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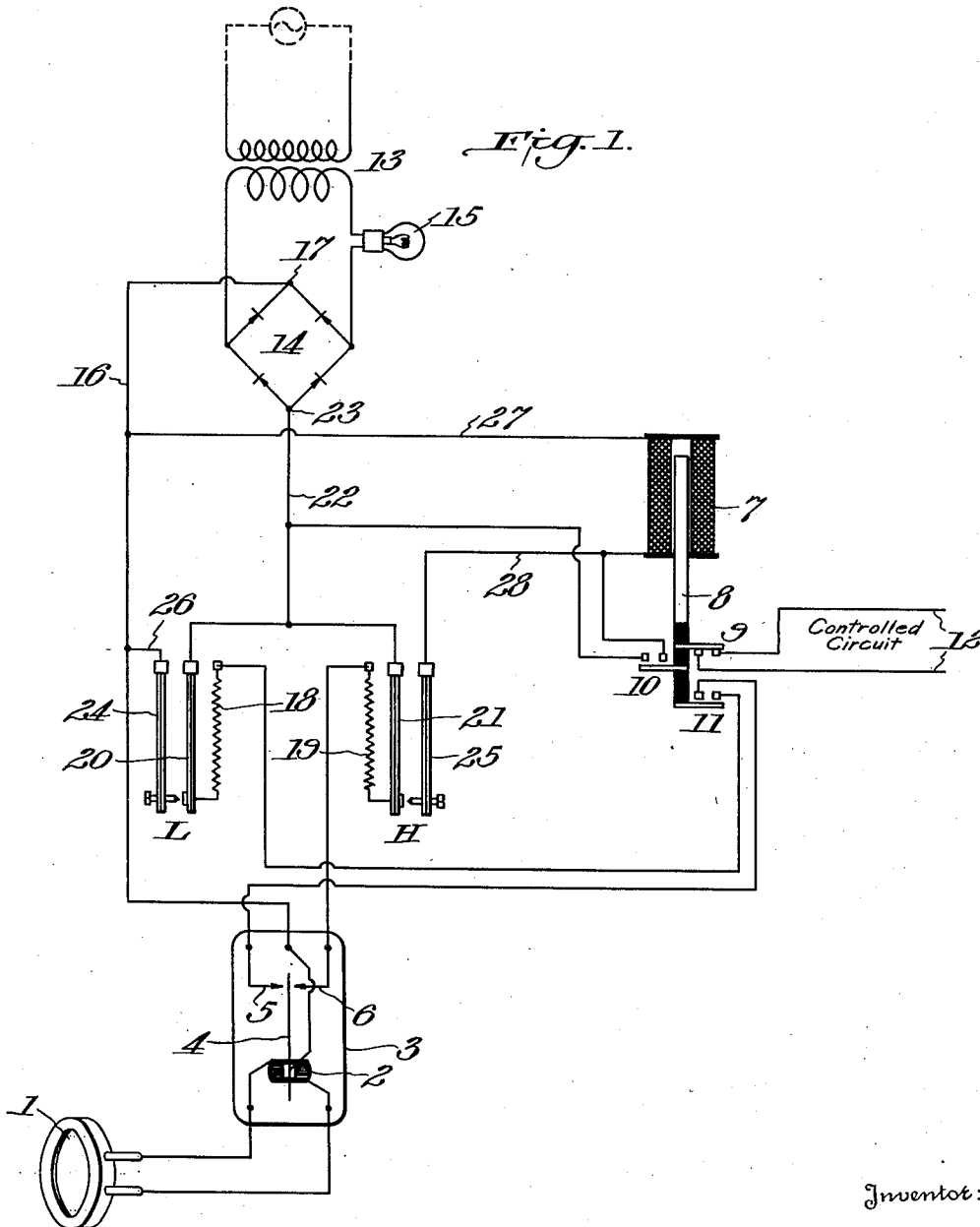
A. H. LAMB

2,057,384

RELAY CIRCUIT

Filed July 7, 1932

3 Sheets-Sheet 1



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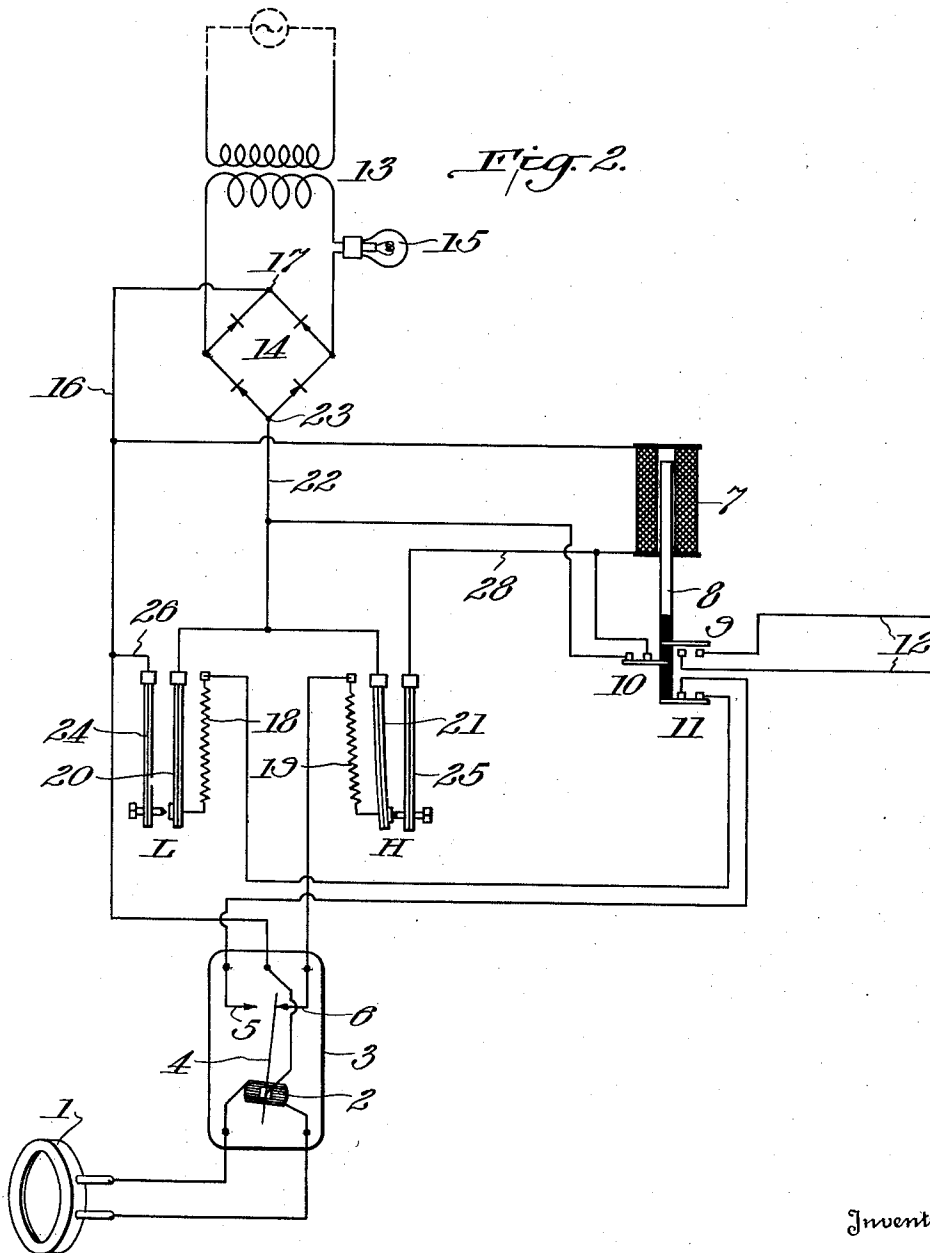
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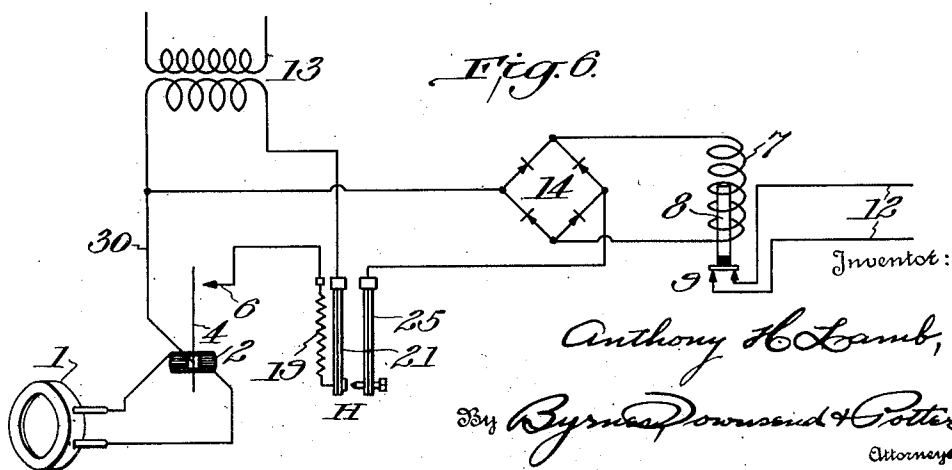
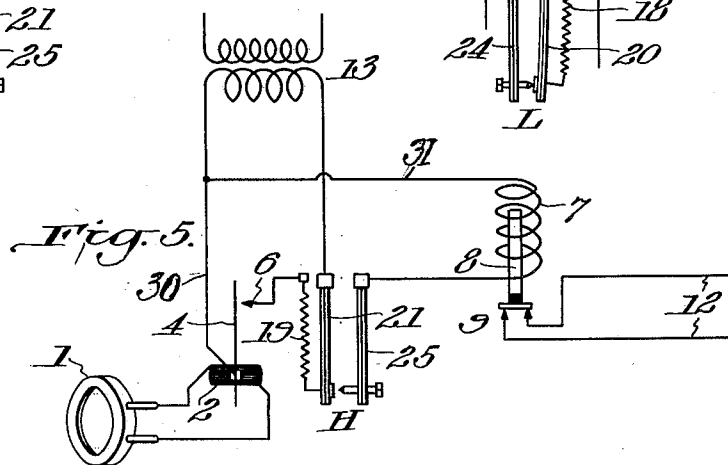
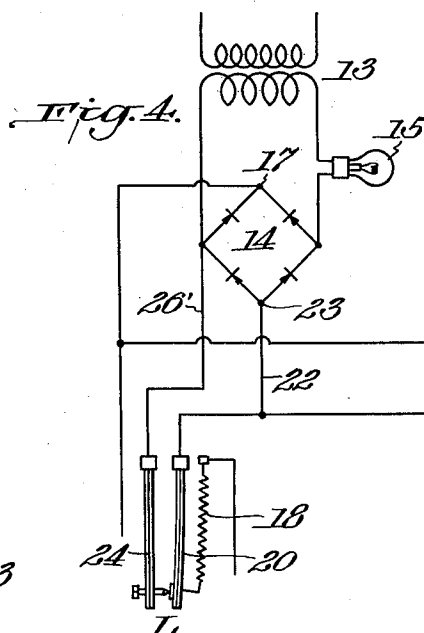
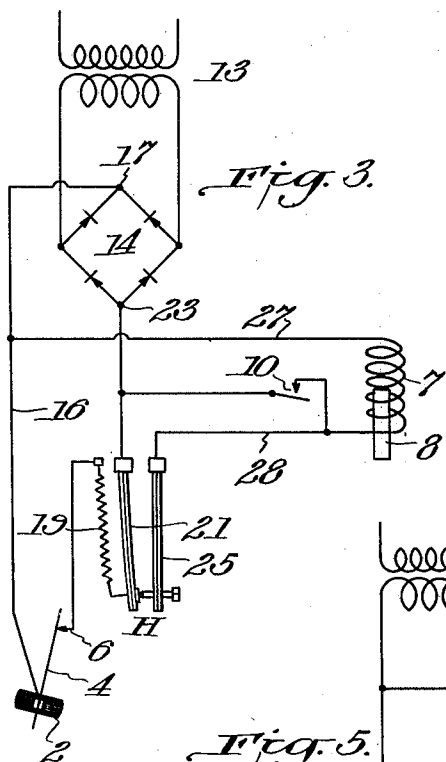
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RELAY CIRCUIT

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11 Claims. (Cl. 250—41.5)

This invention relates to relay circuits and particularly to control circuits of the type including electromagnetic relays.

Electromagnetic relays are open to the serious objection that undue friction or a sticking of the switch contacts may prevent the armature from moving. If the first surge of current does not develop a force sufficient to overcome the resistance to movement, the continued flow of current cannot develop any additional force to move the armature. Due either to this or other causes, relay circuits frequently fail to function properly and dangerous conditions may thereby be established.

The present invention will be described as applied to an automatic illumination control system, such as may be employed for turning on the signal lights at a lighthouse when the normal or solar illumination fails, but it is to be understood that, in its broader aspects, the invention may be embodied in other relay or control systems.

An object of the invention is to provide improved relay control circuits of the type employing electromagnetic relays. An object is to provide control circuits of the type stated and in which, if the relay fails to respond properly when the current flow to the solenoid is first started or is stopped, current is intermittently applied to the solenoid to repeat the application of the force designed to actuate the relay, and this cyclic operation is repeated until the relay does function properly. Another object of the invention is to provide a relay control system in which the controlled or load circuit is normally energized or de-energized, according to the nature of the circuit and safety requirements, and an alternate condition can be established only when the relay system functions properly. More specifically, an object is to provide an automatic control system including a photoelectric device for opening or for closing a controlled circuit under predetermined illumination conditions, and in which the normal condition of the controlled circuit may be altered only when the predetermined conditions obtain and the control system functions properly. A further specific object of the invention is to provide an illumination control system including signal lights that are normally energized, and a photoelectric control effective to extinguish the lights only when the control functions properly and predetermined illumination conditions obtain.

These and other objects and advantages of the invention will be apparent from the follow-

ing specification when taken with the accompanying drawings, in which

Fig. 1 is a circuit diagram of the invention as embodied in an illumination control system in which the controlled circuit is normally energized;

Fig. 2 is a diagram of the same circuit but illustrating the several parts in the position which they occupy just after the controlled circuit is opened;

Fig. 3 is a fragmentary circuit diagram of only those elements effective to insure opening of the controlled circuit;

Fig. 4 is a fragmentary diagram of an alternative arrangement for de-energizing the main relay; and

Figs. 5 and 6 show other circuits for changing the normal operating conditions of the main or controlled circuit.

In the drawings, the reference character 1 identifies a photoelectric cell which is positioned to receive light from the sky or from any other source upon which the system of control is based. The photoelectric cell delivers current to the moving coil 2 of a sensitive relay 3 that has a contact arm 4 cooperating with a lower contact 5 and an upper contact 6.

The main or power relay of the control system includes a solenoid 7 and an armature 8, the armature carrying or otherwise actuating the movable elements of a main switch 9 and auxiliary switches 10 and 11. These elements are shown diagrammatically in the drawings and it is to be understood that the physical structure of the electromagnet and the switches may differ materially from the forms shown. The main switch 9 is included in the controlled circuit 12 and the auxiliary switches are in circuits of the relay system. As shown in Fig. 1, the controlled circuit 12 is normally energized, i. e., the switch 9 is closed, when current flow to the solenoid 7 is interrupted.

Low voltage current for operating the relay system may be obtained from an alternating current power line through a step-down transformer 13 and a full wave rectifier 14, a ballast lamp or resistance 15 being preferably included in the secondary circuit. The transformer may be an ordinary bell-ringing transformer of the type which draws substantially no current when the secondary circuit is open.

A lead 16 extends from the positive terminal 17 of the rectifier bridge 14 to the contact arm 4 of the sensitive relay 3, the contact 5 is connected through switch 11 to the heater coil 18 55

of a thermal switch, and the sensitive relay contact 6 is connected directly to the heater coil 19 of a similar thermal switch. The heating circuits for the coils are completed through their respective movable arms 20, 21, and a common lead 22 to the negative terminal 23 of the rectifier. The thermal switches are preferably of the type in which the relatively stationary contacts are carried on bimetallic strips 24, 25, respectively, to compensate for the flexing of the bimetallic strips 20, 21 which is due to slow changes in the air temperature. For convenience of description, the thermal switch associated with the low current contact 5 is identified generically by reference character L, and the switch associated with the high current contact 6 is identified as H.

The stationary contact of thermal switch L is connected, by a lead 26, to the lead 16 that runs to the positive terminal 17 of the rectifier, and a closing of switch L therefore short-circuits the rectifier through leads 16 and 26, switch L and lead 22.

The solenoid 7 is connected to the positive side 25 of the rectifier by a lead 27 and the opposite terminal of the solenoid is joined, by lead 28, to the stationary contact of the switch H. The auxiliary switch 10 of the main relay is bridged across the leads 22 and 28, i. e., closing of switch 10 connects the solenoid 7 directly across the rectifier terminals.

As shown in Fig. 2, the thermal switch H has been closed and the flow of current to solenoid 7 has lifted the armature 8 to open the main switch 9 and to close the auxiliary switches 10, 11. The successive steps which resulted in this operation are as follows.

The illumination at the light-sensitive cell 1 increased to such value that the increased flow of current through winding 2 moved the contact arm 4 into engagement with the high current contact 6, thus closing the circuit to the heating coil 19 of switch H. This increased illumination continued for such time, say one minute, that the bimetallic strip 21 flexed to engage its contact with that which carries by the "cold" bimetallic strip 25. The closing of switch H connected the solenoid 7 across the rectifier 14 and, with normal operation, this results in a lifting of the armature to open switch 9 of the controlled circuit, and to close switches 10 and 11.

With the closing of the holding switch 10, the solenoid-rectifier circuit is completed around the thermal switch H and therefore the current will continue to flow to the solenoid even though the illumination at the cell 1 falls off and the contact arm 4 leaves the contact 6, thus permitting the switch H to open. The contacts 5 and 6 are preferably separated by a gap corresponding to a difference of, for example, 5 foot-candles in the illumination at the cell 1. Within this range of 5 foot-candles, the contact arm 4 does not engage either contact but, when the illumination falls below the lower critical value, contact arm 4 engages contact 5 and a heating circuit is completed through the coil 18 of switch L. If the condition of subnormal illumination continues for a predetermined period, the switch L is closed and the rectifier 14 is short-circuited. The armature drops down, closing the main switch 9 and opening the circuit to the heating coil 19 at the switch 11. The bimetallic strip 20 cools down after a short interval and the circuit elements again occupy the several positions as shown in Fig. 1.

In the event that the armature 8 fails to respond properly when the thermal switches L and H close, the current impulses to the solenoid 7 will be repeated until the armature does respond. With the circuit as shown in Fig. 1, the open holding switch 11 prevents any change in the main relay until the contact arm 4 engages contact 6 for a period sufficient to effect closure of the switch H. If the armature 8 does not lift to open switch 9 when current flows to the solenoid 7, the holding switch 10 does not close and therefore the solenoid 7 is connected across the rectifier in parallel with the heating coil 19 of switch H, see Fig. 3. The resistances of coil 18 and solenoid 7 are so related that the limited current output of the transformer 13, and rectifier 14 is not sufficient to maintain a current flow in coil 18 which will hold switch H in closed position. When the bimetallic strip 21 cools down under the decreased current flow, the switch H opens and thereby breaks the shunt circuit through the solenoid. The flow of current in coil 18 increases and the switch H closes again to supply current to the solenoid. Current surges are thus repeatedly supplied to solenoid 7 and any incipient welding of the contacts at switch 9 will eventually be broken and the switch will open.

The intermittent application of a force to insure movement of the armature when current flow to the solenoid is interrupted is due to the holding switch 11. With the main relay as shown in Fig. 2, the armature should drop to close switch 9 and open switch 11 when switch L closes. If the armature does not drop, the switch 11 remains closed and therefore the heating circuit to coil 18 of switch L remains closed.

With switch L closed, no current flows in this heating circuit since the rectifier is shorted by switch L. The bimetallic strip 20 therefore cools down and switch L opens to permit current flow to solenoid 7 and also to the heating coil, thus causing switch L to close a second time. This intermittent short circuiting of the rectifier continues until the repeated blows impressed on the armature 8 cause it to drop open, thereby opening the holding switch 11.

As applied to the control of a danger or traffic light, such as a lighthouse, it will be apparent that the invention provides for an extinction of the lights only when the illumination is above a predetermined critical value and the control system is functioning perfectly. This is due to the fact that the main switch 9 in the controlled circuit remains closed so long as power is not applied to the solenoid 7. A failure of the control system may result in an unnecessary closing of the main switch 9 but it cannot result in an opening of the signal light circuit. Furthermore, an intermittent or chattering operation when the illumination approaches the critical control values is prevented by the delay action of the thermal switches L, H and the relatively wide separation of the contacts 5 and 6 of the sensitive relay 3. Changes in illumination take place as a fluctuating or wave phenomenon, and not as a progressive increase or decrease in value. By adjusting the relay contacts to close at a lower value of 5 foot-candles and at an upper value of 10 foot-candles, and designing the switches L, H for approximately one minute of continuous heating to effect closure, I have found that the main relay responds only to definite and relatively permanent changes in the general illumination at the control point, cell 1.

As shown in the fragmentary circuit diagram, 75

Fig. 4, the thermal switch L may be arranged to short-circuit only one arm of the rectifier bridge 14 when the main relay, solenoid 7 and armature 8, is a direct current electromagnet. In this system, the lead 26' extends from the stationary strip 24 of switch L to a bridge junction adjacent the negative terminal junction 23.

For some purposes, it is not necessary to provide a control based upon an upper and a lower critical value of illumination or of some other variable factor. For such uses, the control system may be materially simplified. The relay circuit shown in Fig. 5 is adapted to close and to open the main relay circuit as the illumination passes through a single critical value, but chattering of the main relay is prevented or reduced by including a thermal switch in the system. As many elements of this relay may be identical with some parts of the described circuit, they will be identified by the reference numerals previously used. The sensitive relay 3 has only one contact 6 for engagement by the contact arm 4, and this contact is connected to one terminal of the heating coil 19 of a thermal switch H. By employing an alternating current electromagnet, raw alternating current may be used in the heating and the relay circuits. One terminal of the secondary of the transformer 13 is connected to the contact arm 4 by a lead 30, and to the solenoid 7 by a lead 31. The opposite terminal of the secondary is connected by a lead 32 to the movable contact strip 21, and the stationary contact strip 25 is connected to the solenoid. When the illumination at the photoelectric cell reaches the critical value, the contacts 4, 6 engage and current flows through the heating coil 19, thus closing switch H and passing current to the solenoid 7 to raise the armature 8 and open switch 9 in the controlled circuit 12. When the illumination falls below the critical value, the contacts 4, 6 open and the strip 21 cools down to open switch H, thus interrupting the current flow to the main relay.

Another practical arrangement is to employ raw alternating current for the heating circuit or circuits and rectified current in the main relay circuit. Such a variation, as applied to the Fig. 5 circuit, is illustrated in Fig. 6. The heating circuit of the thermal switch H is the same as in the Fig. 5 circuit, and a rectifier 14 is interposed between the transformer 13 and the solenoid 7. The solenoid 7 is connected as one diagonal of the rectifier bridge 14 and the other junctions of the bridge are connected to the stationary contact strip 25 and to one terminal of the transformer secondary. When contacts 4, 6 engage, the heating circuit is connected across the secondary and, when switch H closes, the rectifier is connected across the transformer.

While the invention has been described as applied to an illumination control system, it will be apparent that certain features are equally useful in other control systems. So far as concerns the positive operation effected by the thermal switches of the Fig. 1 circuit, the photoelectric cell may be replaced by other types of control instruments, or the cell and sensitive relay may be replaced by manually operated switches. For illumination control, safety requirements are best satisfied by employing a normally closed illumination circuit but, for other purposes, it may be desirable to employ a main relay in which the switch 9 opens when current flow to the solenoid 7 is interrupted. The current for operating the

system may, of course, be direct current from batteries or a power source.

It will therefore be apparent that the invention is not limited to the specific circuits herein illustrated and described since various changes, which will be obvious to those familiar with the design and construction of relay circuits, fall within the spirit of my invention as set forth in the following claims.

I claim:

1. In a relay system, the combination with a main relay comprising a solenoid, an armature, a main and an auxiliary switch controlled by said armature, said auxiliary switch being closed when said armature is moved in response to current flow in said solenoid, and a source of current of limited output, of a thermal switch including a heater coil, means for closing a circuit from said source through said coil to close said thermal switch, circuit elements for connecting said solenoid across said source and in parallel with said heater coil upon closure of said thermal switch, and circuit elements including said auxiliary switch for completing said solenoid circuit independently of said thermal switch when the armature moves in response to current flow in said solenoid circuit, the limited current output of said source being insufficient to maintain said thermal switch in closed position when said thermal switch is closed and said auxiliary switch is open.

2. In a relay system, the combination with a main relay comprising a solenoid, an armature, a main and an auxiliary switch controlled by said armature, said auxiliary switch having contacts which are closed when said armature is moved in response to current flow through said solenoid; of a source of direct current, and energizing means for connecting said solenoid across said current source; and means including a thermal switch for interrupting current flow through said main relay; said interrupting means comprising a circuit including in series the contacts of a primary control relay, said auxiliary switch, the heating coil of said thermal switch, and the said source of direct current.

3. A relay system as claimed in claim 2, wherein said current source comprises a rectifier bridge having one pair of terminals for connection to an alternating current power supply and a second pair of terminals across which a direct current voltage is developed by said rectifier bridge, said energizing means connects said main relay across said second pair of terminals, and the contacts of said thermal switch are normally open and are closed by current flow through said heating coil to short-circuit at least one arm of said rectifier bridge.

4. In a relay system, the combination with a main relay, a main switch operated by said relay, and a source of alternating current, of a full wave rectifier, a circuit for connecting the input terminals of said rectifier across said alternating current source, a circuit for connecting said main relay across the output terminals of said rectifier, and control means operative to pass full-wave rectified current to said main relay or alternatively to short-circuit at least a part of said rectifier to render the same inoperative to pass full-wave rectified current to said main relay, said control means including switch means in one of said circuits.

5. In an illumination control system, the combination with a controlled circuit, a normally closed switch in said circuit, and a main relay for

opening said switch, of a photo-electric cell, a second relay actuated by current flow from said cell, a transformer having a primary for connection to an alternating current source and a secondary, a rectifier receiving alternating current from said secondary, thermal switch means for completing a circuit to establish a flow of rectified current from said rectifier to said main relay to energize the same, a second thermal means operative to interrupt the flow of energizing current to said main relay, and means including said second relay for controlling both of said thermal switch means.

6. In an illumination control system, the combination with a main relay having an armature, a source of alternating current, a rectifier, a photo-electric cell, and a second relay controlled by the output of said cell, said second relay having a contact arm movable between a pair of contacts, of means operative repeatedly to energize and de-energize said main relay in the event that the armature of said main relay does not respond substantially immediately to that condition of current flow through said main relay which is established by the engagement of the contact arm of the second relay with one of the said contacts, said means including a pair of thermal switches, means including said relay contacts for completing heating circuits for the respective thermal switches, circuit elements including said thermal switches for alternatively establishing and interrupting current flow through said main relay upon the closure of the respective thermal switches, and means including a pair of auxiliary switches actuated by the said armature for controlling current flow in the respective heating circuits of the said thermal switches.

7. An illumination control as claimed in claim 6, wherein said alternating current source has a limited output of an order insufficient to supply current for the simultaneous energization of one of said heating circuits and said main relay,

and one of said auxiliary switches has contacts closed upon movement of said armature in response to an energization of said main relay to complete an energization circuit for said main relay independent of that thermal switch which closed to establish an initial current flow through said main relay from said source and rectifier.

8. An illumination control as claimed in claim 6, wherein that one of said thermal switches which interrupts current flow through said main relay has contacts for short-circuiting said rectifier, and the said auxiliary switch which controls current flow in the heating circuit of that one thermal switch has contacts serially arranged in that heating circuit and closed by said armature when the latter is in its position corresponding to an energization of said main relay.

9. In a control system, the combination of a main switch having a direct current operating winding, a source of alternating current, rectifier means having input terminals for connection to said alternating current source, circuit elements for connecting said operating winding to the output terminals of said rectifier means, one of said circuit elements being switch means operable in one position to short-circuit said rectifier to prevent the supply of rectified current to said operating winding, and means including an instrument-type relay for controlling the operation of said switch means.

10. A control system as claimed in claim 9, wherein said rectifier means is a full wave rectifier bridge, and said switch means is operable in one position thereof to short-circuit at least one arm of the said rectifier bridge.

11. A control system as claimed in claim 9, wherein said rectifier means is a full wave rectifier bridge, and said switch means is operable in one position thereof to short-circuit one set of terminals of the said rectifier bridge.

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