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C. F. CLIFFORD ET AL

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SYNCHRONISED MAGNETIC ESCAPEMENT

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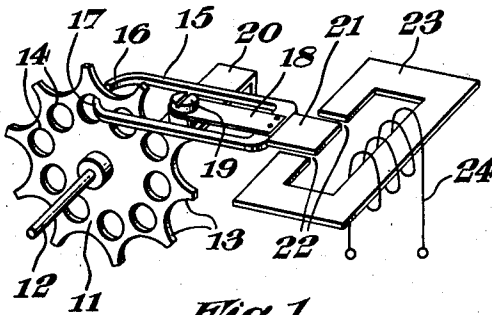


Fig. 1.

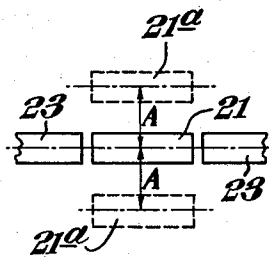


Fig. 2.

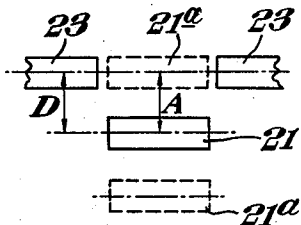


Fig. 3.

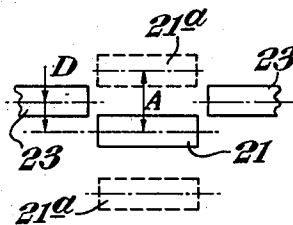


Fig. 4.

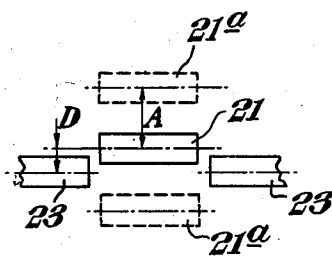


Fig. 5.

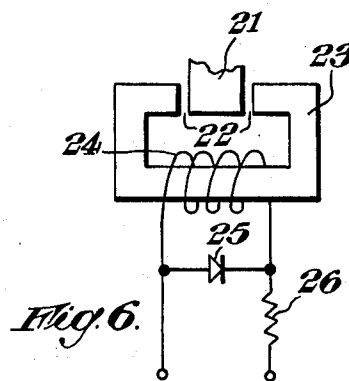


Fig. 6.

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SYNCHRONISED MAGNETIC ESCAPEMENT

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5 Claims. (Cl. 58—26)

This invention relates to mechanical or electro-mechanical oscillators of the kind used for controlling the operation of clocks, and more particularly to a magnetic escapement in which the oscillating member is a magnet.

A magnetic escapement is known in which an escapement wheel made of magnetic material is formed with teeth around its periphery, and openings defining spokes, in such a manner as to leave a circular wavy track around the wheel. This wheel co-operates with a magnet mounted to oscillate in a direction substantially radial to the wheel axis and having its two poles presented to opposite faces of the wavy track on the wheel, so that as the magnetic system oscillates the wheel is allowed to rotate at a speed determined by the natural frequency of oscillation of the magnetic system. The present invention is directed to an improvement in such a system which is applicable to a clock or other timing mechanism adapted to be synchronised with the supply mains frequency.

The invention is particularly applicable to a known type of clock or timing mechanism or the like which is normally driven from alternating current supply mains but also contains a spring which keeps the clock operating for a substantial period if the supply mains should fail. It will, however, be realised that the invention or variations thereof within its scope may be applied to other types of clock or timing mechanism.

In a clock of the type above referred to, a spring is provided, with appropriate gearing, to drive a wheel having teeth formed around its periphery and having apertures cut inside the teeth to form spokes, the spokes being in staggered relationship to the teeth in such a manner that a solid ring of material is left around the wheel which due to the material removed in forming the teeth and spokes constitutes the wavy track.

In normal operation the spring is kept fully wound by a motor driven by the electric mains, to ensure that the clock operates correctly either as a synchronous or a spring driven clock. The natural frequency of the magnetic system is adjusted to correspond as closely as possible to the mains frequency and electromagnetic means are provided to act upon the magnetic system for synchronising with the mains frequency. Such electromagnetic means are in themselves known and may comprise a winding having a magnetic core which is closed except for a gap and a small armature of magnetic material attached to the oscillating magnetic system, the electromagnet being energised at the mains frequency.

In normal operation the escapement wheel is driven by the spring, which is kept fully wound by the motor driven by the electric mains. The escapement wheel rotates and sets the magnetic system in oscillation, the speed of rotation of the wheel being controlled by the frequency of oscillation of the magnetic system. The pulses applied by the electromagnet cause the magnetic system to vibrate synchronously with the mains frequency so that the clock runs as a synchronous clock. In case of failure of the supply mains the spring continues to drive the escapement wheel and the clock continues to run until the spring is run down, unless the mains supply is restored in the meantime. There may be a small time error due to the fact that the natural frequency of the magnetic system may not correspond exactly with the nominal

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frequency of the supply mains and, furthermore, there may be a slight temperature error. These errors are, of course, kept to a minimum by appropriate design. As soon as the mains supply is restored, the electromagnet again takes control and the magnetic system is made to oscillate at the synchronous frequency, while the motor rewinds the spring.

A difficulty experienced with this type of clock is that if the natural frequency of the magnetic system corresponds exactly with that of the mains frequency the application of the synchronising impulses through the electromagnet produces a resonance effect, so that the amplitude of oscillation of the magnetic system increases until the system oscillates with too great an amplitude. This may lead to inconsistent and noisy running or even cause the oscillating member to strike other parts. To reduce this tendency it is necessary to keep the power supplied by the electromagnet is to a very small level. If the mains frequency should depart to more than a small extent from the nominal frequency then it will no longer correspond with the natural frequency of the oscillating system and the amount of power supplied to the electromagnet may be insufficient to maintain reliable synchronisation. The supply frequency, nominally 50 c./s., may vary between about 48 and 50.5 c./s.

The invention consists of a time control mechanism comprising an escapement wheel having a wavy magnetic track therearound and an oscillatory magnetic system co-operating therewith, an armature consisting of a flat thin strip of magnetic material attached to the magnetic system so as to be oscillatory therewith about a repose position, and an electro-magnet having a winding and a magnetic circuit as a thin strip of magnetic material with two ends thereof presenting opposed co-planar pole pieces separated to provide a gap in the magnetic circuit, the armature being oscillatory in a path which extends at least into the gap, and the plane of the armature being substantially parallel to the common plane of the co-planar pole pieces when the armature is in the repose position.

In one form of the invention the armature in its repose position may lie in the same plane as the magnetic circuit.

In another form the plane of the armature in its repose position is so far removed from the plane of the magnetic circuit that the armature at its maximum amplitude of oscillation in one direction just comes into alignment with magnetic circuit.

In another form the plane of the armature in its repose position is spaced to a lesser degree from the plane of the magnetic circuit core so that in its oscillation in the one direction the armature moves into and past the position of alignment with the electromagnetic core.

In a modification of any of the above-described embodiments a half-wave rectifier may be incorporated in the supply circuit to the electromagnet winding so that only half-waves of current are supplied thereto, whereby the frequency of oscillation of the magnetic system may be halved.

To promote a ready understanding of the invention certain embodiments thereof will now be described, by way of example, with reference to the accompanying drawings in which—

FIGURE 1 shows in diagrammatic pictorial form one arrangement of the invention;

FIGURE 2 is a diagram showing the armature arranged so that in its repose position it is in alignment with, i.e. in the same plane as, the magnetic circuit;

FIGURE 3 is a diagram showing the repose position of the armature in a plane displaced by one-half the total

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oscillation amplitude from the plane of the magnetic circuit;

FIGURE 4 is a diagram showing the repose position of the armature in a plane displaced from the plane of the magnetic circuit by an amount equal to one-quarter of its total oscillation amplitude;

FIGURE 5 is a diagram showing the armature in its repose position in a plane displaced from the plane of the magnetic circuit by an amount intermediate between the amounts shown in FIGURES 2 and 4; and

FIGURE 6 is a diagram showing the winding of the electromagnet having a rectifier incorporated in its supply circuit, whereby the oscillation frequency of the magnetic system may be halved.

Referring initially to FIGURE 1, a known type of magnetic escapement is shown in which an escape wheel 11 is supported on a spindle 12 which is carried in bearings (not shown) so that the escape wheel may rotate freely. The escape wheel 11 is made of magnetic material, for example, magnetic iron having low hysteresis, and is provided with teeth 13. In radial alignment with each tooth is a hole 14 so that the contour of the teeth and holes constitute a wavy track of magnetic material around the wheel. A U-shaped permanent magnet 15 has its open ends 16 and 17 turned inwardly towards each other to leave a gap which is somewhat larger than the thickness of the escape wheel 11. The magnet 15 lies in a plane which is approximately tangential to the average diameter of the wavy track formed by the teeth and the holes in the wheel 11.

The magnet 15, at the closed end of the U, is attached to one end of a reed 18, which may conveniently consist of a ribbon of springy material having a substantially zero thermo-elastic co-efficient, and the reed 18 lies within the U formed by the magnet 15. The other end of the reed 18 is attached by means of a screw 19 to a bracket 20 which represents a portion of a fixed structure or framework. The parts are preferably arranged so that the magnet may oscillate about an axis containing the centre of gravity of the magnet and reed assembly. Since the magnet is positioned so that its ends 16 and 17 are substantially tangential to the average diameter or pitch circle of the wavy track on the escape wheel 11, oscillation of the magnet will control the speed of rotation of the wheel 11, which is normally driven by a spring.

In experiments with a system of this type it has been found that if the armature attached to the magnetic system is made of a fairly thin strip of magnetic material of low hysteresis and, for example 0.5 millimetre thick, as shown at 21 in FIGURE 1, and the system is so arranged that this strip oscillates in a gap 22 in a magnetic circuit 23 also made of a strip of magnetic material having an equal thickness, the core being provided with a winding 24, then various effects can be produced according to the repose position of the armature with respect to the poles of the electromagnet. These will now be described.

FIGURE 2 is a diagram showing the armature 21, in its repose position lying in alignment with, i.e., in the same plane as, the two ends of the magnetic circuit 23, so that when oscillating it moves by a distance A in each direction away from its repose position to a position 21a. The total oscillation amplitude is thus 2A. Under this condition the application of current to the electromagnet exerts an additional centralising force on the armature and thereby effectively stiffens the system, so that the natural frequency of oscillation of the oscillating magnetic system is raised to a frequency substantially above the original natural frequency of the mains. In a given system, the amount by which the natural frequency of the magnetic system is raised depends upon the strength of the electromagnet, and therefore upon the magnetizing ampere turns. If such a system is to be used with a 50 c./s. mains supply then the natural frequency of the oscillating magnetic system is made as closely as possible

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50 c./s. When the winding 24 is energized the natural frequency of the magnetic system is raised well above 50 c./s. but the electromagnet forces the magnetic system to continue to oscillate at 50 c./s. Since the magnetic system is no longer oscillating at its natural frequency, resonance effects are avoided and an appreciable amount of power must be applied to the winding 24 to force the magnetic system to continue to oscillate at a frequency of 50 c./s., so that reliable oscillation is assured.

FIGURE 3 is a diagram similar to FIGURE 2, but in this case the repose position of the armature 21 has been displaced so that the armature is no longer in alignment with the ends of the magnetic circuit 23, but the magnetic circuit and the armature lie in parallel planes, the displacement D being equal to the amount by which the armature moves from its repose position during oscillation; thus the dimension D is equal to the half-amplitude dimension A and the armature 21 comes into alignment with the magnetic circuit 23 during one half-cycle of its oscillation and during the succeeding half-cycle it is moving away from the core 23. Under this condition the natural frequency of the oscillating system is reduced, the degree of reduction again being dependent upon the magnetising ampere turns of the winding 24.

With this arrangement there is a pull on the armature 21 tending to pull it into alignment with the magnetic circuit 23 at each half-cycle of alternating current. That is to say, the system oscillates at double the mains frequency. Thus the oscillating magnetic system would be constructed so that its natural frequency of oscillation is 100 c./s. but when the winding 24 is energized the natural frequency of the oscillating system would be reduced to a frequency below 100 c./s. and it would be forced to oscillate at a frequency of 100 c./s. due to the electromagnet.

FIGURE 4 shows an arrangement in which the plane of the armature in its repose position is displaced from the plane of the magnetic circuit by about half the distance it moves from its repose position during oscillation, that is to say, the displacement D is equal to one-half A, so that during one half-cycle of oscillation the armature 21 moves away from the magnetic circuit and during the other half-cycle it moves into and past the position of alignment to the extent of about half its maximum displacement from the neutral point. The maximum synchronising effect is produced with this arrangement for a given amount of power applied to the winding 24, and the frequency of oscillation of the magnetic system is double the mains frequency. Thus for operation on 50 c./s. mains the oscillating magnetic system will be constructed to have a natural frequency of 100 c./s. and energisation of the coil 24 will cause the natural frequency of the oscillating system to be shifted away from the 100 c./s. frequency, but the electromagnet will force the oscillating system to oscillate at a frequency of 100 c./s.

FIGURE 5 is a diagram of an arrangement which is a compromise between the three conditions described in relation to FIGURES 2, 3 and 4. The armature 21 in its repose position lies in a plane parallel to the plane of the magnetic circuit 23 and is displaced therefrom by a fraction less than half of its maximum displacement from its repose position during oscillation. When the armature is displaced in one direction its movement is entirely away from the core 23 while during its displacement in the other direction from the repose position it moves into and past the position of alignment with the magnetic circuit 23. In this arrangement also the natural frequency of oscillation of the magnetic system must be double the mains frequency, that is to say, 100 c./s. for use with 50 c./s. mains, and the arrangement produces good synchronizing characteristics, the natural frequency of oscillation of the magnetic system being raised when power is applied.

It may be convenient to be able to use arrangements

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such as those shown in FIGURES 3, 4 and 5 with magnetic systems which have a natural frequency of 50 c./s. and this may be achieved by using a rectifier in the circuit feeding the winding 24 and such an arrangement is shown by way of example in FIGURE 6. As before, the armature 21 oscillates in the gap 22 in the magnetic circuit 23. The winding 24 has a rectifier 25 connected across it and an impedance, represented by the resistance 26, is connected in series with the electric mains to limit the current through the rectifier 25. When the mains current flows in one direction the resistance of the rectifier 25 is very high, so that the normal current flows through the winding 24 but when the main current flows in the reverse direction the rectifier 25 provides a virtual short circuit of the winding 24, so that practically no current flows through this winding.

If the mains supply should fail, winding 24 is de-energized so that the electromagnet effectively ceases to exist and the natural frequency of the oscillating magnetic system returns to its original level, so that the magnetic escapement continues to control the clock at its correct speed.

A substantial increase in oscillation amplitude resulting from resonance, or an approach to the resonant state, may result in malfunctioning in several ways. The oscillating system may be pulled out of step—that is, out of synchronism—with the escapement wheel, or it may be pulled out of phase, although still running in synchronism with the wheel. These faults may result in irregular running. An excessive oscillation amplitude may also cause the oscillating system to strike stationary parts of the structure, resulting in noisy running or actual damage. These possibilities are substantially eliminated by the invention.

According to a further feature of the invention a protective device may be included in the clock, which comes into operation in case of certain types of malfunctioning.

It is known, in mechanisms of this kind, to provide a guard wire. This consists of a short length of springy wire attached to the oscillating magnet, a part of the length of the wire lying substantially parallel to the oscillation axis. The guard wire is so placed that when the oscillating system and the escape wheel are running correctly the guard wire is carried over the top of each tooth of the wheel and passes down between each adjacent pair of teeth without touching them. If the oscillating magnet should get out of phase or out of step with the wheel then the guard wire strikes the teeth in turn until correct operation is restored. In an improved version of this arrangement for use with this invention two teeth, or two pairs of teeth, at approximately diametrically opposite points on the wheel, are made longer than the other teeth. If the magnetic lock should be broken, or if the oscillating system should begin to oscillate at a harmonic of the intended frequency, the guard wire strikes the long teeth, which causes the escape wheel to stop and restart from rest. If, however, upon energizing the electromagnet, the alternating field is out of phase with

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the mechanical oscillation of the magnetic system, the escapement wheel is allowed to rotate through part of a revolution, so that the oscillating system may stabilise itself in phase with the A.C. supply, before the guard pin can operate.

If the escape wheel has an even number of teeth then the long teeth are at diametrically opposite points on the wheel, but in some instances it may be preferable to have the teeth or pairs of teeth arranged so that they are not quite diametrically opposite, for example, by using an odd number of teeth on the wheel.

We claim:

1. A time control mechanism comprising an escapement wheel having a wavy magnetic track therearound and an oscillatory magnetic system co-operating therewith, an armature consisting of a flat thin strip of magnetic material attached to the magnetic system so as to be oscillatory therewith about a repose position, and an electro-magnet having a winding and a magnetic circuit as a thin strip of magnetic material with two ends thereof presenting opposed co-planar pole pieces separated to provide a gap in the magnetic circuit, the armature being oscillatory in a path which extends at least into the gap, and the plane of the armature being substantially parallel to the common plane of the co-planar pole pieces when the armature is in the repose position.

2. A mechanism as claimed in claim 1, in which the armature in its repose position lies in the common plane of the co-planar pole pieces.

3. A mechanism as claimed in claim 1, in which the armature in its repose position lies wholly outside the gap.

4. A mechanism as claimed in claim 1, in which the armature in its repose position lies partly within and partly outside the gap.

5. A time control mechanism comprising an escapement wheel having a wavy magnetic track therearound and an oscillatory magnetic system co-operating therewith, an armature consisting of a flat thin strip of magnetic material attached to the magnetic system so as to be oscillatory therewith about a repose position, and an electro-magnet having a winding, a half-wave rectifier connected with the winding, and a magnetic circuit as a thin strip of magnetic material with two ends thereof presenting opposed co-planar pole pieces separated to provide a gap in the magnetic circuit, the armature being oscillatory in a path which extends at least into the gap, and the plane of the armature being substantially parallel to the common plane of the co-planar pole pieces when the armature is in the repose position.

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