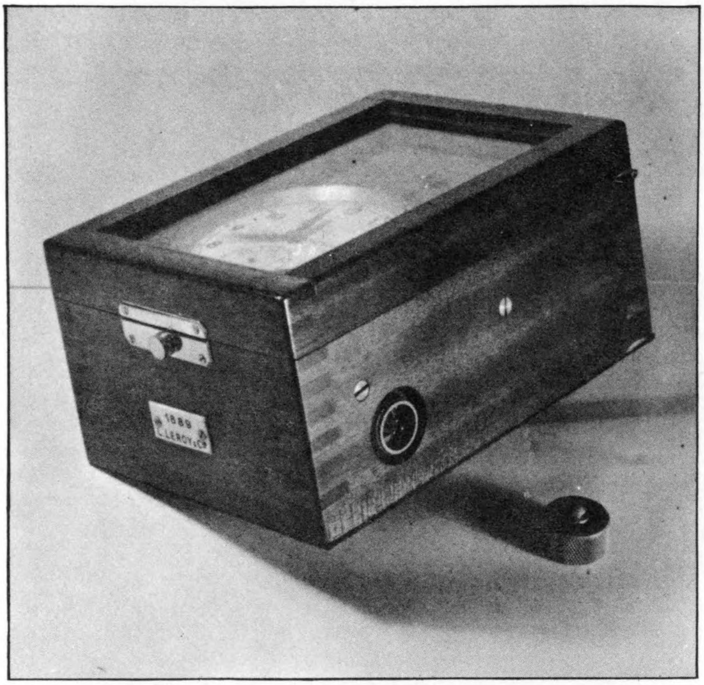

FIG. 3

FIG. 4

— the release coil comprises 5 000 turns of wire 4/100 the of a millimetre in diameter;
— the maintenance coil comprise 1 860 turns of 7/100—millimetre wire;
— the air-gap is of 3/10 millimetre;
— the maintaining transistor is of the P.N.P.—junction type;
— a 5 volt battery supplies the power; this battery is shielded and, as a rule, lasts for at least three years;
— the amplitude of the balance wheel movement, during normal working, is about 430 degrees.

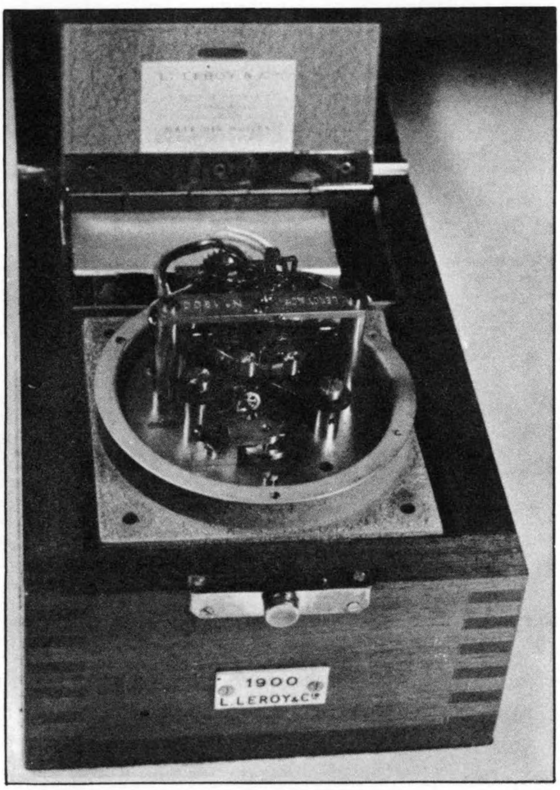

Fig. 5

The motor balance activates, by means of a cam on its axis, a small wheel which brings about a slight turning effect to move the sweep-hand the other two hands (minute and hour hands).

The whole movement is contained in a special metal container which shields it from external magnetic influence. By experiment, it has been found that a field of 20 Gauss has no action on it.

The chronostat III therefore represents a chronometer, without any link to the universal joint, enclosed in its mahogony box, and operating in a completely independent manner. It indicates the time in the same way as a mechanical chronometer.

Possible applications of the chronostat III

On the side of the box is found a synchronization socket : this links, as indicated in the first diagram, to a second junction transistor (P.N.P.) which is gated four times per second by the passage of the current from the maintenance coil.

If, therefore, we connect to the terminals of the synchronization socket a circuit supplied by a 12 volt battery (for example) and one or more repeaters set up in parallel, we may in that way ensure a distribution of time to different points. The circuit is fed through at four impulses per second and the repeaters give as accurate an indication of time as the chronostat III does.

But, for reasons connected with time adjustment of the instrument and particularly with the correction for daily loss or gain in time, we prefer to adopt the following arrangement : the synchronization socket connects to a transistor balance (two diodes and two triodes) and transforms the four impulses per second into two inversed impulses per second, each impulse lasting one half second. This arrangement makes it possible, if the instrument is losing time, to arrange for it to make up a few seconds very rapidly : in shunting the balance, the repeater then receives four impulses per second instead of two and, on this account, the sweep-hands advance twice as rapidly. This double working clearly necessitates careful setting of the impedance of the circuit of the repeaters and also of the fine adjustment of their movements.

This arrangement has moreover been carried out on several ships of the French Navy. On two of these ships, one single chronostat is linked up to 80 repeaters.

Conclusion

We therefore have here a new type of time-piece for navigators and hydrographers.

Its characteristics are comparable to those of good mechanical chronometers. Some chronostats III have undergone tests during the French Navy Hydrographic Office's chronometer competition with satisfactory results. This competition is certainly one of the most severe which exists for selecting chronometers. It can therefore be said that this was a very encouraging performance by a marine time-piece which was first produced hardly three years ago.

It is interesting to repeat the two principe advantages of the chronostat III over mechanical chronometers :

1) It works without interruption and without winding for at least three years;

2) It can, without losing its qualities as a time-piece, command a centralized installation of time distribution and supply, at any time, a high precision signal which is recordable and of a superior quality to that of a chronometer with electrical contacts.

It is thus an interesting instrument from all points of view and lends itself to wide application.