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STARTING CIRCUIT FOR ELECTRICAL DEVICES

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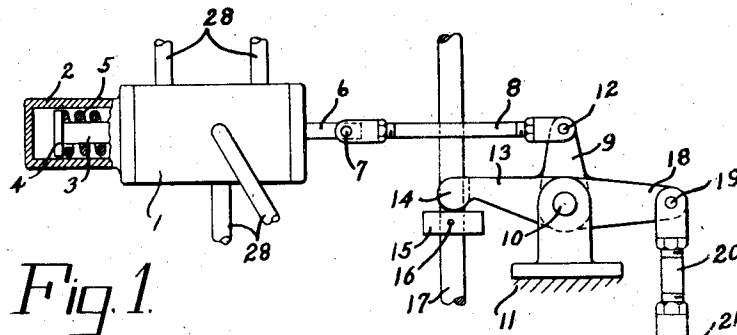


Fig. 1.

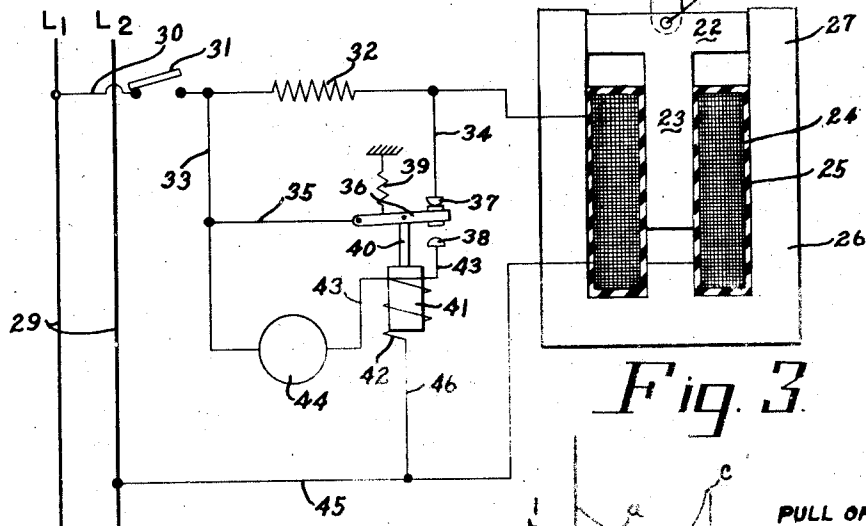
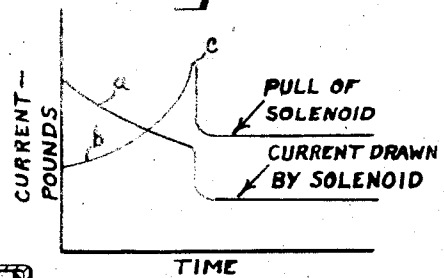
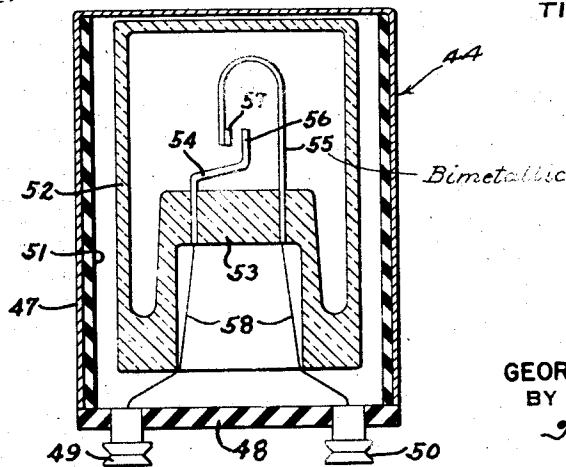


Fig. 2.



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STARTING CIRCUIT FOR ELECTRICAL DEVICES

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The present invention relates to starting devices or systems and more particularly to such devices when they are used in connection with mechanism which is operated by electrical apparatus.

It has been found that when solenoids are employed for actuating certain types of mechanism such as reciprocating valves, the solenoid becomes overheated. This is due to the fact that the power required to actuate the armature of the solenoid is in excess of the amount which can be dissipated by the surface area thereof; the surface area being a function of the physical size of the solenoid. In a particular instance when using a solenoid to operate a piston type valve in connection with a hydraulic press, it was found that the physical size of these solenoids limited their dissipation of power at a safe operating temperature to about 45 watts maximum but that the power actually converted into heat in these solenoids would range upwards to approximately 90 watts. While this difference between the maximum and safe heating dissipating qualities of the solenoid may be reduced by a special design of solenoid, it has been found that this solution was not practical since it involved a different design of solenoid for each particular installation resulting in exorbitant costs.

The primary object of the invention is to provide an improved system accessory of a working electromagnet in which the heating effects are maintained below the safe operating limits without detracting from the work effort of the electromagnet.

A more general object is to provide an electromagnet and an energizing system therefor which are so inter-related that the electromagnet can operate efficiently not only during the initial rush of current therethrough, but also during the normal operating period.

The invention will be better understood when reference is made to the following description and the accompanying drawing in which:

Figure 1 represents a view partly in diagrammatic form, of mechanism including an electromagnetic actuator and its energizing circuit which are constructed and arranged in accordance with the principles of the invention.

Figure 2 is a vertical sectional view taken through a switch accessory forming part of the energizing circuit of the electromagnet, which

Figure 3 is a graph depicting the relations between the pull exercised at the solenoid and the current drawn by the solenoid during a typical cycle of operation.

Referring more particularly to Figure 1, reference character 1 indicates a reciprocating four-way valve contained within a casing and having a cylindrical extension 2. The piston of the valve is indicated at 3, this piston being provided with a flanged end 4 against which presses a spring 5, the purpose of which will be explained presently. The piston 3 extends through the opposite end of the main casing in the form of a rod 6 which is pivotally connected at 7 to a connecting rod 8. There is a three-armed bell crank lever 9 mounted on horizontal bearings 10 which are suitably supported from a foundation 11. The middle leg of the lever 9 is pivoted as indicated at 12 to the connecting rod 8. The left hand leg 13 of the lever terminates in a rounded portion 14 which is adapted to ride on the upper surface of a collar 15 pinned as indicated at 16 to a control rod 17 which may travel with the platen of a hydraulic press. The right hand leg 18 of the lever 9 is swivelled as indicated at 19 to a vertical connecting rod 20 which is pivotally mounted as indicated at 21 to the cross bar 22 of a downwardly extending plunger 23. This plunger is received within an opening formed in the solenoid 24 and the latter is suitably insulated as indicated at 25 from a surrounding mass of iron laminations 26. The two outer legs of the laminations may be extended upwardly as may be indicated at 27 so as to form a guide for the cross bar 22. It is apparent that the latter and the plunger 23 are constituted of magnetic materials. The arrangement is such that when the solenoid 24 is energized the cross bar 22 is pulled downwardly to swing the lever 9 clockwise and thereby exert a pull on the piston rod 6 against the action of the spring 5. Assume that the conduits 28 are connected in the conventional manner between a hydraulic motor or press, a source of high pressure fluid such as a pump and an exhaust fluid reservoir such as a tank. The movement of the valve within the casing 1 to the right will cause pressure fluid to be admitted to one side of the piston (not shown) of the hydraulic motor or press and exhausted from the opposite side. As the platen of the press moves downward the control rod 17 is carried with it and when the platen has reached its lowest downward position the electromagnet 24 is automatically caused to be deenergized whereupon the spring 5 will automatically shift the valve rod 6 to its extreme left hand position past neutral so as to cause the introduction of pressure fluid to the pull back side of the piston in the hydraulic motor or press while exhausting the opposite side.

Thus, the platen (not shown) and the control rod 17 are caused to move upwardly, and in a predetermined position along its travel the collar 15 will engage the knob 14 of the lever 9 to move the lever clockwise and to shift the valve within the cylinder 1 to neutral, thus stopping further movement of the hydraulic motor or press. The apparatus and system which is specifically described up to this point is of conventional design and does not form part of my invention but represents a typical and practical use of the invention which will now be described.

When a valve and lever system such as illustrated and described is initially placed in operation, the power required at the precise moment of starting is considerably more than the effort which is necessary to continue the movement in the same direction. This is particularly true in the case of a reciprocatory or slidable element as distinguished from a rotary device and in which the reciprocatory element is subjected to pressure fluid. Under such circumstances the greater effort required to be exerted by the electromagnet in initiating movement of the element is derived from increased current through the solenoid, which current is subsequently translated into heat. Since no provision is normally made for compensating for this heat, it represents a substantial increase over the heat generated in the electromagnet during the continued operation of the same under more normal conditions. In accordance with my invention an improved circuit is provided by which the voltage impressed on the electromagnet at the start is somewhat greater than the continuous operating voltage so that in effect the voltage is reduced after the parts have been given an initial movement. Any predetermined amount of time delay in applying the reduced voltage to the electromagnet or solenoid may be obtained by the improved system so that the amount of extra effort available at the electromagnet and required to initiate movement of the reciprocatory parts may be accurately controlled.

Referring again to Figure 1, reference character 29 designates a main supply circuit from which a conductor 30 is taken through a switch 31 to a resistor 32 and finally to one side of the solenoid 24. Wires 33, 34 are connected to opposite sides of the resistor 32, the wire 33 being connected to a conductor 35. An armature 36 is adapted to swing between contacts 37, 38 and the conductor 35 is connected to this armature. The latter is normally urged upward by a tension spring 39 and the wire 34 is connected to the contact 37 so that in effect the resistor 32 is short circuited. The armature 36 is swivelly connected to a rod 40 which terminates in a plunger 41. The latter is received by a solenoid indicated at 42 and a conductor 43 is taken from one end of the solenoid to a time delay switch 44. The details of the switch will be explained in connection with Figure 2. This conductor 43 is also extended to make contact with the element 38. Conductor 33 is extended and connects with the other side of the switch 44. A wire 45 is taken from the mains 29 and connects with the lower end of the solenoid 42 through a conductor 46. The wire 45 is extended and connected to the lower end of the main solenoid 24.

The time delay switch 44 may be contained in a thin metal housing or casing 47 carried on a base 48 of insulating material in which a pair of binding posts or terminals 49, 50 are mounted. A cylinder of insulating material 51 is received by

the inner surface of the casing 49 in order to insulate the casing from the contained elements. The latter may include a glass envelope 52 preferably of cylindrical configuration having a stem 53 through which the interior of the envelope may be evacuated. The latter is filled with inert gas at a pressure sufficient to support a glow discharge when voltage is applied between the two opposed electrodes. These electrodes are preferably mounted on the stem 53 and electrode 54 may comprise a rod-like element bent to shape and terminating in a vertical portion 56. The electrode 55 has a horseshoe or loop shape and may be formed of a bi-metallic strip terminating in a contact element 57. Leading-in conductors 58 are connected between the electrodes 54, 55 and the binding posts 49, 50 respectively. When voltage is applied between the terminals 49, 50, a glow discharge is set up between the contacts 56, 57.

The bi-metallic strip 55 becomes heated and the loop 55 "tightens" so as to cause the contact 57 to approach nearer the rod 56, finally to make contact therewith. Translating this movement of the bi-metallic strip and the final contact between elements 56, 57 to the circuit diagram (Figure 1), it will be noted that the current through the solenoid 42 steadily increases until it reaches a value sufficient to cause the plunger 41 to be pulled downwardly thereby swinging the armature 36 to make contact with the element 38.

Under these conditions the movement of the armature 36 from its upper to its lower position serves to remove the short-circuit about the resistor 32 and to apply a short-circuit across the switch 44. Thus, the resistance of the element 32 is inserted in series with the solenoid 24 and the switch 44 becomes de-energized. The effect of this resistance is to reduce the voltage applied to the solenoid 24 and thus cut down the heating effects. When the glow discharge switch 44 is de-energized the bi-metallic strip 55 slowly cools and eventually breaks the circuit between the contacts 56 and 57, so that the switch automatically resets for the next cycle of operation.

It is evident that by regulating the distance between the contacts 56, 57 the time delay effect in causing contact to be made may also be controlled so that the instant of time at which the voltage applied to solenoid 24 is to be cut down by introducing resistance 32 may be accurately determined.

The effect of this decrease in voltage applied to the solenoid is diagrammatically illustrated in Figure 3. The ordinate of the diagram is in terms of current and the abscissa represents time. The curve *a* represents the current drawn by the solenoid 24 and indicates first an initial decay of current, subsequent to the closing of the switch 31, due to the increasing inductive effect of the circuit as the armature moves into the solenoid.

After the armature 23 has been drawn completely into the solenoid 24, the switch 44 closes and energizes the solenoid 42. The energizing of the solenoid 42 is effective to actuate the armature 36 to break the contact thereof with the contact 37 and to establish a contact thereof with the contact 38.

At the instant of the opening of the contact between the armature 36 and the contact 37, the current drain at the solenoid shows an abrupt decrease because at this moment the resistance 32 is effectively introduced into the circuit. Subsequent to the opening of this contact, the current through the solenoid remains at the sub-

stantially constant but greatly decreased value due to the voltage drop across the resistor 32.

Substantially simultaneously with the opening of the contact between the armature 36 and the contact 37, the armature makes contact with the contact 38, thus establishing a holding circuit for the solenoid 24 which maintains the same energized until the switch 31 is opened at the end of the solenoid.

Curve b represents the effective pull exerted by the solenoid on the cross bar 22. Due to the rather long airgap in the magnetic circuit comprising the laminations 26 and the plunger 23, the effective pull is initially quite small even though the current drawn by the solenoid is at a maximum. As the valve parts respond to the movement of the cross bar 22 and the plunger 23 moves into the solenoid, the effective pull increases until it reaches a maximum indicated at the point c which represents the pull on the plunger when the same is in its innermost position. Point c may coincide with or precede the actuation of the solenoid 42, at which latter time the pull abruptly decreases and is finally maintained at a constant lower amount represented by the effect of the reduced voltage applied to the solenoid. It will be noted that the final or holding in pull on the plunger 23, even with the voltage reduced is ample to maintain the armature in its shifted position.

Whereas prior to the use of the time delay switch 44 and the short-circuits connected respectively across the resistor 32 and the switch 44 it was found that the solenoid 24 became excessively heated during normal operation, the use of my invention serves effectively to lower the heating effects of the solenoid 24. The maximum pull at the cross bar 22 was not decreased by making this change as can be readily seen from the operating characteristics shown in Figure 3. It is evident that the circuit and apparatus shown and described lend themselves to the operation of a solenoid at a considerable over-voltage to greatly increase the initial current in rush and consequent initial pull of the solenoid. I have found that the flow type of time delay switch operates satisfactorily in connection with the circuit shown and for the purposes stated but it will be understood that any of several well known time delay devices could be used.

It will be understood that I desire to comprehend within my invention such modifications as come within the scope of the claims and the invention.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Apparatus for actuating a movable member comprising an electromagnet including a plunger connected to said member, a circuit including a resistor for supplying said electromagnet with electrical energy, a shunt circuit in parallel with said resistor including a switch normally biased to complete said circuit, a solenoid actuator for actuating said switch to interrupt said shunt circuit, a time delay circuit for energizing said solenoid including a glow discharge device in which one of the electrodes is constituted of a bi-metallic element in order to close a circuit through said solenoid upon the lapse of a predetermined length of time following the energization of said electromagnet.

2. In combination, an electromagnetic actuator including a solenoid, a circuit for supplying electrical energy to said solenoid, a resistor normally connected in said circuit and a time delay device effectively shunted across said resistor for connecting and disconnecting the resistor in said energy supply circuit, said device including a glow discharge tube connected in series with the solenoid of said actuator, a plunger for said solenoid, and circuit connections whereby when the glow discharge tube is energized the resistor in the energy supply circuit is cut into the circuit but when the glow discharge tube is deenergized said resistor is short-circuited.

3. In combination, an electromagnetic actuator including a solenoid, a circuit for supplying electrical energy to said solenoid, a resistor normally connected in said circuit, and a time delay device shunted across said resistor for connecting and disconnecting the resistor in said energy supply circuit, said device including a glow discharge tube provided with a thermostatic electrode and connected in series with the solenoid of said actuator, said solenoid having a plunger, an armature secured to the plunger, one end of said resistor and one of the electrodes of the discharge device being connected together through a conductor to said armature, one end of the solenoid being connected to another electrode of the discharge tube, and the opposite end of the solenoid being connected to a terminal which is adapted to be contacted by the armature when the plunger is moved in one direction, a second terminal on the opposite side of the armature from the first mentioned terminal adapted to be contacted by the armature when the plunger is moved in the opposite direction, said second terminal being connected with the end of the resistor opposite from the end to which the glow discharge tube is connected.

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