PATENT SPECIFICATION

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COMPLETE SPECIFICATION.

Method for Synchronizing Oscillating Pendulums Chiefly Adapted for Time Distribution Systems.

We, Établissements Léon Hatot, a corporation organized and existing under the laws of the French Republic, of 23, rue de la Michodière, Paris, France, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention has for its object the synchronization of oscillating pendulums by periodic electric impulses of small intensity caused by the closing of a master switch controlled by a masterclock for instance and passing through the circuit feeding a coil controlling the oscillating pendulum.

According to the invention this oscillating pendulum actuates a local switch inserted in the feeding circuit so as to close the said local switch before the master switch is closed by the masterclock and to open it before the masterswitch is opened. Moreover the period of the oscillations of the oscillating pendulum varies according to its amplitude and thereby any lack of synchronism will cause a variation of the duration of the time during which both the master switch and the local switch are closed; thus the electric impulses will be strengthened or weakened; the amplitude of the oscillations will vary correspondingly and consequently makes the period vary so as to bring the oscillating system back to synchronism.

In a preferred form of execution the period of the pendulum is made variable by means of the shape given to the local switch which consists of a spring strip pressing on the pendulum and guided by a cam so that the torque bringing the device back to its position of equilibrium shall cease to be proportional to the displacement and cause the period to decrease as the amplitude increases.

This method is particularly well adapted for time distribution and can also be used for controlling the switch sending periodically current into the control coil of the masterclock.

In the former methods of actuating the receiving clocks by synchronism with a main controlling clock, the latter periodically sends a current into the coil of the pendulum to be synchronised, the oscillating period of the pendulum to be synchronised being substantially independent of the amplitude. The coil is directly connected to the main line. In order that the maintaining current may correct the oscillating period of the pendulum to be synchronised, it is indispensable that the impulse should be produced before or after the vertical, and that this impulse should be relatively strong. For if the impulse took place at the vertical, it would cause a phase difference of increasing value between the impulse and the movement of the receiving pendulum; the impulses would thus cause retardation; in short, an effect would be produced which is analogous to the well known "out of step" effect in synchronous electric motors.

Experience shows that in the case of a well-designed pendulum with a very free oscillation, the load or resistant work is extremely small, so that the power impulses, only compensating the losses, would be too small to have any practical effect upon the period of the pendulum to be synchronised. For this reason their value must be increased.

But if in these conditions the synchronising impulses were exercised solely in the direction of the movement, the amplitude might become excessive. In

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this event it is essential to damp the oscillations of the pendulum by a device absorbing an amount of energy which increases with the amplitude (braking by Foucault currents or electromagnetic braking).

For all these reasons, it becomes necessary in the preceding systems to expend a much greater amount of electric energy than would be required for the maintenance of the oscillations if it were possible to use with a pendulum which is perfectly free, power impulses which take place always at the most favourable moments, i.e. when the pendulum passes in proximity to the vertical (maximum speed).

The present invention relates to a new method for obtaining the synchronism without expending an amount of energy exceeding the minimum value required for the maintenance of the motion of the pendulum, even though the damping should be reduced to an extremely small value. In this manner the current used in the known systems can be reduced in the ratio of more than 100 to 1.

The said method also allows the elimination of all damage to the contact controlled by the masterclock, as the breaking of the circuit is operated by the local switch and not by the masterswitch. It further provides for the uniformity of the amplitude of the oscillations of the synchronised pendulums, and for an improved stability in working, irrespectively of the variations in the source of electrical energy and of the passive resistances.

In the known methods, the stability of operation in synchronism is due to the fact that any increase in the phase difference of the movement with respect to the synchronising impulse will cause a variable modification of the period which the pendulum would have possessed did it oscillate freely.

However according to invention, the small impulses cause no change in the period which the pendulum would have had if it oscillated naturally at the same amplitude. But on the contrary, any increase in the phase difference will cause a considerable change in the value of the energy received by the pendulum and will thus tend to modify the amplitude, thus causing a variation in the period, thereby limiting the increase in the phase difference and maintaining the synchronous operation.

A somewhat similar method has already been proposed whereby a double switch is used, one controlled by the masterclock and the other by a secondary pendulum, an electromagnet controlling latter being energized by the current flowing through it during the simultaneous closing of both switches. But in such devices the pendulums are held up by the magnetic attraction of the electromagnet during a time such as will restore synchronism, whereby a much larger expenditure of power is required than with the small impulses used in present invention which are sent through the electromagnet when the pendulum is near the vertical.

The small impulses do not affect the period of oscillation and only affect the amplitude after a long time whereby as explained hereinabove the synchronism is restored.

Hereinafter, a time distributing system will be described embodying said invention and wherein the receiving clocks actuate a suitable clockwork for moving the hands. The impulses though shown as transmitted only through wire could also be transmitted by wireless without affecting the scope of the invention.

In the appended drawings:

Figs. 1 and 1^a show diagrammatically a system of time distribution by synchronised clocks arranged according to the invention. Fig. 2 is a diagram showing the variations in the oscillating period of the pendulum which it is proposed to synchronise with the amplitude of the oscillations.

In Fig. 1, the central station comprises a battery S and a switch I_1 which is controlled by the standard clock (not shown) in such manner as to establish at intervals of time T suitable electric contacts whose duration is less than $\frac{T}{2}$. (This duration may for instance be about $\frac{T}{4}$).

The driving element of each receiving device consists of a pendulum O which is provided with electromagnetic driving means consisting of the magnet A secured to the pendulum, and the fixed coil B. The latter is connected to the central station by the line F_1 F_2 but a switch I_2 controlled by the pendulum O, is placed in the circuit in such manner that the coil will be only supplied with current when I_1 and I_2 are closed at the same time. The switch I_2 consists of the spring strip r entering into contact with the pendulum rod during the half-oscillations to the left of the vertical. For the sake of clearness in the following description, it will be supposed that the position of said strip when at rest is such that the contact will take place at the moment of passage through the vertical—it will be further observed that it may be advantageous to make the contact at I_2 for a period which exceeds $\frac{T}{2}$.

It is essential to note that the said contact may be so arranged as to operate practically without damping the movement of the pendulum. In fact, the energy absorbed in order to raise the spring *r* will be restored by the latter when it returns to the initial position. The only loss will be that due to the friction of the parts entering into contact. But one may reduce the sliding of these parts upon each other by bringing the support of the said spring nearer to the center of oscillation of the pendulum.

In the present device, the action of gravity exercises a torque tending to bring back the pendulum to the vertical position. This torque is proportional to the distance *a* from the mean position when this distance is small. When the pendulum swings to the left of the vertical, as shown in Fig. 1[a], the spring *r* will exercise a further torque which is added to that due to gravity.

The law of this additional couple relative to the distance *a* will be of the form K *a* when there is a simple flexion and the bend is small (K being a constant); but this law may be changed by utilising a cam *c* which is so arranged that the free length of the spring decreases as the distance *a* increases. In this manner it may be arranged that the resulting torque which brings back the pendulum to the vertical shall increase at a greater rate than that of simple proportionality. It is well known that thereby the natural oscillations cease to be isochronous. They will have a smaller duration as the amplitude of the oscillations is greater.

If for example one plots as abscissæ the speeds V of the electromagnet when the pendulum passes through the vertical position, and as ordinates the durations U of a complete oscillation a curve will be obtained such as is shown in the full line in Fig. 2. In order to obtain the synchronism by the method forming the object of the invention, the length of the synchronised pendulum is so selected that for a speed V_1 corresponding to the desired amplitude of oscillation, the period of the pendulum shall be equal to the period T of the closing of the switch I_1 in the central station.

When this condition is obtained, the receiving clocks set up an oscillation in synchronism with the emissions of the principal clock. The keeping up of the oscillations is very stable in the following conditions.

The phase difference between the movement of the receiving clock and the synchronising impulses is such that at each oscillation in the direction *f* the current begins to flow when the switch I_1 closes and is cut off when the switch I_2 opens. The value of the said phase difference is automatically regulated in such manner that the durations of contact shall be sufficient to maintain the oscillations at an amplitude at which the natural period of the oscillations of the receiving pendulum is equal to the period of the synchronising impulses.

We will limit the discussion to a few theoretical points concerning this result, examining what takes place when by reason of an accidental increase in the voltage E of the battery or reduction of the passive resistances, the power work exceeds the load work and in this event the system will tend to assume a larger amplitude.

Since the impulses have an extremely low value, they will have no direct and immediate effect upon the period of the pendulum, and this latter will remain the same as if the pendulum oscillated naturally at the same amplitude, but after a time they will change the said amplitude. However the curve (Fig. 2) shows that an increase in the stated amplitude will cause a reduction in the period of the movement and hence a reduction of the phase difference between the movement and the impulses. The duration of contact will diminish and also the power expended, and this will arrest the increase in the amplitude and will after a time diminish the latter.

Accordingly a new manner of working will be finally established, characterized by shorter durations of the flow of current, whereby the mean power expended will be exactly equal to the work done. The amplitude herein will remain such that the natural period of the pendulum shall be equal to the period of the synchronising impulses.

It should be observed that the circuit is broken at the switches of the receiving clocks and not at the contact of the principal clock I_1, this being favorable for the proper preservation of the latter. The amount of current in use is very small, since the receiving pendulums oscillate with very small damping, and receive the current when the speed of displacement of the magnet is considerable, thus offering a high electric efficiency.

The hereinbefore described method can be employed for the maintenance of the oscillations of the pendulum of the principal clock, and for this purpose a receiving pendulum may operate a switch sending an intermittent current into a coil acting upon a magnet which is secured to the pendulum of the principal clock. We may further place in the maintaining circuit of the principal clock one or more switches controlled by the pendulum of this clock.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. Method for synchronizing oscillating pendulums by periodic electric impulses of small intensity caused by the closing of a master switch controlled by a masterclock for instance and passing through the circuit feeding a coil controlling the pendulum, in which the said pendulum actuates a local switch inserted in said circuit, in such a manner that it closes said switch before the masterswitch is closed by the masterclock and opens same before the masterswitch is opened, the pendulum having further a period of oscillation varying with its amplitude, whereby any lack of synchronism will cause a variation of the duration of the time during which both the masterswitch and the local switch are closed, thus strengthening or weakening the electric impulses, the amplitude of the oscillations varying correspondingly and consequently making the period vary so as to bring the oscillating device back to synchronism.

2. Method for synchronizing oscillating pendulums as claimed in Claim 1, by means of a local switch consisting in a spring strip whereof one end is mounted upon a fixed support disposed in proximity to the suspension point of the pendulum, and the other end can enter into contact with the pendulum rod and is thus raised by the latter at each oscillation, said spring being guided by a cam in such manner that the torque which brings back the pendulum to the position of equilibrium shall not be proportional to the displacement from the mean position of the pendulum and that the natural period of the said pendulum shall decrease as the amplitude increases.

3. Method for synchronizing oscillating pendulums as claimed in Claim 1 adapted for distribution of time by means of a master clock adapted for the periodic closing of an electric or radioelectric circuit comprising a source of current and a main line, the synchronised pendulums the natural oscillating period of which is close to that of the masterclock being connected to the main line and actuating the clockwork for the hands.

4. Method for synchronizing oscillating pendulums as claimed in Claim 1 adapted for controlling a switch serving for sending periodically current to keep up or to help keep up the oscillations of the masterclock.

5. Method for synchronizing oscillating pendulums substantially as described hereinabove with reference to appended drawings.

Dated this 9th day of September, 1924.

MARKS & CLERK.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1926.

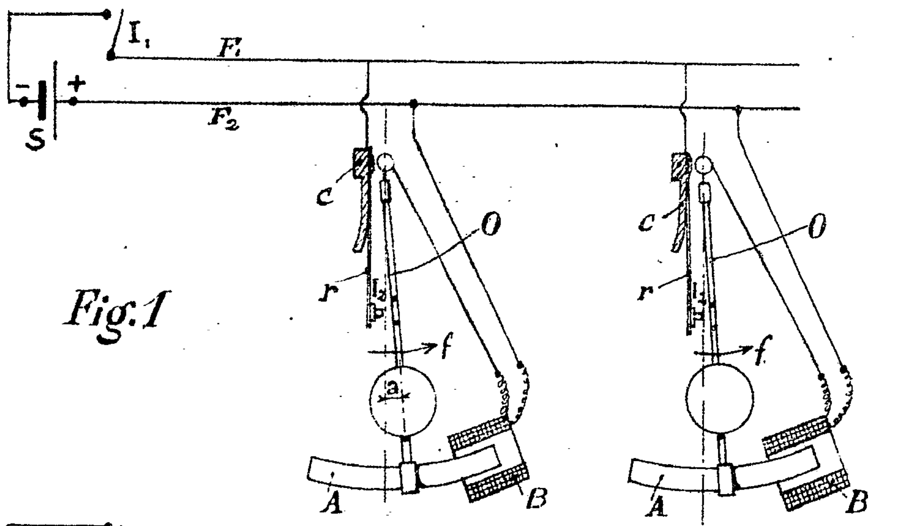

Fig. 1

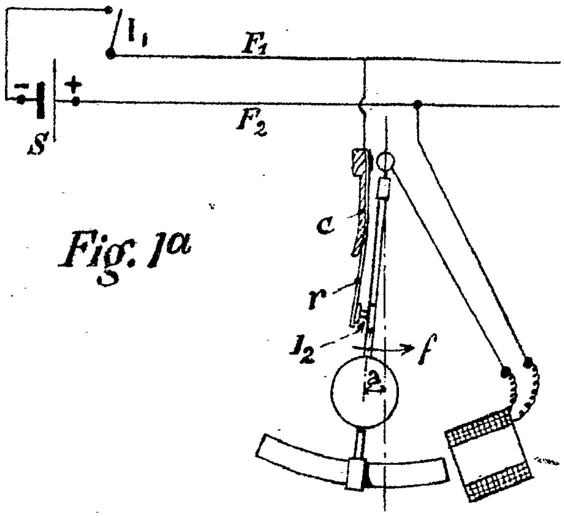

Fig. 1a

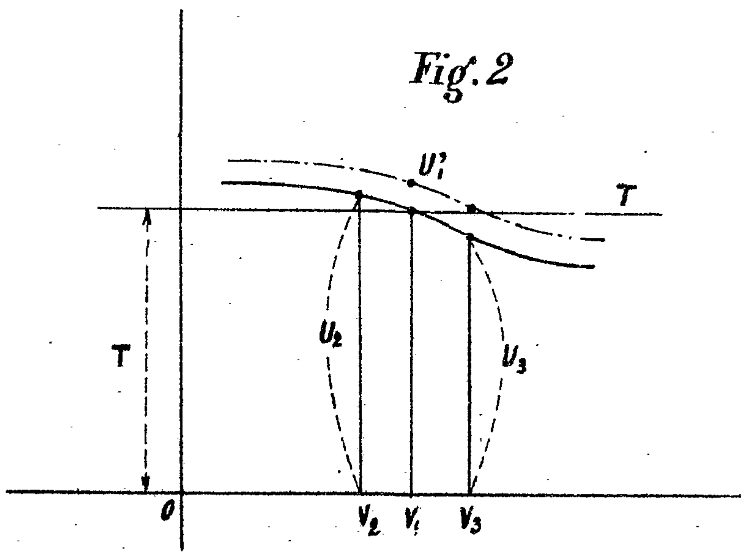

Fig. 2