Sept. 5, 1944. T. B. GIBBS ET AL 2,357,645

ELECTRIC CLOCK

Filed May 20, 1942

Fig. 2.

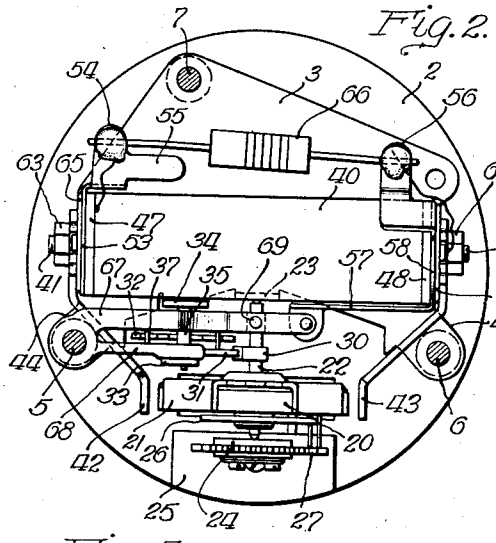


Fig. 1.

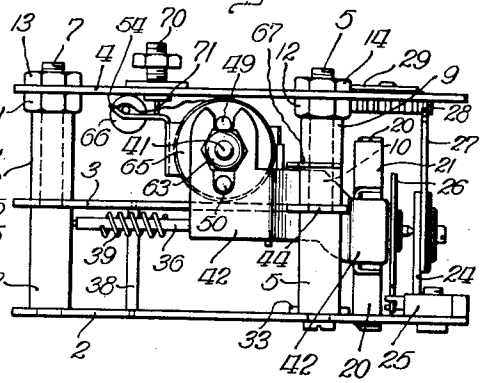


Fig. 4.

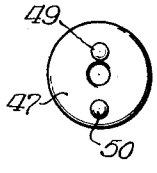


Fig. 3.

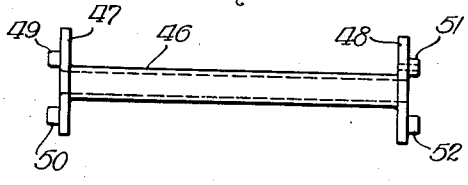


Fig. 5.

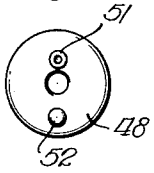


Fig. 6.

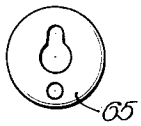


Fig. 10.

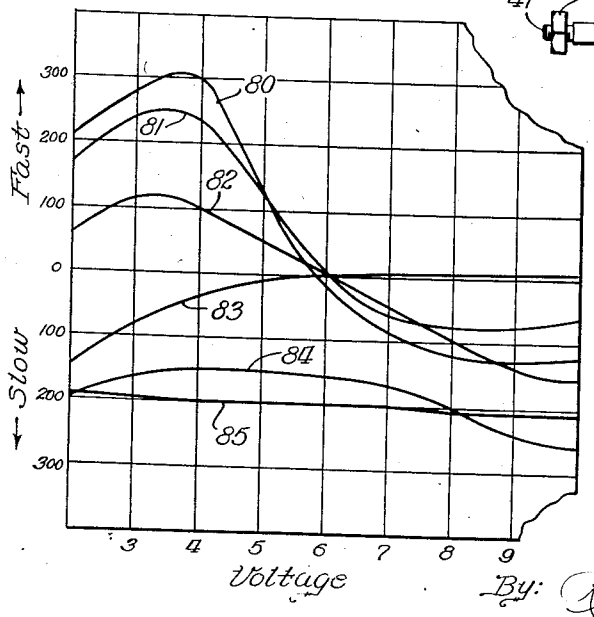


Fig. 7.

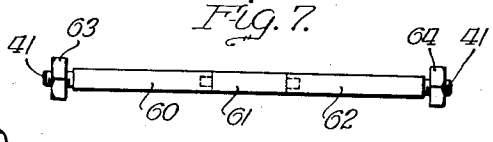


Fig. 8.

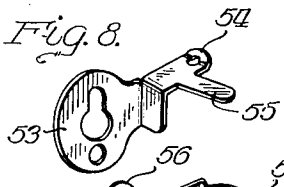
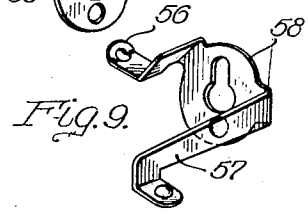


Fig. 9.



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Patented Sept. 5, 1944

2,357,645

UNITED STATES PATENT OFFICE

2,357,645

ELECTRIC CLOCK

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Application May 20, 1942, Serial No. 443,753

11 Claims. (Cl. 58—28)

The present invention relates in general to clocks of the electromagnetically driven balance type, such as are used in automobiles, for example; and the object of the invention is to produce a new and improved clock of this character.

More specifically, the object of the invention is to produce a clock of the foregoing type which is adapted to maintain a substantially constant rate notwithstanding the changes in voltage to which the clock is subjected in practice. The object is attained by a novel construction of the magnetic circuit of the electromagnet which drives the balance.

A further object of the invention is an improved spool and terminal construction for the electromagnet.

The invention will be described in detail hereinafter, reference being had to the accompanying drawing, in which—

Fig. 1 is a side view of an automobile clock embodying the invention;

Fig. 2 is a rear view of the clock, with the back frame plate removed to expose the electromagnet and other parts;

Fig. 3 shows the spool on which the magnet coil is wound;

Figs. 4 and 5 are end views of the spool;

Fig. 6 shows one of the insulating washers employed to insulate the coil terminal members;

Fig. 7 shows the core of the electromagnet;

Fig. 8 shows in perspective the terminal member used at one end of the spool;

Fig. 9 shows in perspective the combined terminal member and contact spring used at the other end of the spool; and

Fig. 10 shows a number of curves which indicate how the rate of a clock varies with the voltage, depending on the construction of the electromagnetic circuit.

The clock illustrated herein may be considered as an improvement on the clock shown and described in the application of Jean Fink et al., Ser. No. 365,240, filed November 12, 1940, to which reference may be made for a detailed description of the construction and operation of those parts of the clock which are not involved in the present invention.

Referring to the drawing, the various parts of the clock are mounted on a frame which comprises the front plate, 2, the plate 3, and three posts 5, 6 and 7. The front plate 2 may be circular in shape and has the three posts secured to it by a riveting or staking operation. Each post is reduced in diameter for about half its length, as shown by the dotted lines in Fig. 1, whereby shoulders are formed, and the ends of these reduced portions are threaded. The plate 3, the shape of which can be seen clearly from Fig. 2, has holes drilled therein to receive the posts 5, 6 and 7, and rests against the aforementioned shoulders. The plate 3 is clamped in position by means of three nuts such as 11 and 12, which are threaded on the posts, and a number of tubular spacers. There are two spacers such as 8 on the posts 7 and 6, respectively, and two shorter spacers 9 and 10 on the post 5.

The back plate 4 is preferably made of insulating material and is readily removable. This plate has holes drilled to correspond to the location of the posts 5, 6 and 7, and is clamped against the nuts such as 11 and 12 by nuts such as 13 and 14.

The balance comprises a ring 20, of brass or other suitable non-magnetic material, and a four-pole armature 21 in which the ring 50 is supported. The armature 21 may be a sheet metal stamping and is of magnetic material. The armature is rigidly mounted on an arbor 22, which has a bearing at one end in the down-turned portion 23 of the frame plate 3 and a bearing at the other end which is mounted on the balance cock 24. The balance cock has a base 25 which is secured to the frame plate 2.

The usual hairspring is indicated by reference numeral 26. A regulating mechanism is also provided and includes a toothed sector 27 which is rotatably mounted on the balance cock in known manner. The sector 27 meshes with a gear 28 which is mounted on the back plate 4 and which may be rotated by means of the pointer 29. These parts function in the usual manner, the movement of the pointed rotating gear 28 and sector 27 and the latter moving the regulating pins along the hairspring to change the effective length thereof.

On the balance arbor 2 there is mounted a single tooth pinion 30 which actuates the pallet lever 31 during the oscillation of the balance in each direction. The pallet lever is supported on a shaft 35 which has a bearing at one end in the up-turned portion 34 of frame plate 3 and at the other end in a bracket 33 which projects upward from the frame plate 2. Beneath the shaft 35 there is an arbor 36 on which the escape wheel 32 is supported. The arbor 36 is partly shown in Fig. 1 and has a bearing at one end in the frame post 7. At the other end the arbor 36 has a bearing in the bracket 33. The pallet lever 31 drives the escape wheel by means of two pins or pallets 37. The arbor 36 on which the escape

wheel is mounted drives the clock movement by means of a worm 39 and a gear wheel in mesh therewith which is mounted on the shaft 38. The rest of the gear train has been omitted, as it is well known and is not involved in the invention.

The balance is maintained in oscillation by means of an electromagnet comprising the winding 40, core 41, and pole pieces 42 and 43. This electromagnet will now be described more in detail.

The two pole pieces 42 and 43 are sheet metal stampings of the shape shown in Fig. 1 and bent to the form shown in Fig. 2. The pole pieces are slotted about midway between their ends. The frame plate 3 is provided with ears 44 and 45 by means of which it is supported on the posts 5 and 6 and the two pole pieces are forced onto these two ears, respectively, before the frame plate 3 is assembled in the frame. Thus the pole pieces are firmly supported on plate 3.

The pole pieces are preferably made of a high grade, pure, annealed iron such as Armco iron. The armature 21 of the balance is preferably made of the same material.

The coil 40 is wound on a spool which is shown in detail in Fig. 3. This spool is molded from a suitable plastic material and comprises the tubular portion 46 and the two heads 47 and 48. There are two integrally formed studs 49 and 50 projecting from the head 47 and two similar studs 51 and 52 projecting from the head 48. There is an opening through the head 48 and stud 51 which is provided to enable the inside end of the winding to be brought outside the spool. The winding preferably consists of about 3100 turns of No. 34 enameled copper magnet wire and has a resistance of about 60 ohms. The winding has a suitable cover, as indicated in Fig. 2.

The terminal member shown in Fig. 8 includes a perforated disc-shaped portion 53 which is assembled on the head 47 of the spool as shown in Fig. 2, the studs 49 and 50 projecting through the openings in the part 53. The terminal member also includes a slightly curved soldering terminal 54 and a flexible terminal strip 55. The terminal member shown in Fig. 9 also includes a perforated disc-shaped portion, designated by numeral 58, which is assembled on the head 48 of the spool, as shown in Fig. 2. This terminal member has a soldering terminal 56 and a contact spring 57 formed integrally therewith.

The core of the electromagnet is shown in Fig. 7. It comprises a round rod approximately 1⅝ inches long and .093 inch in diameter and is threaded at the ends for the nuts 63 and 64. The core may be made of Mu metal. Preferably, however, and as shown in the drawing, the core is made in three sections, of which the sections 60 and 62 are made of the same material as the pole pieces 42 and 43, Armco iron, for example, while the section 61 is made of Mu metal. The three sections may be joined together in any suitable manner, by means of threaded joints, for example, or they may be welded together. The all Mu metal core is the same as the core shown in Fig. 7, except that it comprises only a single section. If the joints are omitted, therefore, this figure may be considered as an illustration of the core made of Mu metal throughout.

The complete coil with the terminal members and core may be assembled on the frame plate 3 after the pole pieces 42 and 43 are put on as previously described and before the plate 3 is assembled in the frame. The nuts 63 and 64 having been removed, the core is inserted in the wound spool and the terminal members are assembled on the spool heads as previously described. The central openings in the disc-shaped parts 53 and 58 are large enough to avoid contact between these parts and the core. An insulating washer, such as 65, Fig. 6, is then put on outside each terminal member and the spool is inserted between the pole pieces 42 and 43. As shown in Fig. 1, the pole pieces are bifurcated at the ends, forming slots to receive the threaded ends of the core and the projections on the spool heads. The nuts 63 and 64 are now replaced and are tightened up, whereby the spool and terminal members are securely clamped between the pole pieces. It will be seen that the projections on the spool heads are effective to exactly position the terminal members relative to the coil and also serve to position the coil and terminal members relative to the pole pieces 42 and 43 and the frame plate 3.

The reference character 66 indicates a resistor which is connected in bridge of the coil. One of the terminal wires of the resistor is soldered to the terminal 54 along with the outside end of the coil winding, as shown in Fig. 2. The inside end of the winding is brought out through the hollow spool head projection 51 and is soldered to terminal 56 with the other terminal wire of the resistor.

The contact spring 57 is the fixed contact spring of a pair of contact springs which are provided for controlling the circuit of the electromagnet. The movable contact spring of the pair is indicated at 67 and is clamped at one end between the tubular spacers 9 and 10 on post 5. Formed integrally with spring 67 is a spring 68, which is the restoring spring for the pallet lever 31. The contact spring 67 has a small armature 69 on the lower side which is riveted to the spring, and there is a small permanent magnet (not shown) eccentrically mounted on the balance arbor 22 beneath the armature. The contact spring 67 is so adjusted that there is a small gap between it and the fixed contact spring 57, but during each oscillation of the balance the permanent magnet on the balance arbor attracts the armature 69 and thereby causes the contact spring 67 to engage the spring 57 and close contact therewith. At times when the power is off and the balance is not oscillating the permanent magnet holds the contact closed.

After the other parts have been assembled the back plate 4 may be put on, as shown in Fig. 1. The back plate carries a binding post 70 and when it is assembled in position a pin 71 secured to the binding post 70 engages the terminal strip 55.

The clock is provided with hands and a dial and a suitable casing by means of which it may be mounted on the instrument panel of an automobile. When so installed the clock operates from the usual 6-volt storage battery with which the car is provided, the live terminal of the battery being connected to the binding post 70. The complete circuit of the electromagnet extends from the live pole of the battery by way of binding post 70, pin 71, terminal strip 55, soldering terminal 54, winding 40, soldering terminal 56, contact spring 57, contact spring 67, frame of clock, and the frame of the car to the other pole of the battery.

The clock is self-starting and begins to run as soon as it is connected up as above described. Current flow over the circuit as traced energizes the electromagnet, which rotates the balance in

one direction or the other through an angular distance of a few degrees, whereupon the armature 69 is released and spring 67 breaks contact with spring 57, thus opening the magnet circuit. The rotation of the balance tensions the hairspring 26 and the direction of rotation is shortly reversed, with the result that the circuit of the electromagnet is again closed when the permanent magnet on arbor 22 passes the armature 69. Thus the balance is given another rotative impulse, but in the opposite direction. The operation continues in this manner and in a very short time the balance will attain its normal amplitude, a power impulse being delivered to it during each oscillation when the permanent magnet passes the armature 69.

The oscillatory motion of the balance drives the clock through the medium of the pinion 30, pallet lever 31, and escape wheel 32. The operation of the drive mechanism is fully explained in the pending application previously referred to and accordingly need not be discussed further herein.

The rate of the clock is adjusted by means of the regulator mechanism, which adjusts the length of the hairspring; and were it not for the fact that the clock is used in an automobile there would be no special difficulty in making it keep reasonably accurate time. The necessity of driving the clock from the automobile storage battery introduces a special problem, however. The normal voltage of the battery is about 6 volts, but it may drop as low as 4 volts or even less on starting and rise to 8 volts or more when the battery is charging. These varying voltages tend to affect the rate of the clock by varying the amplitude of the balance. The amplitude depends on the power delivered, which in turn is proportionate to the square of the voltage, unless some means is employed to prevent this result.

A clock of the type described herein will run with a fairly constant rate if the amplitude of the balance is not less than about 360 degrees and is not greater than about 460 degrees; that is, there is a certain range within which the amplitude may vary without appreciably affecting the rate. Efforts have been made in the past to eliminate or reduce the effect of voltage changes on the amplitude of the balance by so arranging the magnetic circuit of the driving electromagnet that it will become saturated at a low voltage, on the theory that if saturation is obtained at the minimum operating voltage an increase in the voltage cannot increase the amount of power delivered to the balance and hence cannot affect the amplitude. These efforts have not been entirely successful, even though a small variation in amplitude is permissible, as indicated by the range specified above.

The present invention according to which a constant rate is obtained notwithstanding large voltage variations depends on the principle of saturation but utilizes it in a different manner. In the attempts made in the past to secure a relatively constant power and amplitude by means of the saturation principle attention has naturally been directed to those parts which are immediately involved in the delivery of power to the balance and the problem has been attacked by limiting the cross-section of the pole pieces or the balance armature and by using for these parts magnetic materials which become saturated at a low flux value. A certain measure of improvement resulted from these endeavors, although as mentioned above the results were less successful than was anticipated. However, since the experiments were conducted on an extensive scale it was thought for a considerable time that the maximum possible results had been obtained.

It has now been discovered that wholly unexpected and highly satisfactory results can be secured by attacking the problem from the standpoint of the core of the electromagnet instead of the pole pieces and balance armature. These latter parts are not restricted as to flux-carrying capacity but are made of relatively large cross-section and of material having a high maximum permeability, and the limitation as to flux-carrying capacity is imposed at the core of the electromagnet. The electromagnet is thus operated with the core in a condition of saturation, while the flux in the pole pieces and balance armature is far below the saturation point. Saturation of the core at the desired low voltage is obtained by limiting the cross-section of the core and by utilizing a magnetic material such as Mu metal, which has a high permeability at low flux densities and a relatively low maximum permeability. The best results are secured by confining the use of the Mu metal to a short section at the center of the core.

A large number of tests have been made in order to determine the merits of the new magnetic circuit as compared to former designs, and the results of a few of these tests are illustrated by the curves shown in Fig. 10. In making these tests a clock having a certain magnetic structure was regulated to run accurately at 6 volts and the rate was checked at different voltages while the voltage was varied over a range of about 3 to 10 volts. The rates for different voltages thus determined were then used to plot a curve showing the performance of a clock having such magnetic structure. The test was then repeated using the same clock with different magnetic structures and thus data was obtained for plotting additional curves. Since the same clock was used in all cases, the differences in performance can be attributed to the differences in magnetic structure. Such series of tests have been run on a number of different clocks and, while the results varied somewhat due to differences in hair-springs, friction and other factors, the curves shown in Fig. 10 are typical. It should be stated that in most cases the clock would not start to run at a voltage much below 3 volts and hence the rate values shown for 2 volts result from a continuation of the portions of the curves actually determined. The rates were checked by means of a watch timing apparatus, which enabled a complete series of tests on a clock to be performed and the results tabulated in a few minutes. All tests were made at the same temperature, which eliminated any change in rate due to this factor.

Curve 80 is a curve showing the performance of a clock having the entire magnetic circuit, including core, pole pieces and balance armature, made of soft iron, the particular material used being Armco iron. The upward slope of the curve at 3 volts is due to the fact that with a voltage less than about 4 volts the clock does not receive enough power to take care of the load on the escapement adequately, although the clock starts at 3 volts or somewhat less. The maximum rate is attained at about 4 volts, the curve showing that the clock runs about 300 seconds per day (24 hrs.) fast at this voltage. As the voltage is increased, the amplitude of the balance increases and the rate decreases until at about 6

volts the clock runs at the correct rate. With further increases in voltage the curve begins to flatten out and the rate becomes substantially constant in the range between 8 and 10 volts. Over the normal operating range between 4 and 8 volts, however, the rate changes from about 300 seconds per day fast to more than 100 seconds per day slow.

Curve 81 shows how the rate of the same clock varies when a Mu metal balance armature is used, the core and pole pieces being of soft iron. This curve has characteristics similar to those of curve 80, but indicates some improvement.

A further improvement is indicated by curve 82, which shows the performance of the clock when a Mu metal balance and Mu metal pole pieces were used. It will be seen, however, that the performance is still far from satisfactory, as the rate variation covers a range of about 200 seconds per day over the voltage range between 4 and 8 volts.

Curve 83 shows the performance of the clock when equipped with a Mu metal core, the pole pieces and balance armature being of soft iron. This curve shows a radical change in performance, the rate being substantially constant over a range extending from about 5 volts to 10 volts. A lack of power in the range 3–5 volts is indicated, however.

In order to remedy this defect a larger core was tried, the diameter being increased from .093 inch to .120 inch, and the result is shown by curve 84. This curve and curve 85 are displaced below the zero axis in order to avoid confusion with the other curves. Curve 84 shows a very satisfactory performance and some further improvement might be obtained by a further increase in core diameter. However, the clock as designed is rather small and it is not practicable to increase the core dimensions any further without redesigning the coil and other parts.

Curve 85 shows the rate of the clock using the preferred magnetic circuit in which all the parts are of soft iron except for a small section at the center of the core which is made of Mu metal, as illustrated in Fig. 7. As can be seen from the curve, the rate is substantially constant over the entire operating range, with a considerable factor of safety at both ends of the range. It is believed that this entirely satisfactory result is in part or mainly attributable to the fact that the leakage flux is eliminated by confining that portion of the magnetic circuit which becomes saturated to the core of the coil and by making all other parts of the magnetic circuit of sufficient flux-carrying capacity to carry all the flux produced.

The core construction shown in Fig. 7 has the additional advantage over an all Mu metal core of a substantial saving in Mu metal, which is very much more expensive than Armco iron. The difference in the cost of the two materials largely compensates for the more expensive jointed construction and probably shows an actual gain when welded joints are used. An additional saving in cost may be obtained by using a Mu metal section at one end of the core rather than in the center, which eliminates one joint. A clock having a magnet core so constructed has an excellent performance under different voltage conditions, but the tests which have been made indicate that it is not as good as a clock using the core shown in Fig. 7.

Other modifications may be made in the magnetic circuit within the scope of the invention, which consists in making the balance armature and the pole pieces, or at least those parts of the pole pieces which are not directly associated with the core, of ample cross-section and of such material that the magnetic flux is at all times below the saturation value, whereas that part of the magnetic circuit which becomes saturated is associated with the coil and is preferably centrally located inside the coil.

Although Mu metal and Armco iron are specifically referred to herein and in the claims, it will be understood that these terms are intended to include equivalent magnetic materials.

The invention having been described, that which is believed to be new and for which the protection of Letters Patent is desired will be pointed out in the appended claims.

What is claimed is:

1. In a clock of the electromagnetically driven balance type, an electromagnet including a spool and winding thereon, terminal members for the winding of the magnet, said members including parts having openings therein adapted to be clamped against the spool heads and integrally formed contact parts adapted to be included in the magnet circuit, and a plurality of locating studs projecting from each spool head through the said openings in the adjacent part of the associated terminal member.

2. In a clock of the electromagnetically driven balance type, an electromagnet including a spool of molded plastic material having integrally formed projections at each head thereof, and a terminal member associated with each spool head, each terminal member including a perforated part clamped against the associated spool head in an angular position determined by the projections thereon, a soldering tab to which one end of the magnet winding is soldered, and a contact member included in the magnet circuit, the said perforated part, soldering tab and contact member of each terminal member being integrally formed from a single piece of sheet material.

3. A clock as claimed in claim 2, wherein the spool has a core which projects from the ends thereof between the projections in the spool heads, and pole pieces are provided having slots to receive the ends of the core and the spool head projections, said pole pieces being clamped against the spool heads outside of the terminal members by nuts threaded on the core.

4. In a clock of the electromagnetically driven balance type, a sub-assembly comprising a frame plate having projecting ears, pole pieces rigidly mounted on said plate by means of slots through which said ears project, said pole pieces having upwardly projecting slotted end portions, a magnet assembly comprising a spool and winding and a core projecting from the spool at both ends, the said spool having projections on each of the heads located on a diameter thereof, said magnet assembly also including terminal members on the spool heads having perforations through which the ends of the core and the said projections protrude, said magnet assembly being inserted between the said slotted end portions of said pole pieces with the said spool head projections extending into the slots of the pole pieces and the ends of the core extending through said slots, insulators inserted between the terminal members and the slotted end portions of said pole pieces, and nuts threaded on the ends of said core by means of which the said pole pieces are clamped to the magnet assembly.

5. In a clock of the electromagnetically driven balance type, a balance armature, and an electromagnet for driving said armature comprising a core of uniform diameter having a winding thereon and pole pieces extending from the ends of the core into operative relation to said balance armature, the said core being made of Mu metal and the armature and pole pieces being made of soft iron.

6. In a clock, an oscillatable element, means for driving said element comprising an armature connected thereto and an electromagnet having pole pieces cooperating with said armature, said electromagnet having a core which is made in part of soft iron and in part of Mu metal, and the said armature and pole pieces being made of soft iron, the Mu metal portion of said core being inside the winding of the electromagnet.

7. In a clock, an oscillatable element, means for driving said element comprising an armature connected thereto and an electromagnet having pole pieces cooperating with said armature, said electromagnet having a core composed of three sections of which the center section is of Mu metal and the two end sections are of soft iron, and the said armature and pole pieces being made of soft iron.

8. In a clock, an oscillatable element, means for driving said element comprising an armature connected thereto and an electromagnet having pole pieces cooperating with said armature, said electromagnet having a core of uniform cross-section composed in part of a magnetic material which has a high permeability at low flux densities and a low saturation flux density, and the remainder of the core and the said armature and pole pieces being composed of a magnetic material which has a relatively high saturation flux density.

9. In a clock, an oscillatable element, means for driving said element comprising an armature connected thereto and an electromagnet having pole pieces cooperating with said armature, a winding for said electromagnet adapted to be energized at different voltages, and a core of uniform cross-section for said electromagnet which becomes saturated at a predetermined minimum voltage, the said armature and pole pieces having a flux carrying capacity which substantially exceeds the flux carrying capacity of the core.

10. In a clock, an oscillatable element, means for driving said element comprising an armature connected thereto and an electromagnet having pole pieces cooperating with said armature, a winding for said electromagnet adapted to be energized at different voltages, and a core for said electromagnet having a uniform diameter and including a section inside said winding which becomes saturated at a predetermined minimum voltage, the remainder of the core and the said armature and pole pieces having sufficient flux carrying capacity so that they do not become saturated at said minimum voltage.

11. In a clock of the electromagnetically driven balance type adapted to operate on different voltages, an electromagnet structure including a magnet winding and an armature, and a magnetic circuit including said armature and a section adapted to become saturated at a predetermined minimum voltage, said section being composed of Mu metal and located inside said winding, and all other parts of said magnetic circuit being composed of soft iron and having such flux carrying capacity that they do not become saturated at said minimum voltage.

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