

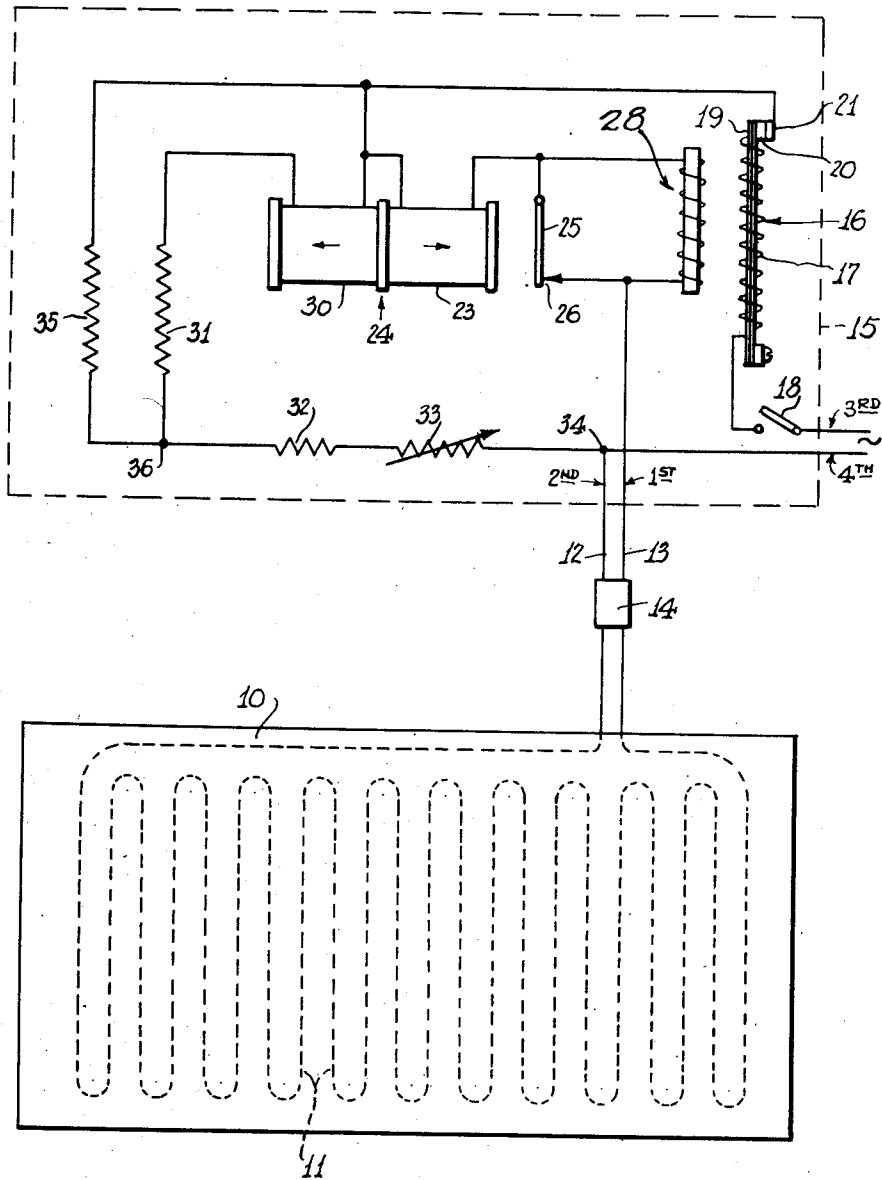
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TEMPERATURE RESPONSIVE PROTECTIVE DEVICE FOR ELECTRIC CIRCUITS

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TEMPERATURE RESPONSIVE PROTECTIVE
DEVICE FOR ELECTRIC CIRCUITS

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This invention relates to protective devices and more particularly to temperature responsive protective devices adapted to control electric circuits in accordance with temperature changes.

While not limited thereto, the present invention has particular utility as a protective device for preventing overheating of flexible electric heaters such as electric blankets, electric heating pads, and the like, and shall be described, by way of example, with reference to an electric blanket.

Considering an electric blanket, it occasionally happens that during use the blanket becomes bunched or folded, or after use is rolled up at the foot of the bed while still energized. Under such conditions, the heat lost from the folded or rolled section of the heating conductor is greatly reduced, and this tends to cause localized heating with the attendant possibility of scorching and fire. The main temperature control unit is generally unresponsive to a local rise in temperature and, therefore, it has been found necessary to resort to such expedients as incorporating a number of thermostats at strategic locations within the blanket, connected to interrupt the circuit in the event of an overheat. However, this is attendant with numerous disadvantages.

One object of the present invention is to provide an improved arrangement of apparatus for protecting electric circuits of the aforementioned character which does not require the use of such thermostats or any other auxiliary devices within the electric blanket itself and which is unaffected by fluctuations in the voltage of the source supplying current to the device although fully responsive to abnormal changes in temperature of the blanket.

In accordance with the invention, there is provided a protective device which depends for its operation upon the change in resistance of the heating element due to an abnormal rise in temperature.

Another object of the invention is to provide a protective device of the above nature which will interrupt the supply of current to the heating element in response to an abnormal rise in temperature but will automatically recycle itself and restore the current supply after an interval so that normal operation may resume if meanwhile the fault has been eliminated.

The invention will be better understood from the following description when taken in connection with the accompanying drawing, the single figure of which diagrammatically illustrates an electric blanket temperature control system embodying the invention.

Referring now to the drawing, 10 represents a conventional electric blanket including a heating coil or element 11 which is arranged in a plurality of convolutions spread evenly throughout the blanket area to provide uniform heating. The heating element is shown connected by means of conductors 12 and 13 to the temperature control apparatus included within the dashed lines 15. It is to be understood that the conductors 12 and 13 may be provided with a suitable plug connection to render separable the blanket and controller.

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The control circuit 15 includes a conventional bimetallic switch 16 for controlling the blanket temperature in a well-known manner in response to changes in the ambient temperature. The bimetallic switch 16 includes a heater element 17 which has one end connected to power switch 18 while the other end is connected to the bimetallic element 19 which is provided at its free end with a contact 20. In the absence of current flowing through element 17, contact 20 is arranged to close against a stationary contact 21. Contact 21 is connected to one terminal of a current coil 23, forming a part of differential relay 24. The other terminal of current coil 23 is connected over two paths to conductor 13. The first path includes armature 25 of the relay 24 and stationary contact 26. In the absence of current in the windings of the relay, the armature makes contact with contact 26. The second path includes an auxiliary heating element 28 arranged in heat transfer relationship with respect to bimetallic element 19. It should be noted that element 28 is connected across armature 25 and contact 26. Contact 21 is also connected to one terminal of the voltage coil 30 of relay 24, the other terminal of the voltage coil being connected through resistors 31, 32 and 33 in series to a junction point 34. Resistor 33 is variable as illustrated. Point 34 is joined to conductor 12. A further resistor 35 having a non-linear voltage characteristic is provided with one terminal connected to contact 21 and the other terminal connected to the junction between resistors 31 and 32. Point 34 and power switch 18 are connected through suitable conductors to a source of energy for the apparatus. If desired, a neon indicating lamp and resistor, or the like, may be connected between point 34 and the control circuit side of switch 18 to indicate the position of the latter.

The protective device operates in the following manner. Before switch 18 is closed to supply current to the system, the blanket is cold and the resistance of the heating element 11 is at a minimum. Bimetallic element 19 is also cold and contacts 20 and 21 are engaged. Armature 25 and contact 26 are likewise engaged. Upon closing switch 18, current will flow from the source through heater 17, contacts 20 and 21, winding 23, armature 25, contact 26, conductor 13, the blanket heating element 11, conductor 12 and back to the source. Current also flows through resistor 35 in parallel with winding 30 and resistor 31, then through resistors 32 and 33 back to the source.

Assuming for the moment a fixed supply voltage, the resistance of the last-mentioned circuit including winding 30 will have some fixed value determined by the choice of resistors 31, 32, and 35 and the setting of resistor 33. Thus winding 30 will develop a fixed amount of magnetic flux (in proportion to its ampere turns) which, due to its polarization, tends to attract armature 25 and open its circuit. However, since the blanket resistance is at a minimum the current through winding 23 is at a maximum. Its polarization is such as to oppose the flux developed by winding 30 and the net magnetic flux (due to the net ampere turns) is insufficient to open the contacts of the relay. With the contacts closed there is a short-circuit path across auxiliary heater 28 and it remains cold or inoperative.

After a time, blanket 10 increases in temperature and the resistance of element 11 increases causing a decrease in the current flowing through winding 23. However, during normal operation the resistance of the blanket heating element 11 will not rise above a certain critical value. As long as the resistance of element 11 does not exceed the aforementioned critical value, the net magnetic flux of the relay 24 will be inadequate for opening its contacts. The critical value can be adjusted by varying resistor 33 which alters the current flowing through

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winding 30. This current may be considered as a reference current against which the current through the blanket is compared.

Now assuming one of the accidental occurrences enumerated above, the temperature of some portion of element 11 will far exceed its normal value. The current through winding 23 will now be reduced sufficiently to permit relay 24 to operate, disengaging armature 25 and contact 26. The result is that auxiliary heating element 28, having a relatively high resistance, is now in circuit, in series with blanket element 11. The initial effect is to materially reduce the current flowing through element 11, permitting it to cool, and at the same time to reduce the current flowing through winding 23 still further so that there is no chance of the relay contacts closing again.

The same effect could be realized by omitting element 28 in which case the blanket current would be interrupted completely. However, in many instances the folding of the blanket or other condition which has caused the blanket to overheat is only temporary and so it is desirable to provide some means for recycling the apparatus after a period sufficient to allow the overheated point to cool. It is for this purpose that element 28 is included. When the relay contacts opened, the entire circuit current was reduced below that necessary to cause heater element 17 to operate bimetallic switch 16. But now current is flowing through element 28 which is positioned adjacent the bimetallic element 19. It is adjusted to have a relatively long time delay of, say, three to five minutes, after which switch 16 operates interrupting the current to the entire circuit. Since neither winding of relay 24 is energized its contacts re-engage. Now, upon re-engagement of contacts 20 and 21 after a brief cooling period, the apparatus will operate in normal fashion, assuming the resistance and thus the temperature of the heating element 11 has dropped below the critical value.

As with most standby control devices, it is desirable that the device per se consume as little power as possible. For efficient operation, most of the power utilized should be converted to heat in the blanket. To this end winding 23 which is in series with the blanket should have a low impedance and, therefore, is chosen with relatively few turns. On the other hand, winding 30 is in parallel with the blanket and, therefore, it should be constructed with relatively many turns and have high impedance.

Up to now it has been assumed that the supply voltage has remained constant. This, however, is not attainable in practice and, therefore, the ideal controller should be designed to operate irrespective of voltage fluctuations. Considering the instant device, it should be apparent that the relay operates only when the magnetic flux or net number of ampere turns has reached a given level. In accordance with the operation set forth above, the net number of ampere turns is equal to the number of ampere turns on the voltage coil 30, minus the number of ampere turns on the current coil 23. This can be represented by the following equation:

$$K = N_v I_v - N_c I_c \quad (1)$$

where:

K =net number of ampere turns,
 N_v =number of turns on the voltage coil,
 N_c =number of turns on the current coil,
 I_v =current through the voltage coil, and
 I_c =current through the current coil.

Neglecting resistor 35 for the moment, it should be apparent that the currents through each of the relay windings vary in proportion to variations in the line voltage. For the reasons set forth above N_v will be greater than N_c . Therefore, K will vary with line voltage fluctuations, an increase thereof causing the relay to operate. Hence, neglecting resistor 35, the control would interpret an increased line voltage as an increase in blanket temperature.

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Now considering resistor 35, whose resistance decreases as the voltage applied across its terminals increases, it is seen that it shunts voltage coil 30 and resistor 31 more effectively with increase in voltage so that the voltage coil current, I_v , no longer increases proportionately. Naturally the converse is also true, as the voltage decreases, the shunting caused by resistor 35 is less effective. By the proper choice of resistors 31, 32, 33 and 35, it is possible to maintain K substantially constant with fluctuations in line voltage. If we assume that the line voltage changes by $X\%$ then we must satisfy the following equation if K is to remain constant:

$$\Delta I_v = \frac{N_c}{N_v} \cdot \frac{X}{100} \cdot I_c \quad (2)$$

However, we also have the relation:

$$\Delta I_v = \frac{dI_v}{dV} \Delta V \quad (3)$$

where;

I_v =change in voltage coil current,
 ΔV =change in line voltage, and
 V =line voltage.

Solving the equations applicable to the circuit it can be shown that

$$\frac{dI_v}{dV} = \frac{A}{R_b R_a + A(R_a + R_b)} \quad (4)$$

where:

$$A = \frac{L \left(\frac{H}{A_r} \right)^{\frac{1}{N+1}}}{N+1} \left[\frac{V - I_v (R_a + R_b)}{R_b} \right]^{\frac{-N}{N+1}} \quad (5)$$

and

R_b =the sum of the resistances of resistors 32 and 33,
 R_a =the sum of the resistance of winding 30 and resistor 31,

L =length of voltage sensitive resistor 35 in centimeters,
 H =constant pertaining to resistivity of resistor 35,
 N =exponent connecting resistance of resistor 35 with its voltage gradient, and
 A_r =cross-sectional area of the resistor 35.

If we combine Equations 2, 3 and 4 we get the following:

$$\frac{N_c}{N_v} \cdot \frac{X}{100} \cdot I_c = \frac{A}{R_b R_a + A(R_a + R_b)} \Delta V \quad (6)$$

Therefore to maintain the circuit insensitive to voltage fluctuations of $X\%$ we must choose the circuit constants so as to satisfy Equation 6.

Although the circuit has been described in terms of a voltage sensitive resistor, it should be understood that it will function equally well using a gas discharge tube or any other voltage sensitive element.

The reason for including resistor 32 in series with variable resistor 33 should now be obvious. In order for resistor 35 to influence the current flowing through winding 30 it is necessary that some impedance be present between points 34 and 36. Therefore, resistor 32 has been included to fix the minimum resistance between the above two points. The relative sizes of resistors 32 and 33 are determined by the sensitivity desired from the temperature adjustment control resistor 33. Depending upon the constants of resistor 35, resistor 31 may be eliminated.

If desired, resistor 31 or 32 may have a negative temperature coefficient of resistance with a suitable characteristic such that it will compensate for the positive temperature coefficient of resistance of the copper wire usually used to wind coil 30 of relay 24. This means that the control setting is held constant regardless of ambient temperature conditions and regardless of the length of time the control has been turned on.

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It will thus be seen that the invention provides a very simple overheat protective device which functions independent of supply voltage fluctuations and which automatically recycles to resume normal operation upon removal of the fault.

While only one embodiment of the invention has been shown and described, it will be understood that minor changes in the construction, combination, and arrangement of parts may be made without departure from the spirit and scope of the invention as claimed.

Having thus described our invention, what is claimed is:

1. A control device for an electrical heating element comprising a first and second conductor for connection to said heating element, a third and fourth conductor for connection to a source of energy, a differential relay comprising a first winding and a second winding and a pair of relay contacts, said first winding being connected between said first and third conductors, said second winding being connected between said second and third conductors, a connection between said second and fourth conductors, said relay contacts being connected in series with said first winding and arranged to open when the currents through said two windings bear a given relationship, and a switch device included in the connections between said third conductor and both said windings, said switch device and said relay contacts being intercoupled and arranged such that the switch device will interrupt the circuit for both said windings in response to opening of said relay contacts, thereby to automatically reset said differential relay, said switch device comprising a bimetallic element and a high resistance heating unit therefor, said heating unit being connected across said relay contacts, said switch device further comprising a second heating unit for said bimetallic element, said second heating unit being connected in series with contacts forming a part of said switch device whereby the switch device functions as a primary temperature control regulating the temperatures of the heating element as a function of the ambient temperature, and second differential functions as an auxiliary control device for preventing the temperature of said heating element from exceeding a predetermined safe maximum.

2. A controlled electrical heating system comprising a

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resistive heating element connected in series with an ambient temperature sensitive, temperature controlling switch device and an independent auxiliary protective switch for connection to a source of energy, means responsive to overheating of at least a portion of said heating element for operating said auxiliary protective switch at least to reduce the supply of energy to said heating element, and means connected to said auxiliary protective switch and said temperature controlling switch device for operating the latter in response to operation of the former, operation of said temperature controlling device being operative to reset said auxiliary switch and re-cycle the heating system, said temperature controlling switch device comprising a bimetallic switch member having a heater element, the contacts of said bimetallic switch member being connected in series with its said heater element and the said resistive heating element, said means which is connected to both said protective switch and said switch device comprising an auxiliary heating unit connected across terminals of said protective switch and arranged in heat transfer relationship with respect to said bimetallic switch member.

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