Aug. 30, 1949. J. R. BARR 2,480,538

THERMAL SWITCH

Filed June 22, 1948

Fig. 1.

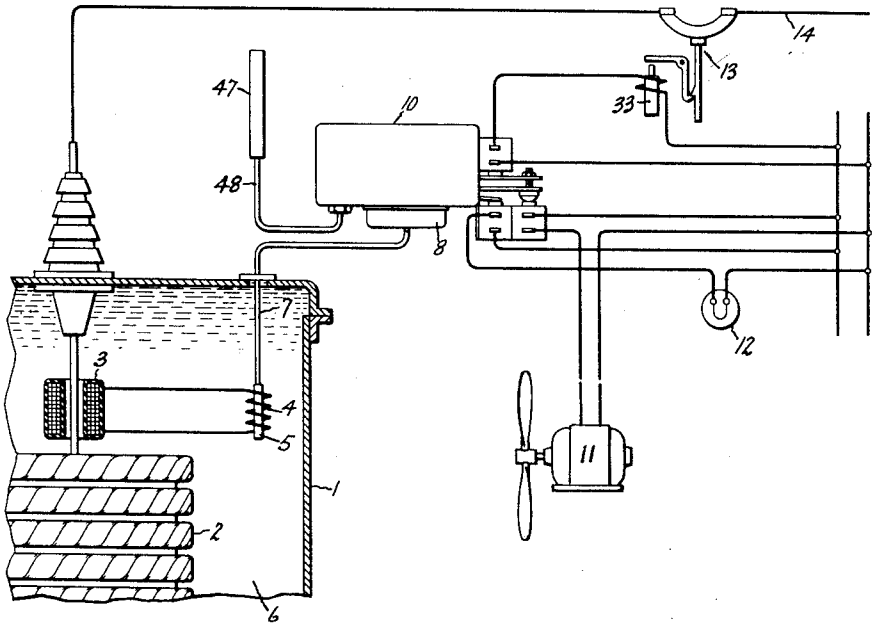


Fig. 2.

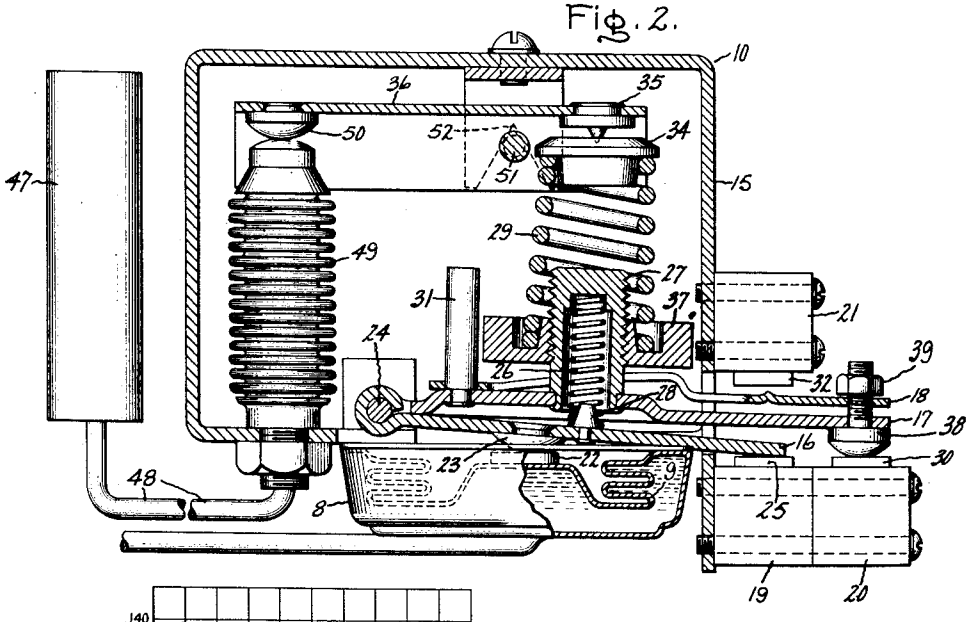
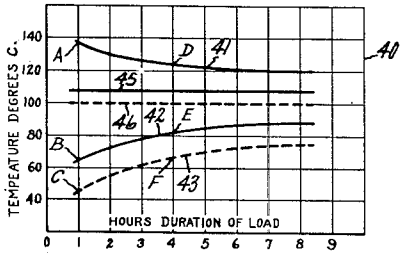


Fig. 3.



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THERMAL SWITCH

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3 Claims. (Cl. 200—81.5)

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This invention relates to thermal relays and more particularly to a thermal relay which operates sequentially a plurality of switches.

In the case of a transformer, or a similar electrical device, protective equipment is required which will indicate unusual overheating of the transformer coils. Also, the equipment is designed so that it is able to carry certain predetermined overloads for fixed periods of time. Thus it may be desirable to construct, for example, a protective thermal relay which, in the case of slight overheating of the transformer, turns on a fan to cool the transformer oil; if the overheating is more intense rings a warning bell, and when the overheating has reached a predetermined high value opens the circuit breakers and disconnects the transformer from the line. Such devices have been built but in the past have required three separate relay units, one to accomplish each of the prescribed operations. The use of three relays is undesirable due to the added expense and the increase in the space requirements.

In accordance with this invention the individual relays have been incorporated into a single thermostatic relay unit which performs, in the desired sequence, a plurality of operations.

It is an object of this invention to provide a new and simple thermal relay which will perform a plurality of functions sequentially using only one relay device.

It is a further object of this invention to provide a new and simple thermal relay which performs sequentially a plurality of operations and is economical to construct and possesses a long operating life.

A further object of this invention is to provide such a thermal relay which is compensated for changes in ambient temperature.

The invention will be better understood from the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

In the drawing Fig. 1 is a diagram of a preferred form of this invention as applied to use with a high tension transformer; Fig. 2 is a partially cross-sectional side elevation of a preferred form of the invention, and Fig. 3 is a graph illustrating curves useful in the explanation of the invention.

Referring now to the drawing, there is shown therein, by way of example, in Fig. 1, an application of a preferred form of this invention to use as a protective device in the operation of a high voltage transformer 1. In transformer operation

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overloading is manifest by excessive internal heating and the resulting danger of insulation and dielectric breakdown. Normally, breakdown will occur at the point of most intense heating within the transformer coils 2, and the life of the transformer 1 is determined by the "hot-spot" temperature and the length of time which the winding remains at that temperature. As shown in Fig. 1, a measure of the load carried by the transformer 1 and the resulting heating within the windings 2 may be accomplished by employing a current transformer 3 whose secondary winding leads to a heating element 4 which is mounted on a thermally responsive element or bulb 5. The whole device is immersed in the same dielectric medium 6 as the transformer coils 2. Therefore, the heater element 4 carries a current which is proportional to the transformer load current and it raises the temperature of the thermally-responsive element 5 above the liquid dielectric 6 temperature just as the load current raises the actual hot-spot temperature. The thermally-responsive element or bulb 5 is partially filled with a liquid, such a methyl alcohol, the remainder of the bulb 5 being filled with the vapor of the same liquid. The vapor pressure, which is a function of its temperature, is transmitted hydraulically by a capillary tube 7 to a liquid filled container 8 which houses a bellows 9, as seen in Fig. 2.

In the illustrated case, three separate operations may be performed by the thermostatic relay device 10. A fan 11 may be placed in operation, a warning light or buzzer 12 may be activated, and if the overheating of the transformer 1 becomes excessive, a circuit breaker 13 is automatically tripped disconnecting the transformer 1 from the line 14. These operations are sequential and are dependent upon the vapor pressure built up within the bulb 5.

The change of hydraulic pressure as transmitted through the capillary tube 7 from the thermostatically-sensitive element 5 acts to compress or expand the bellows 9 which is mounted in the container 8 on the under side of a rectangular frame 15 which is the main structural member of the thermal relay 10. The movement of the bellows 9 is, in turn, transmitted to the switch arms 16, 17 and 18 which operate the switches 19, 20 and 21 and make or break the circuits to the fan 11, the bulb 12, and the circuit breaker 13. The bellows 9 has fastened to it a small preferably metallic projection 22 which acts as an extension of the bellows 9 and presses against a button 23 which is riveted to the switch arm

16. As the hydraulic pressure within the container 8 increases due to the heating of the thermostatic liquid within the bulb 5, the bellows 9 is compressed forcing the projection 22 firmly against the button 23. As the button 23 is raised the switch arm 16, which is movably mounted at one extremity to a shaft 24, also raises and if the movement of the projection 22 is sufficient the switch arm 16 will be raised off the contact button 25 of the switch 19 and the circuit to the cooling fan 11 will be closed causing the fan 11 to be placed in operation.

The motive force provided by the expandable bellows 9 must be sufficient, in activating the fan 11, to overcome the resistive force of a spring 26 which is mounted within a hollow shaft 27 attached to the switch arm 17. The spring 26 is held in contact with the arm 16 by a rivet 28. As the spring 26 is compressed and the switch arm 16 is raised off the switch button 25 causing the cooling fan 11 to be placed in operation, the arm 16 comes in contact with the switch arm 17 which is also movably mounted on the shaft 24. The switch arm 17 must move against the pressure of an adjustable conical spring 29 and if its movement is sufficient it is raised off the contact button 30 of the switch 20 causing the warning light or buzzer 12 to operate. The switch arms 17 and 18 are fastened near the shaft 24 end by a rivet 31 and both arms move as a unit. Further movement of the projection 22, which is the result of continued compression of the bellows 9, will cause the switch arm 18 to come in contact with the button 32 of the switch 21 activating a solenoid 33 which causes the circuit breaker 13 to open, removing load from the transformer 1.

The conical spring 29, against which the switch arms 17 and 19 operate, is so constructed that equal temperature changes within the thermostatically sensitive unit 5, which is located within the transformer oil or dielectric fluid 6, will cause equal deflections of the spring 29. The spring 29 is connected, at its upper extremity to a crown 34 which rests against a rivet 35 fastened to a lever 36 through which ambient temperature corrections are accomplished, and at its lower end to a knurled threaded nut 37 which rides on the shaft 27. Thus, by adjusting the position of the nut 37 the tension of the conical spring 29 may be varied thereby controlling the thermostatic bulb 5 temperature at which the movement of the switch arms 17 and 18 will cause the operation of the warning buzzer or light 12 and the circuit breaker 13. The linear separation of the switch arms 17 and 18 at the extremity which is not fastened by the rivet 31 may be controlled by a screw 38 and a nut 39. This separation is a measure of the temperature increment which is necessary to cause the transformer 1 to be removed from the circuit 14 after the warning buzzer or light 12 has been caused to operate.

It is important to remember that what is actually desired is an integration of two factors; the hot-spot temperature, and the length of time the winding remains at that temperature. The thermostatic relay must be so calibrated that its operation is a function of these variables. Fig. 3 illustrates the application of this relay for evaluating transformer loads in terms of transformer life being expended rather than simply indicating when the transformer hot-spot temperature reaches a predetermined value. In the latter case ambient temperature compensation would not be required if the temperature gradient of the bulb 5 over the oil 6 was designed equal to the rise of the hot-spot temperature over the cooling fluid 6.

An American Standards Association sub-committee published a transformer emergency loading guide, later adopted by the National Electrical Manufacturers' Association, which recommended permitting a hot-spot temperature of 137° C. if the load lasted only one hour, 130° C. for a two hour load and 120° C. for an eight hour load. These loads, the report explained, would cause a loss in transformer life of not more than one per cent.

Relay devices are not customarily designed to factor time intervals of more than a few seconds or at most a few minutes and, therefore, time intervals of hours present an entirely new problem. It was discovered that by properly proportioning the current transformer 3 and its associated heater 4 so that the temperature rise of the bulb 5 over the cooling fluid 6 was about 60% (this figure depends upon transformer characteristics) that of the winding hot-spot over the transformer oil 6, the relay would evaluate loads in accordance with the American Standards Association loading guide. Since the relay bulb 5 did not actually attain the hot-spot temperature but rather a value part way between that of the hot-spot and the oil 6, any change in ambient conditions would result in a different transformer fluid 6 temperature and a new relay bulb 5 setting. Thus, the need for ambient temperature compensation becomes obvious. The foregoing can be more easily understood if reference is made to the graph 40 shown in Fig. 3, wherein the duration, in hours, of the load carried by the transformer 1 is shown as the horizontal axis and temperature in degrees centigrade is shown on the vertical axis. This chart differs from the usual curve in that it indicates the hot-spot, curve 41, and the transformer fluid temperatures, curves 42 and 43, at the end of various permissible emergency loading condition and various ambient temperatures. For example, the vertical line above the one hour point on the horizontal axis represents the end point of loads of one hour duration. Point A on the curve 41 shows that the maximum permissible hot-spot temperature is 137° C. for loads of one hour duration. Such a load would, on a typical transformer result in an oil temperature B of 65° C. in a 30° C. ambient, and an oil temperature C of 45° in a 0° C. ambient. For emergency loads of four hours duration it can be seen that the permissible hot-spot temperature D of 125° C. would be associated with an oil temperature E of 83° C. in a 30° C. ambient and an oil temperature F of 67° C. if the ambient temperature were zero.

Midway between the hot-spot curve 41 and the oil temperature curves 42 and 43, which are drawn for 30° C. and 0° C. ambient temperatures, are two horizontal lines 45 and 46, respectively, which represent the relay operating temperatures, the solid line 45 for 30° C. ambient condition and the dashed line 46 for the zero ambient condition. Referring to curve 45, it will be noted that the temperature difference between the oil and the relay operating temperature at any particular time is very close to 60% of the difference between the oil and the hot-spot temperature. This same 60% relationship will be seen to hold for the zero ambient, oil, and relay operating curves 43 and 46. Thus it can be seen that if the hot-spot temperature as a function of time lies in a region

above the curve 41 the relay device will initiate the operation of its cooperating equipment.

Transformers with different design characteristics may require slight modifications in this 60% multiplication factor and also in the relay setting to give the most accurate results. Modification in the multiplication factor is accomplished by changing the design of the current transformer 3 and altering the heater 4 characteristics.

Ambient temperature compensation is accomplished by adjusting the bias of the conical spring 29; increasing it when the ambient temperature increases and decreasing it when the temperature decreases. A thermally responsive bulb 47 is connected through a capillary tube 48 to an operating bellows 49 which is forced against a metal rivet 50 mounted in the lever 36. The shaft 51 which passes through the lever 36, the lever 36 being formed from a channel-shaped metallic piece, is forced into a groove 52 by the pressure of the spring 29 and the bellows 49. When there is a decrease in ambient temperature the bellows 49 contracts, the conical spring 29 expands and its biasing force is decreased.

While there has been shown and described a particular embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications can be made therein without departing from the invention and, therefore, it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

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

1. A thermal relay device for controlling a plurality of operations, said thermal relay device including an expansible bellows, a housing for said expansible bellows, a thermally responsive element comprising a bulb, a capillary tube connecting said bulb to said expansible bellows housing, liquid filling said expansible bellows housing and said capillary tube, and said liquid partially filling said bulb, a plurality of switch arms cooperating with said expansible bellows mounted one above the other and separated one from the other at one extremity, corresponding electrical switches for each of said switch arms, said switch arms making or breaking electrical circuits leading to said switches, a conical spring mounted on an adjustable collar above said switch arms and cooperating with said expansible bellows, said spring providing a biasing force for retarding the motion of said expansible bellows, said spring being constructed so that said biasing force is such that equal temperature changes acting on said bulb of said thermally responsive element cause equal deflections of said spring, said biasing force being adjustable, said switch arms being caused to move against said biasing force of said spring by the thermal expansion of said liquid in said bulb of said thermally responsive element as transmitted to said expansible bellows housing and said expansible bellows through said capillary tube, a second spring mounted between at least one of said switch arms and said conical spring providing a biasing force for retarding the motion of said expansible bellows, at least one of said switch arms being caused to move against said biasing force of said second spring by the thermal expansion of said liquid in said bulb of said thermally responsive element.

2. A thermal relay device for controlling a plurality of operations, said thermal relay device including an expansible bellows, a housing for said expansible bellows, a thermally responsive element comprising a bulb, a capillary tube connecting said bulb to said expansible bellows housing, liquid filling said expansible bellows housing and said capillary tube, and said liquid partially filling said bulb, a plurality of switch arms cooperating with said expansible bellows, mounted one above the other and separated one from the other at one extremity, corresponding electrical switches for each of said switch arms, said switch arms making or breaking electrical circuits leading to said switches, a conical spring mounted on an adjustable collar above said switch arms and cooperating with said expansible bellows, said spring providing a biasing force for retarding the motion of said expansible bellows, said spring being constructed so that said biasing force is such that equal temperature changes acting on said bulb of said thermally responsive element cause equal deflections of said spring, said biasing force being adjustable, said switch arms being caused to move against said biasing force of said spring by the thermal expansion of said liquid in said bulb of said thermally responsive element as transmitted to said expansible bellows housing and said expansible bellows through said capillary tube, a second spring mounted between at least one of said switch arms and said conical spring providing a biasing force for retarding the motion of said expansible bellows, at least one of said switch arms being caused to move against said biasing force of said second spring by the thermal expansion of said liquid in said bulb of said thermally responsive element and means included in said thermal relay device for adjusting said biasing force of said conical spring in accordance with variations in ambient temperature.

3. A thermal relay device for controlling a plurality of operations, said thermal relay device including an expansible bellows, a housing for said expansible bellows, a thermally responsive element comprising a bulb, a capillary tube connecting said bulb to said expansible bellows housing, liquid filling said expansible bellows housing and said capillary tube, and said liquid partially filling said bulb, a plurality of switch arms cooperating with said expansible bellows mounted one above the other and separated one from the other at one extremity, corresponding electrical switches for each of said switch arms, said switch arms making or breaking electrical circuits leading to said switches, a conical spring mounted on an adjustable collar above said switch arms and cooperating with said expansible bellows, said spring providing a biasing force for retarding the motion of said expansible bellows, said spring being constructed so that said biasing force is such that equal temperature changes acting on said bulb of said thermally responsive element cause equal deflections of said spring, said biasing force being adjustable, said switch arms being caused to move against said biasing force of said spring by the thermal expansion of said liquid in said bulb of said thermally responsive element as transmitted to said expansible bellows housing and said expansible bellows through said capillary tube, a second spring mounted between at least one of said switch arms and said conical spring providing a biasing force for retarding the motion of said expansible bellows, at least one of said switch arms being caused to move against said biasing force of said second spring by the thermal expansion of said liquid in said bulb of said thermally responsive element, means included in said thermal relay device for adjust-

ing said biasing force of said conical spring in accordance with variations in ambient temperature, said last mentioned means including an expansible bellows, a bulb, a capillary tube connecting said last mentioned expansible bellows and said last mentioned bulb, liquid filling said last mentioned expansible bellows, said last mentioned bulb and said last mentioned capillary tube, lever means for fastening said last mentioned expansible bellows to said spring, the extension of said last mentioned expansible bellows due to an increase in ambient temperature compressing said spring through the action of said lever.

JAMES R. BARR.

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