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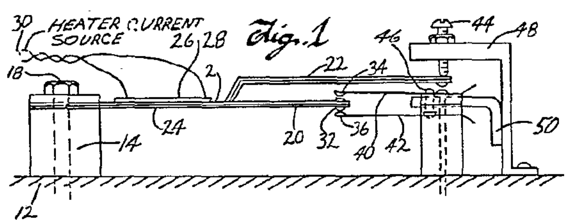
(54) Thermal switch and control circuit for diesel engine glow plug control.

(57) A thermally operated bimetal switch has a cantilever supported bimetal element with three sections, a heater controlled section adjacent the cantilever support, a switch arm section and a compensator arm section extending parallel to each other away from the heater section. The compensator arm section engages a stop. The switch can be adjusted to provide undercompensation, overcompensation or full compensation for ambient temperature changes over controlled temperature ranges. A control circuit utilizing a thermal switch is described by which glow plugs are heated at a high rate but are temperature limited to prevent burnout of the glow plugs.



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THERMAL SWITCH AND CONTROL CIRCUIT FOR DIESEL ENGINE GLOW PLUG CONTROL

Field of the Invention

This invention relates to thermal switches and a control circuit using a thermal switch for controlling diesel engine glow plugs.

Background of the Invention

The use of glow plugs to preheat the combustion chambers in a diesel engine is well known. Various types of control circuits for operating the glow plugs have been heretofore proposed. Glow plug control circuits have been devised in which the glow plugs operate at a voltage which allows the glow plugs to be turned on for an indefinite period of time and under normal voltage conditions will never exceed a safe operating temperature. Glow plugs of this type take a long time to reach operating temperature and therefore do not lend themselves to fast starts. Other control circuits have been devised which operate to heat the glow plugs rapidly but limit the maximum temperature of the glow plugs by turning off the electrical power to the glow plugs after a controlled time interval which is insufficient to permit excessive temperatures of the glow plugs to occur. The latter type of circuit has also used some temperature responsive arrangement for cycling the glow plugs on and off to maintain the glow plugs within a predetermined temperature range for a sufficient period of time to allow starting of the engine. For example, U.S. Patents 4,075,998 and 4,106,465 disclose glow plug control circuits in which glow plugs are disconnected a controlled time interval after the glow plugs have been turned on. Both these circuits utilize a thermally responsive switch, but the switch is in series with the glow plugs. This can present a problem if one of the glow plugs fails since the current is reduced through heater, increasing the thermal time-out period. Also a series heater at higher voltage does not track the glow plugs and therefore may leave them on too long, causing burn out. This is particularly true for high temperature coefficient of resistance found in current types of glow plugs. U.S. Patent 4,177,785 shows a glow plug control circuit which not only turns the glow plugs off but limits the temperature of the glow plugs by cycling the glow plugs on and off until the engine is started.

Summary of the Invention

The present invention is directed to an improved control for glow plugs which utilizes a thermal switch which can be adjusted to provide full compensation for ambient temperature changes over a predetermined temperature range while providing undercompensation or overcompensation as required in other ambient operating temperature ranges. Thus the thermal switch of the present invention is particularly suited to glow plug control circuits in which it is desired to provide substantially constant thermal operating time of the switch over a lower temperature range while providing a substantially undercompensated performance in response to ambient temperatures at higher engine temperatures, as where the engine is already warmed up or partially warmed up. The present invention further provides an improved control circuit which allows the glow plugs to heat rapidly but which limits the maximum temperature of the glow plugs to prevent damage by excessive heating. The control circuit of the present invention indicates when preheating has been sufficient to allow starting of the engine.

These and other advantages of the present invention are achieved by providing a thermal switch made of a single elongated strip of bimetal material which is anchored at one end to a cantilever support and which is bifurcated at the other end to provide two parallel arms. One arm acts as a movable contact arm of a switch. The other arm is constrained by a pivot or stop and operates as an ambient temperature compensator. By changing the position of the stop, the ambient temperature compensation characteristics of the element can be controlled.

The control circuit for the glow plug has a power relay which is turned on by closing an ignition switch. At the same time a "WAIT" indicator lamp is turned on and current is applied to the heater of a thermal switch. After a timed interval, the thermal switch turns off the indicator lamp and applies current to a second thermal switch. The second thermal switch, after a timed interval, releases the power relay by energizing a control relay. The thermal switches are connected so that an over-voltage shortens the time intervals to protect the glow plugs from overheating. An increase in the ambient temperature condition of the engine also shortens the control time intervals.

Brief Description of the Drawings

For a better understanding of the invention reference should be made to the accompanying drawings, wherein:

FIG. 1 is a side view of the thermal switch of the present invention;

FIG. 2 is a plan view of the thermal switch;

FIGS. 3-6 are schematic representations of the switch useful in explaining its operation;

FIG. 7 is a plan view of an alternative embodiment of the thermal switch;

FIG. 8 is a side view of the embodiment of FIG. 7;

FIG. 9 is a graphical representation of the ambient temperature characteristics that can be achieved with the thermal switch;

FIG. 10 is a schematic circuit diagram of a glow plug control utilizing the thermal switch; and

FIGS. 11-14 show alternative embodiments of the glow plug circuit.

Detailed Description

Referring to FIGS. 1 and 2, there is shown an embodiment of a thermal switch indicated generally at 10 according to the present invention. The thermal switch 10 is mounted on a suitable base 12 to which is secured a supporting block 14. A bimetal element, indicated generally at 16, is supported at one end on the block 14 by bolts 18, the block 14 providing a cantilever support for the elongated bimetal element. The bimetal element 16 is preferably made of a single piece of bimetal material formed of two thin layers of dissimilar metals having different coefficients of thermal expansion, causing the bimetal to bend up or down relative to the supporting block 14 with change in temperature of the bimetal element.

The bimetal element is bifurcated at the unsupported end, shown in FIG. 2, to divide the element into two arms, a switch arm 20 and a compensator arm 22. An actuator section 24 of the bimetal element extends between the arms and the supporting block 14. An electrical heating element 26 having an insulator base 28 is mounted on the actuator section 24. An electric current is passed through the heater element 26 through leads from a suitable power source (not shown).

The switch arm 20 supports a moving switch contact 32 adjacent the outer end of the arm. The switch contact 32 is moved by the arm between a pair of fixed switch contacts 34 and 36. The fixed contacts are supported from the base 12 by an insulator support 38 and contact fingers 40 and 42.

Movement of the compensator arm 22 is limited by a pair of stops in the form of adjustable screws 44 and 46. The stop screws are in turn adjustably supported from the base 12 by suitable brackets 48 and 50. The position of the stops lengthwise of the actuator arm 22 can be made adjustable or may be fixed. The screws 44 and 46 are also adjustable vertically to adjust the size and relative vertical position of the gap between the opposing ends of the screws.

Operation of the thermal switch of FIGS. 1 and 2 can best be understood by reference to FIGS. 3-6. Referring first to FIG. 3, the bimetal element is shown in a position, indicated by the solid line, for a given ambient temperature condition. As the temperature of the bimetal element is increased, the compensator arm 22 moves upwardly to the dotted line position indicated at 22'. Similarly, the switch arm moves up as indicated by the dotted line position 20'. Assume that a force is then applied as indicated by the arrow F which pushes the compensator arm downwardly from the position 22' to the initial position 22. This force will cause movement of the switch arm 20, but the amount of movement will be determined by the rigidity of the compensator arm 22 as compared to the rigidity of the actuator section 24. If the width W of the actuator arm 22 is made relatively small, it will be seen that the compensator arm 22 will be much more flexible than the actuator section 24. The result of this condition, as illustrated in FIG. 4, is that the force F in restoring the compensator arm 22 back to its initial position causes relatively little flexing of the actuator section 24, most of the bending action being limited to the more flexible compensator arm 22. As a result, the position of the moving contact 32 is relatively unchanged by the force F and therefore remains at the position 32' as a result of the increased temperature.

The arrangement of FIG. 4 may be referred to as an undercompensated condition of operation for the thermal switch of FIG. 1. If the force F is considered as being applied by the stop screw 44 by way of limiting the upward movement of the actuator arm 22 in response to an increase in ambient temperature, then it will be seen that the arrangement of FIG. 4 provides relatively no compensation for movement of the contact arm 20 with change in ambient temperature. On the other hand, as shown in FIG. 5, if the compensator arm 22 is made relatively rigid compared to the actuator section 24, the force F, in stopping movement of the outer end of the compensator arm 22, causes the moving contact 32 to move downwardly to the position 32' as the ambient temperature increases. This, in effect, is an overcompensated condition since the moving contact has moved in the opposite direction from the free movement depicted by FIG. 3.

Thus it will be seen that by adjusting the relative rigidity, for example, of the compensator arm 22 relative to the actuator section 24, a condition can be obtained where the system is neither undercompensated or overcompensated but in fact is fully compensated, so that the moving contact 32 is not moved in either direction with change in ambient temperature. It will be further appreciated that in an undercompensated condition, as illustrated in FIG. 4, the time required to close the contacts in response to current applied to the heater 26 will be substantially shorter than the time required to close the contacts for the overcompensated condition of FIG. 5. Rather than change the width W to change the relative rigidity of the compensator arm, the position of the stop can be moved closer in or further out from the actuator section 24, as indicated by L_1 and L_2 of FIG. 6.

Referring to FIG. 9, there is shown a plot of time to actuate the switch as a function of ambient temperature. Assuming that at colder temperatures the actuator arm is against the stop screw 46, as shown in FIG. 6, an increase in ambient temperature will produce a change in time to actuate which may follow any one of a family of curves, three of which are shown at L_1, L_1' and L_1''. These slopes correspond to an undercompensated or overcompensated condition as determined by the distance L_1 of the stop along the compensating arm. As L_1 becomes longer, the temperature compensation increases and the switching time increases. Similarly, as the ambient temperature causes the bimetal to move against the stop screw 44, a second family of curves will occur, as indicated at L_2, L_2', and L_2'', depending on the position L_2 of the stop screw 44. A transition region exists in which the compensator arm moves through the gap between the two screws. Variation in time to actuate the switch in this transitional gap varies depending on various factors. The significant thing is that the slope in the two regions in which the bimetal is against one stop or the other can be varied and, in fact, the system can go through a transition from an undercompensated to an overcompensated condition by having the stops at unequal distances L_1 and L_2. Thus the performance characteristic of the switch can be controlled to assume any of a wide range of switching time characteristics.

The bifurcated arrangement shown in FIG. 1 and 2 shows the actuator arm 22 as being offset from the plane of the contact arm 20 and the actuator section 24. This offset is not important to the operation of the switch and was provided in the drawing primarily to be able to separately show the two arms in a side view. The arm arrangements of FIGS. 1 and 2 can be modified as shown in FIGS. 7 and 8 in which two compensator arms 122 extend on either side of the switch arm 120 and are joined at their outer end by a bridging section 123. Fixed contacts are supported on either side of the bimetal element 116 in the manner shown in FIG. 8.

The thermal switch 10 can be made to operate as a snap action switch by adding an over-center spring 47, as shown in FIG. 6, between the end of the control arm 20 and a fixed point.

The above-described compensated thermally actuated switch has the advantages that no special geometry, no reversal of the bimetal, or other complicated modification is required to achieve control over changes in ambient conditions. Large contact movement is also achieved. Various changes such as modifying the width of the bimetal element, changing the area of the heater, making the switch arm and/or the compensator arm of non-bimetal are other changes that can be made to achieve special performance effects.

The thermal switch described above is particularly suited to operating a glow plug control circuit, such as the circuit shown in FIG. 10. The glow plugs, indicated at 52, are heated from a battery 54 through a power relay 56 when the relay is energized. The relay 56 is energized from the battery 54 when an ignition switch 58 is closed, completing a current path from the battery 54 through the normally closed contacts of a control relay 60 to the power relay 56. At the same time a current path is completed from the battery 54 through an indicator light 62 and through the heater element 64 of a thermally actuated switch 56. Because of the relatively low resistance of the heater 64 compared to the indicator lamp 62, there is a very small voltage drop across the heater resistor 64. At the same time, a current path is completed through the heater element 68 of a thermally actuated switch 70 connected in parallel with the power relay 56. The thermal switches 66 and 70 are preferably of the type described above, the thermal switch 70 having a relatively long time period (10-20 seconds) while the thermal switch 66 has a relatively short actuating period (.5-20 seconds). When the thermally operated contacts 72 of the switch 70 are closed, a short is connected across the lamp 62, causing the lamp to turn off and signaling to the operator that the diesel engine can be started. At the same time, the full battery voltage is applied across the heater 64 causing the thermal switch 66 to time out and close the contacts 74. The closing of the contacts causes the control relay 60 to be energized, thereby breaking the circuit to the power relay 56 to turn off the glow plugs 52. The normally open contact of the relay 60 acts as a holding circuit for maintaining the control relay energized until the ignition switch 58 is opened to turn off the engine. In order to ensure that the glow plugs 52 remain on during the starting of the engine, the power relay 56 may be energized by closing a starter switch 76 which also operates the starting circuit (not shown). The glow plugs are protected against overheating during starting due to the voltage drop of the battery resulting from the large current drain during cranking of the engine by the starter. This circuit is particularly well suited for the high temperature coefficient of resistance plugs currently being used in diesel engines.

FIG. 11 shows a circuit similar to that of FIG. 10 except that the thermal switch 70' includes both normally closed and normally open contacts. The circuit to the lamp 62 is provided by the normally closed contacts of the switch 70'. After a thermal delay time, the normally closed contacts open, turning off the lamp 62. After a further delay, the normally open contacts are closed, completing a circuit through the heater 64 of the thermally actuated switch 66. After time-out, the contacts 74 are closed, actuating the control relay 60. This circuit, in effect, provides three timing intervals, the additional interval being the time required for the switch 70' to change from the normally closed to the normally open switch condition.

FIG. 12 is substantially the same as FIG. 11. However, the thermal switch 66 is eliminated and the normally open contacts of the thermal switch 70 are used directly to energize the control relay 60. It will be noted, that in each of the above-described circuits, an over-voltage causes all times to be shortened due to the more rapid heating of the thermally actuated switch 70' so that energy to the glow plugs remains substantially constant with changes in battery voltage.

FIGS. 13 and 14 show a control circuit which operates in substantially the same manner as the circuits described above but utilizes a single thermal actuated switch which uses the heating time to time out the turning off of the indicator lamp 62 and uses the cooling time of the same thermal switch to time out the turning off of the glow plugs. This requires a thermally actuated switch which has a controlled hysteresis time between the closing and opening of the same set of contacts with heating and cooling of the switch. Such hysteresis is generally provided by a snap action type switch, for example, such as a switch with an overcenter spring as shown in FIG. 6. Referring to FIG. 13, a thermally actuated switch 80 is shown which has two bimetal elements controlled respectively by a heater 82 and a heater 84. The heater 82 causes the normally open contacts to close while the heater 84 causes the contacts to open. In the arrangement of FIG. 13, when the ignition switch is closed, the power relay 56 completes a power circuit to the glow plugs 52 and turns on the indicator lamp 62. At the same time a circuit is completed from the battery through the heater 82 of the thermal actuated switch 80. After the control time out period, the normally open contacts of the switch 80 are closed, causing the control relay 60 to be energized and a hold circuit provided by a diode 86 connected across the power relay 56 to maintain the glow plugs energized. At the same time the energizing of the control relay 60 interrupts the current path through the indicator light 62, causing the indicator light to be turned off. Also, the current path through the heater 82 is interrupted. After an additional delay caused by the hysteresis effect of the thermal switch, the contacts again open, interrupting the holding circuit on the power relay 56.

It will be noted that during the time that the normally open contacts of the thermal switch are closed, the heater 84 is energized. In the event of an over-voltage of the battery, the heater 84 shortens the time in which the contacts open, thereby shortening the time the glow plugs are energized. Thus over-voltage protection of the glow plugs is provided.

FIG. 14 shows a modification of the circuit of FIG. 13 but includes a thermally operated circuit breaker switch 90 having a heater 92 and normally closed contacts 94. Once the contacts of the thermal switch 82 close, the heater 92 is energized, causing the contacts 94 to open, de-energizing the power relay 56 and the heater 92. This allows the contacts 94 to close again, repeating the cycle. Thus as long as the contacts of the thermally actuated switch 82 remain closed due to the hysteresis effect of that switch, the thermal switch 92 continues to cycle the glow plugs on and off and thereby limiting the energy input to the plugs.

WHAT IS CLAIMED IS:

1. A thermally actuated switch comprising an elongated thermal strip, means rigidly supporting the thermal strip at one end, the strip being flexible to allow movement of the outer end of the strip by bending of the strip, the opposite end being divided longitudinally into a contact arm and a compensator arm extending parallel to each other, the outer ends of the arms being movable relative to each other with flexing of the arms, switch means including a fixed contact and a moving contact actuated by motion of the outer end of the contact arm to open and close an electrical current path, heater means positioned adjacent the strip between the support and the inner end of the arms, at least the portion of the strip adjacent the heater being a bimetal, and stop means for limiting movement of the outer end of the compensator arm.

2. Apparatus of claim 1 wherein the stop means includes a stop on side of the compensator arm.

3. Apparatus of claim 1 wherein the stop means includes a stop on both sides of the compensator arms.

4. Apparatus of claim 3 wherein the stops on opposite sides of the compensator arms are positioned at different distances from said means supporting the thermal strip.

5. Apparatus of claim 3 wherein the stops are spaced apart to provide a gap through which the compensator moves from one stop to the other.

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Fig. 1

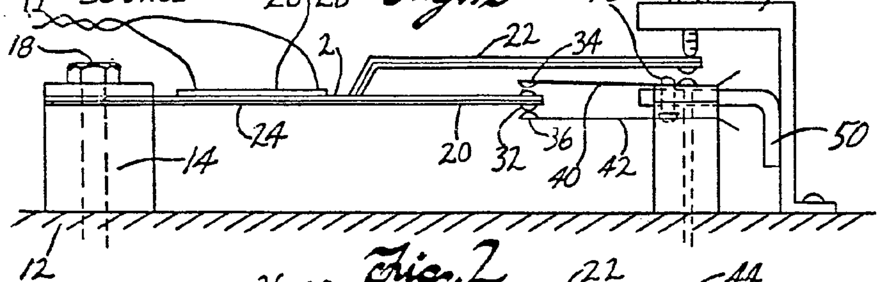


Fig. 2

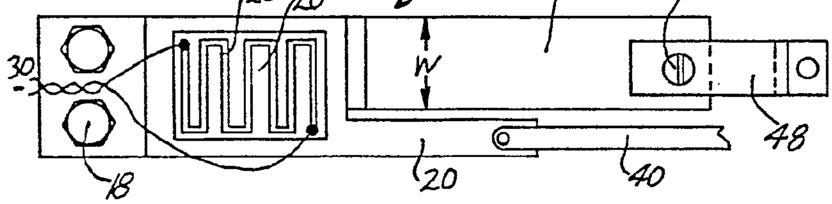


Fig. 3

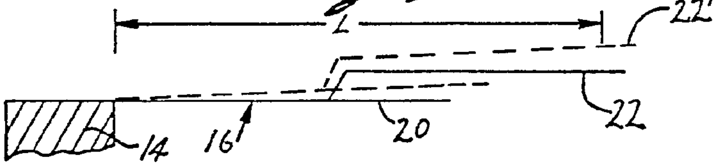


Fig. 4

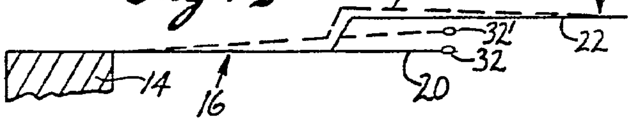


Fig. 5

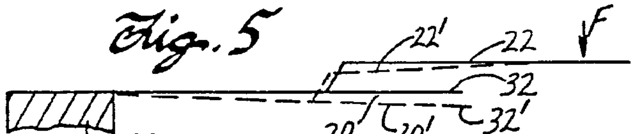


Fig. 6

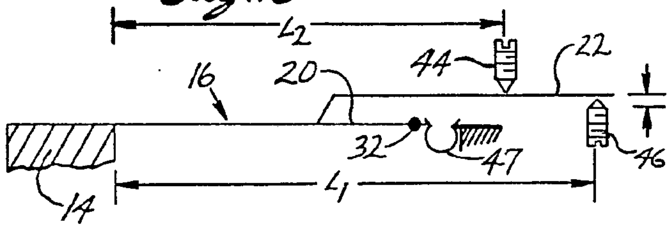


Fig. 7

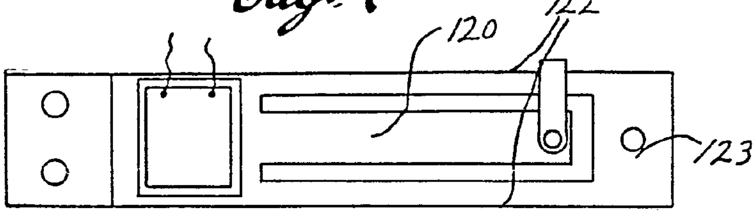
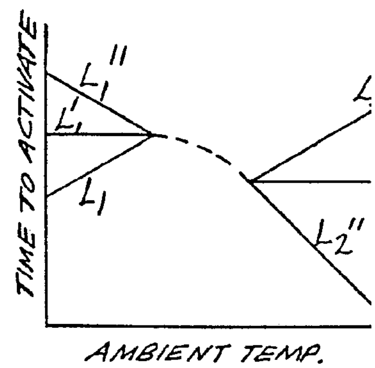


Fig. 9



116 Fig. 8 134

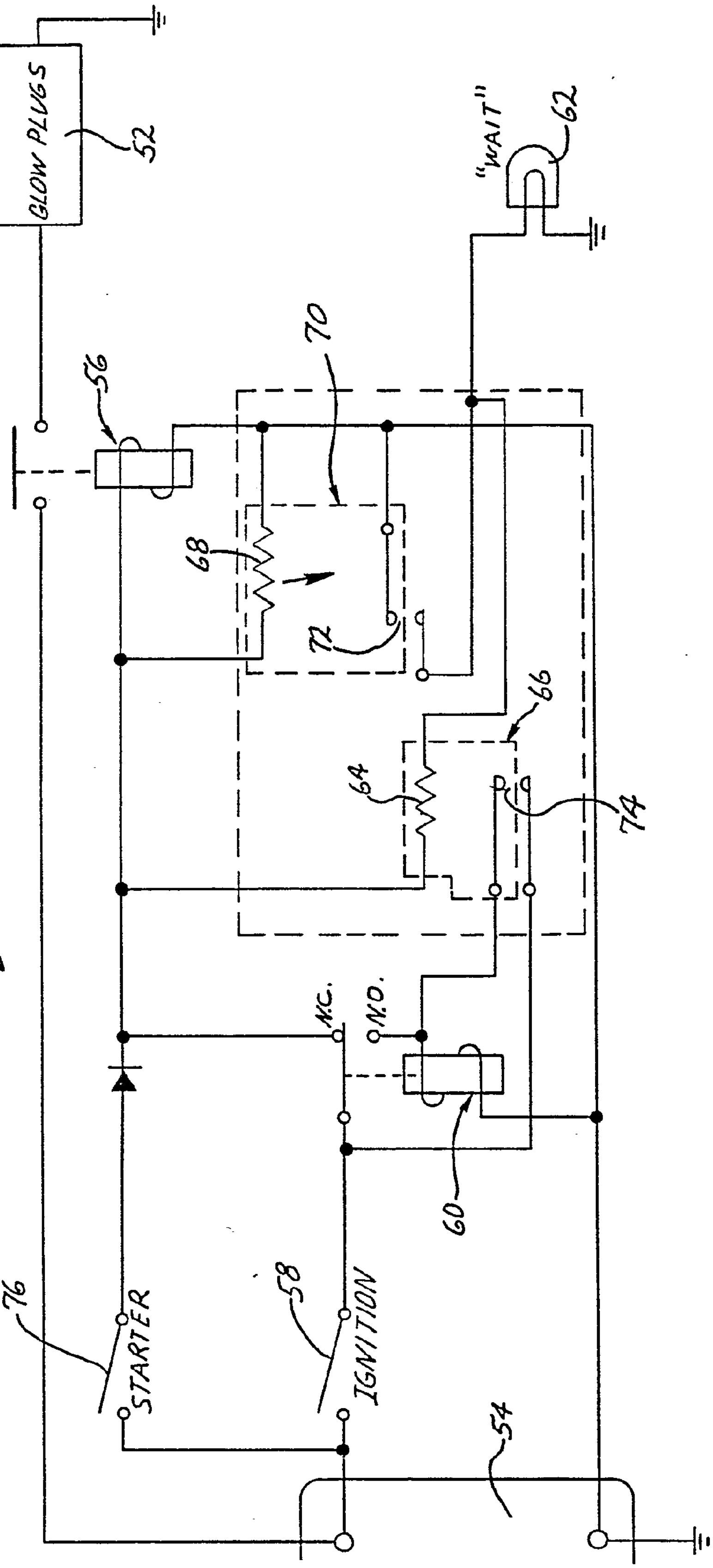

GLOW PLUGS
52
56
70
68
72
"WAIT"
62
66
64
74
N.C.
N.O.
60
76
STARTER
58
IGNITION
54

Fig. 10

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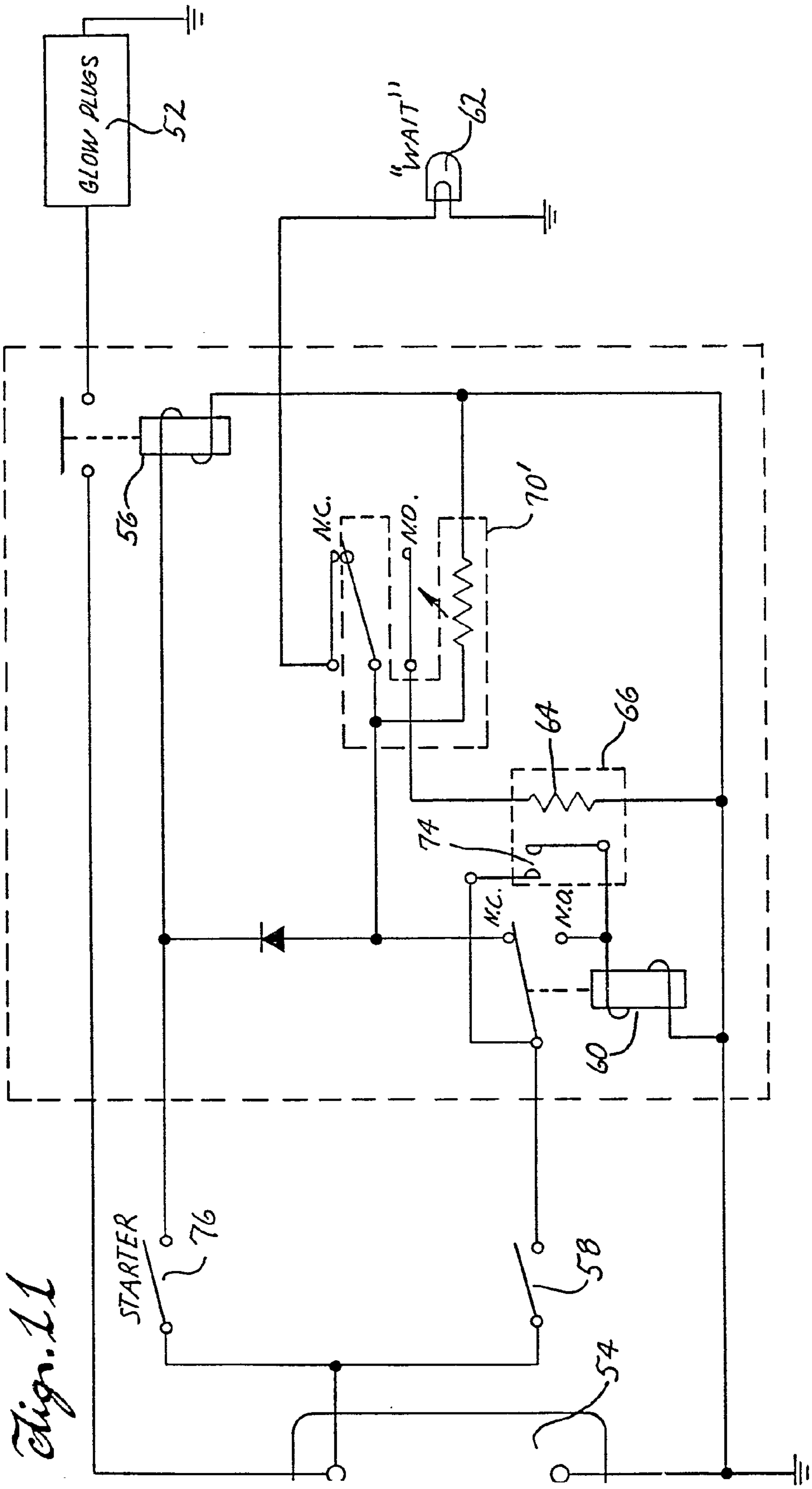

Fig. 11

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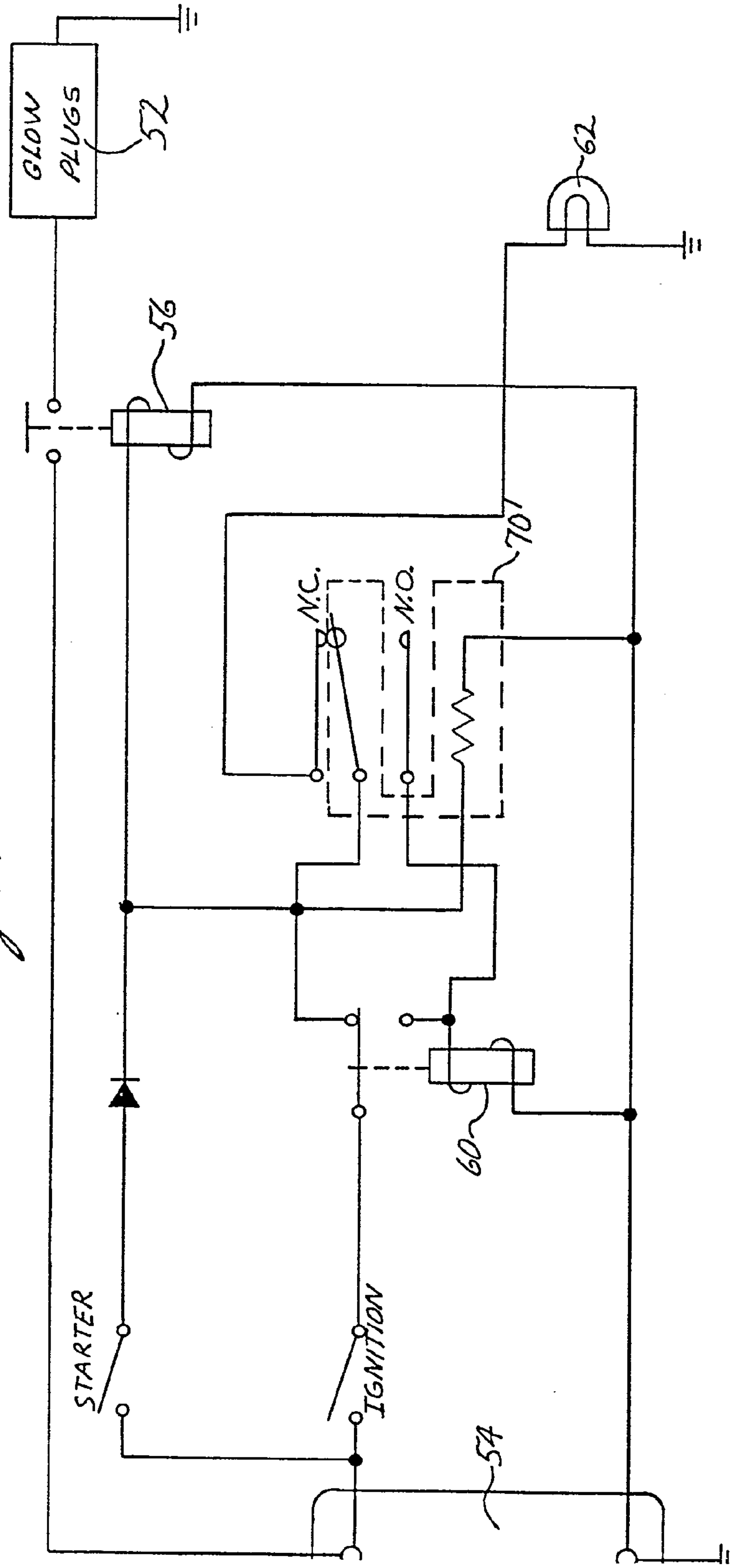
Fig.12



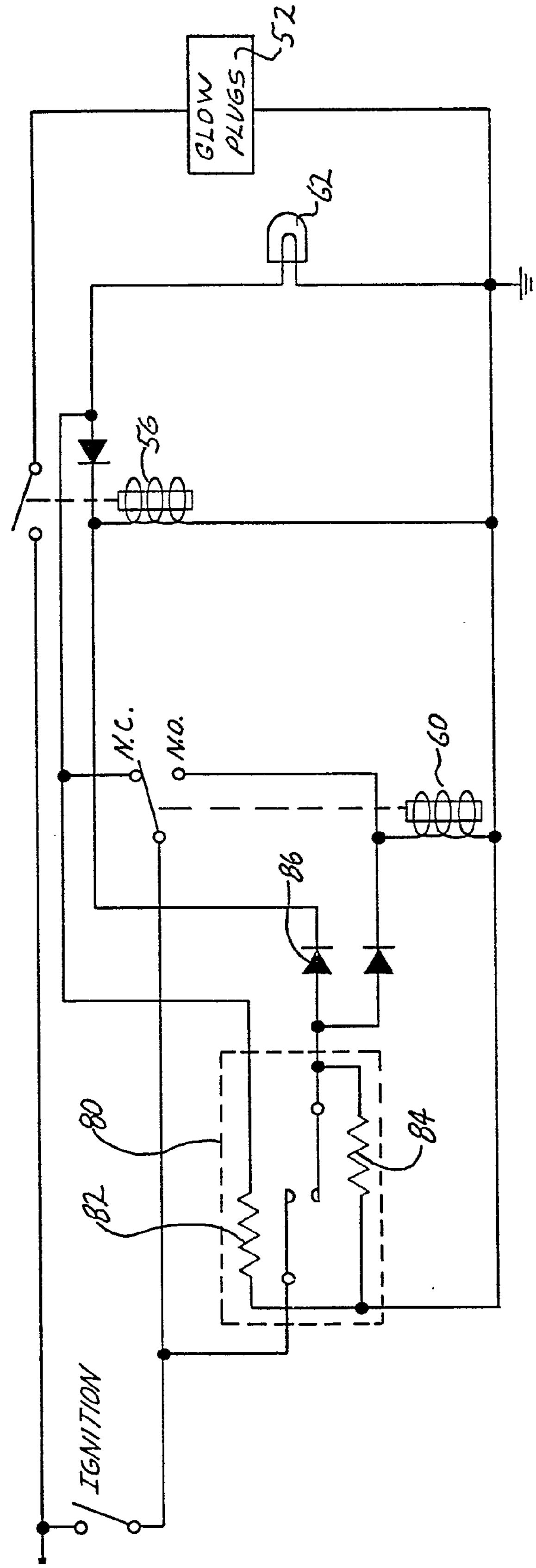


Fig. 13

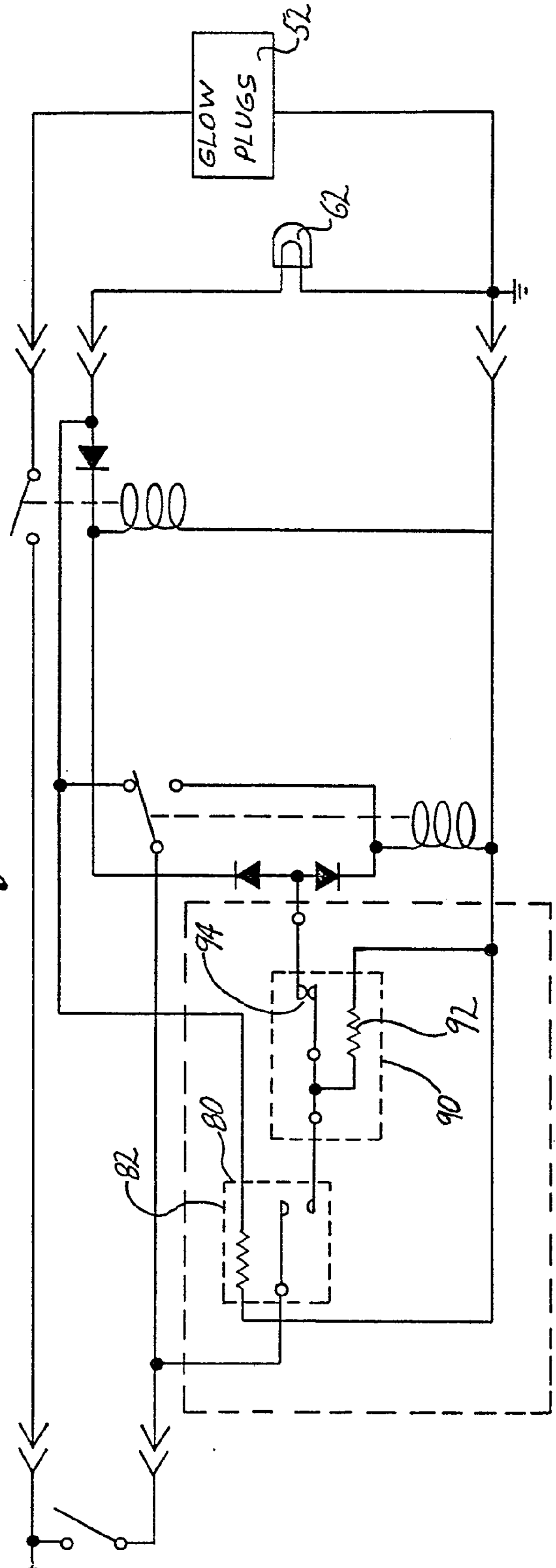


Fig.14