Dec. 15, 1942. H. R. CRAGO 2,305,407

PULSATION APPARATUS

Filed Aug. 27, 1940

Fig. 1.

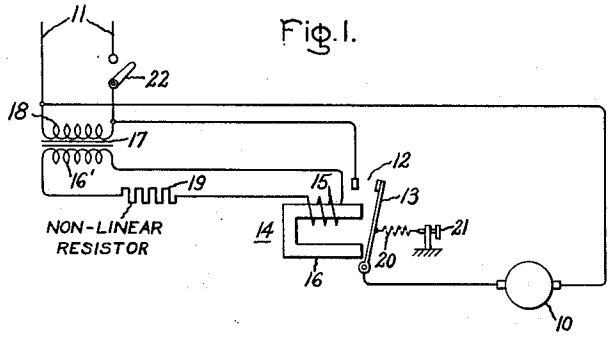


Fig. 2.

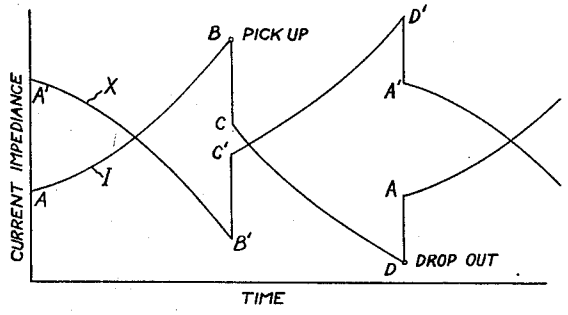
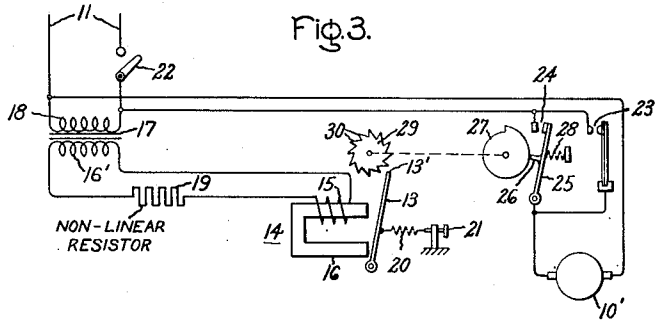


Fig. 3.



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PULSATION APPARATUS

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Application August 27, 1940, Serial No. 354,407

3 Claims. (Cl. 172—239)

My invention relates to alternating current apparatus in which the effective value of the current is caused to undergo regularly recurring variations or pulsations.

It is an object of my invention to provide improved electrical means for producing pulsations in the effective value of the current in an alternating current circuit.

It is a further object of my invention to provide improved apparatus for converting alternating current energy into periodic mechanical motion that shall be simple in construction and have a minimum of parts.

According to my invention a magnetic armature of an electromagnet, having an operating coil energized from a source of alternating current, is continuously moved between the attracted and unattracted positions by causing the effective value of the current in the operating coil to pulsate above the pick up and below the drop out values for the armature. This pulsating action is accomplished by connecting a resistor having a negative temperature coefficient of resistance in series with the electromagnet operating coil. Thus when the magnetic armature picks up, the inductance of the operating coil increases, thereby increasing the impedance of the circuit and decreasing the current therein. The decrease in current results in an increase of the resistance of the resistor thereby further decreasing the current which finally falls below the "drop out" value and the armature drops out, that is, it moves to the unattracted position. The drop out of the armature decreases the inductance of the operating coil and the resultant impedance of the circuit and the current increases. This increase in current decreases the resistance of the resistor which further increases the current to a point where the armature finally picks up again.

Thus the effective value of the current in the operating coil pulsates at a frequency which is relatively low as compared to the frequency of the current supply. The armature which is attracted by the flux produced by the operating coil oscillates at the same pulsation frequency and such mechanical movement is useful in operating control switches, timers, etc.

My invention will be better understood from the following description taken in connection with the drawing in which Fig. 1 represents a control system embodying my invention; Fig. 2 illustrates the curves of current and impedance v. time which are useful in explaining the operation of my invention; and Fig. 3 illustrates the application of my invention to a stoker control.

Referring to Fig. 1 of the drawing, I have shown an electrical load device such as a motor 10 which is intermittently connected to a source of current supply such as an alternating current source 11 by a timing switch 12. The timing switch 12 is operated by the armature 13 of an electromagnet 14 and for the purpose of simplicity and convenience may have one of its contacts directly mounted on the armature 13. The electromagnet 14 has an operating coil 15 which is wound on one leg of a U-shaped magnetic core member 16. The operating coil 15 of the electromagnet 14 is energized from the secondary 16' of a control transformer 17 having its primary 18 connected to the alternating current supply 11.

The operating coil 15 has connected in series therewith a non-linear resistor 19 having a negative temperature coefficient of resistance. Materials like boron and some forms of carbon have relatively high negative temperature coefficients of resistance so that under ordinary conditions their resistance decreases with an increase of current therethrough due to the heating effect of the current. In a pending application Serial No. 327,901 of Chester I. Hall, filed April 4, 1940, which is assigned to the same assignee as this application, there is described and claimed a resistance material having a very high negative temperature coefficient of resistance which has been found to give satisfactory operation in my apparatus. This material may be a mixture of magnesium oxide, copper oxide and sodium silicate having ratios by weight respectively of 2.52, .25, and 1.47. This mixture is highly compressed, sintered into a coherent mass and bonded intimately with the surfaces of two electrodes.

The armature 13, which is made of non-permanent magnetic material, is biased to the unattracted position by means of a biasing spring 20, the tension of which may be controlled by an adjusting screw 21. When the current in the operating coil 15 reaches a first predetermined or "pick up" value the armature 13 snaps to the left to the attracted position overcoming the biasing force of the spring 20. In this position the switch 12 is closed and the armature member closes the open end of the core member 16 of the electromagnet 14 whereby the permeance of the magnetic circuit through the core 16 is considerably increased. When the current in the operating coil 15 decreases below a second lower predetermined or "drop out" value the armature 13 is snapped to the right to the unat-

tracted position by the spring 20 and switch number 12 is opened. The movement of the armature 13 back to the unattracted position acts to decrease the permeance of the magnetic circuit through the core 16. The reason why the armature 13 snaps from the unattracted to the attracted position when the current in the operating coil exceeds the "pick up" value and does not assume an intermediate position is that when the magnetic pull is sufficient to overcome the force of the biasing spring 20 and start movement of the armature the magnetic pull increases much more rapidly than the opposing force of the spring during movement of the armature so that the armature continues its movement to the end of its travel. This is accomplished by properly correlating the force of the biasing spring and the magnetic pull of its armature. Similarly, when the current in the operating coil falls below the "drop out" value at which the spring force is sufficient to overcome the magnetic pull on the armature and the armature moves toward the unattracted position, the magnetic pull decreases much more rapidly than the force of the spring so that the armature continues its movement to the opposite end of its travel and does not assume an intermediate position. This action results in a current differential of operation of the electromagnet armature so that the "pick up" current value is different from and greater than the "drop out" current value.

In operation when the operating coil 15 is energized from the source of alternating current supply 11 by the closing of a suitable control switch 22, the armature member 13 periodically moves between the attracted and unattracted positions operating the timing switch 12 which in turn causes intermittent energization of the load device or motor 10. The oscillation of the armature 13 between the attracted and unattracted positions is due to the fact that the effective value of the current in the operating coil 15 pulsates above and below the pick up and drop out values for the armature 13. The reason for the pulsation of the current passing through operating coil 15 may be best understood by reference to Fig. 2 of the drawing which shows the relations of the current and impedance with time in the circuit through which the energizing current for coil 15 flows.

In the following discussion the term energizing circuit will be used to mean the circuit including the resistor 19, and the operating coil 15 of the electromagnet 14. Referring now to Fig. 2 of the drawing, the curve I shows the relation of the current in the energizing circuit with time and the curve X shows the relation of the impedance of the energizing circuit with time. When the transformer is energized, as by the closure of the control switch 22, the current in the energizing circuit is at some value indicated at the point A and impedance of the circuit, represented by the curve X, is at some value A'. At this point the armature 13 is unattracted. The passage of the current through the resistor 19 causes its temperature to increase so that the resultant resistance of the resistor decreases. This causes the overall impedance of the energizing circuit to fall until the point B' is reached and consequently the current rises until a corresponding point B is reached. The value of the current at the point B is the pick up value, that is, the value of current in coil 15 required to move the armature to the left or attracted position against the bias of the spring 20. When the current value reaches the point B and the armature moves to the attracted position the permeance of the magnetic circuit through the core member 16 is increased due to the fact that the magnetic armature member 13 then closes the air gap at the open end of the core 16. This increase in magnetic permeance also causes an increase of the inductance of operating coil 15 which in turn increases the impedance of the energizing circuit. This causes the impedance of the energizing circuit to rise abruptly to the point C' and consequently the current falls abruptly to the value indicated at C. The decrease in current in the energizing circuit caused by the movement of the armature 13 to the attracted position causes the temperature of the resistor 19 to decrease. This decrease in temperature then causes an increase in the impedance of the energizing circuit due to the fact that the resistance of resistor 19 increases. The impedance of the energizing circuit then increases until the point D' is reached and the current decreases until the point D is reached. The value of the current at the point D is the "drop out" value, that is, the value of the current in the operating coil 15 at which the armature is snapped to the unattracted position by the biasing spring 20. The movement of the armature 13 to the right or unattracted position opens switch 12 and also reestablishes the air gap at the end of core 16 thereby causing a decrease in the permeance of the magnetic circuit. The decrease in permeance causes a decrease in the inductance of operating coil 15 and a decrease in the impedance of the energizing circuit. Thus when the armature moves to the unattracted position the impedance of the energizing circuit falls from the point D' to the point A' and correspondingly the current increases from the point D to the point A. The current in the energizing circuit then begins to increase and the cycle of operation previously described repeats itself. Thus it is seen that while switch 22 is closed and the energizing circuit is energized from a source of alternating current, the armature continuously oscillates between the attracted and unattracted positions.

The frequency of the pulsations of the effective value of the current in the energizing circuit may be varied by adjusting the tension of the spring 20 by the adjusting nut 21. In this manner the frequency of the pulsations may be varied over a relatively wide range. The frequency of the pulsations of the effective value of the current and also the corresponding movement of the armature is independent of the frequency of the alternating current supply. When I say independent I mean that there is no synchronous relation between the oscillation of the armature and the cycles of the alternating current supply. However, a change in frequency of the supply current would, of course, change the value of the impedance of the operating coil 15 and would to that extent change the operation of the circuit.

The reciprocating movement of the armature 13 may very advantageously be used to operate a timing mechanism. Such a timing mechanism has the advantage that it may be connected directly to an alternating current source of supply and will operate continuously without the need of current interrupting switches which are apt to deteriorate very rapidly. In Fig. 3 of the drawing I have shown such a timing mechanism connected to intermittently operate a stoker motor 10' driving a stoker of a furnace not shown. The stoker motor 10' is arranged to be energized from the source 11 whenever the thermostatic

switch 23, located in the zone heated by the furnace with which the stoker is associated, calls for heat. It is necessary to energize periodically the stoker independently of the thermostatic switch 23 to prevent the fire from going out during intervals when the heat demand is low. This is accomplished by connecting a timing switch 24 in parallel with the thermostatically operated switch 23 which is adapted to close and cause energization of the stoker at regular intervals. The switch 24 is shown as operated by a pivoted lever 25 having a projection 26 which is biased against the surface of a rotating cam 27 by a biasing spring 28. By virtue of this arrangement the switch is operated once for each complete revolution of the cam 27. The cam member 27, mounted upon a suitable shaft, not shown, is driven by means of a wheel 29 having a plurality of projecting teeth 30. When the armature 13 moves to the attracted position, the portion 13' of the armature engages one of the teeth 30 and causes the wheel 29 to rotate a fraction of a revolution depending upon the number of teeth and the stroke of the armature. While the armature 13 oscillates between the attracted and unattracted positions the wheel 29 and cam 27 rotate and the switch 24 periodically opens and closes, operating the stoker motor at the regular intervals. The rate of opening and closing of the switch 24 may be conveniently changed by adjusting the tension of spring 20 by turning the adjusting nut 21. Of course, the shape of cam 27 and the number and shape of teeth on the wheel 29 may also be changed to accomplish the same result. The remainder of the apparatus shown in Fig. 3 is the same as that shown and described in connection with Fig. 1 and like parts have been given like reference numerals.

While I have shown and described particular embodiments of my invention, it will become apparent to those skilled in the art that my invention has other applications and that changes and modifications may be made without departing from the spirit and scope of my invention. I, therefore, aim in the appended claims to cover all such modifications and changes.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Apparatus for converting alternating current energy into periodic mechanical motion comprising an electromagnet, said electromagnet having a movable armature biased to an unattracted position and an operating coil therefor the inductance of which is increased upon movement of said armature to an attracted position, an alternating current energizing circuit connected to said coil, said armature moving to said attracted position when the current in said circuit exceeds a "pick-up" value and moving to said unattracted position when the current in said circuit falls below a "drop-out" value, and a resistor connected in series circuit relation with said circuit, said resistor having a resistance variable inversely with the temperature thereof and having a value such that the current flowing in said circuit when said armature is in said unattracted position is sufficient to heat said resistor until its resistance decreases to a point where the current in said circuit rises above said "pick-up" value and when said armature is in said attracted position the reduced current flow in said circuit and resultant decreased heating in said resistor caused by the increase in the inductance of said operating coil increases the resistance of said resistor to a point where the current of said circuit falls below said "drop-out" value whereby said armature periodically moves between the attracted and unattracted positions due to the cyclic variation in the impedance of said circuit.

2. In combination an electromagnet having an armature biased to an unattracted position, said electromagnet comprising an operating coil having spaced apart "pick-up" and "drop-out" current values serially connected in an alternating current energizing circuit and a core structure so arranged that the inductance of said operating coil increases when said armature moves to an attracted position, and a resistor connected in series circuit relation with said energizing circuit, said resistor having a resistance variable inversely with temperature and having a value such that the current flowing in said circuit when said armature is in said unattracted position is sufficient to heat said resistor until its resistance decreases to a point where the current in said circuit rises above said "pick-up" value and when said armature is in said attracted position the reduced current flow in said circuit and the resultant decreased heating in said resistor caused by the increase in the inductance of said operating coil increases the resistance of said resistor to a point where the current of said circuit falls below said "drop-out" value whereby said armature periodically moves between attracted and unattracted positions.

3. In combination an electromagnet having an armature biased to an unattracted position, said electromagnet comprising an operating coil having spaced apart "pick-up" and "drop-out" current values serially connected in an alternating current energizing circuit and a core structure so arranged that the inductance of said operating coil increases when said armature moves to an attracted position, a resistor connected in series circuit relation with said energizing circuit, said resistor having a resistance variable inversely with temperature and having a value such that the current flowing in said circuit when said armature is in said unattracted position is sufficient to heat said resistor until its resistance decreases to a point where the current in said circuit rises above said "pick-up" value and when said armature is in said attracted position the reduced current flow in said circuit and the resultant decreased heating in said resistor caused by the increase in the inductance of said operating coil increases the resistance of said resistor to a point where the current of said circuit falls below said "drop-out" value whereby said armature periodically moves between attracted and unattracted positions, and means for adjusting the bias on said armature to vary the periodicity of the armature movement.

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