

[54] **FLUID-COOLED TRANSFORMER HAVING A TEMPERATURE RESPONSIVE INDICATING AND CONTROLLING DEVICE**

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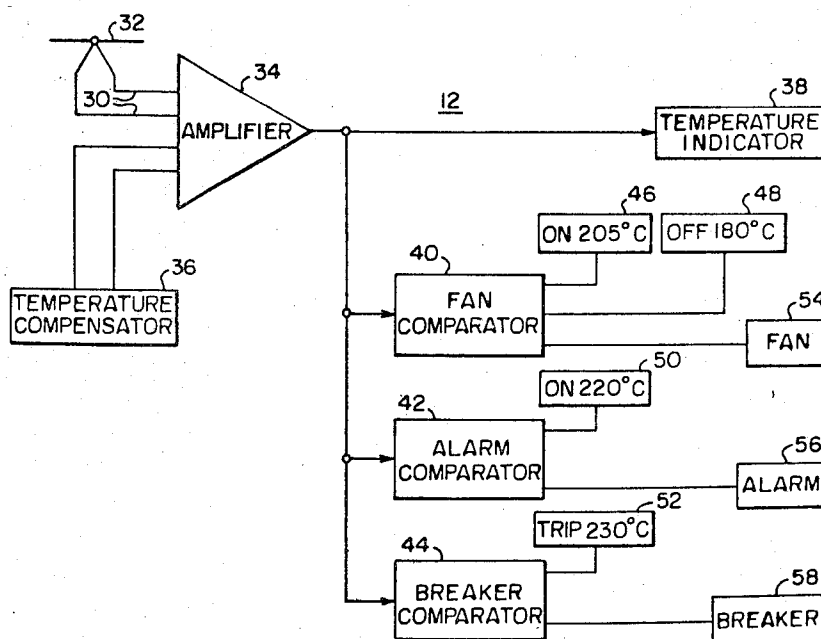
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[57]

ABSTRACT

Temperature responsive device suitable for use with air-cooled power transformers. The temperature responsive device indicates the temperature at a predetermined location within the transformer and controls the activation of fans, alarms, and circuit breakers associated with the transformer. Electrical isolation between a temperature sensing element and the controlled auxiliary apparatus is provided by light channels across which the control information is transmitted.

4 Claims, 3 Drawing Figures



SHEET 1 OF 2

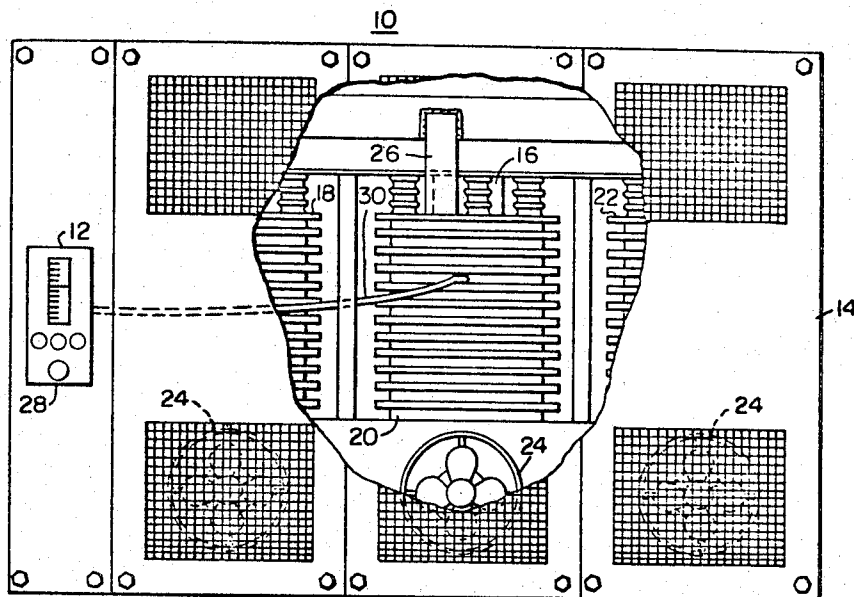


FIG. 1

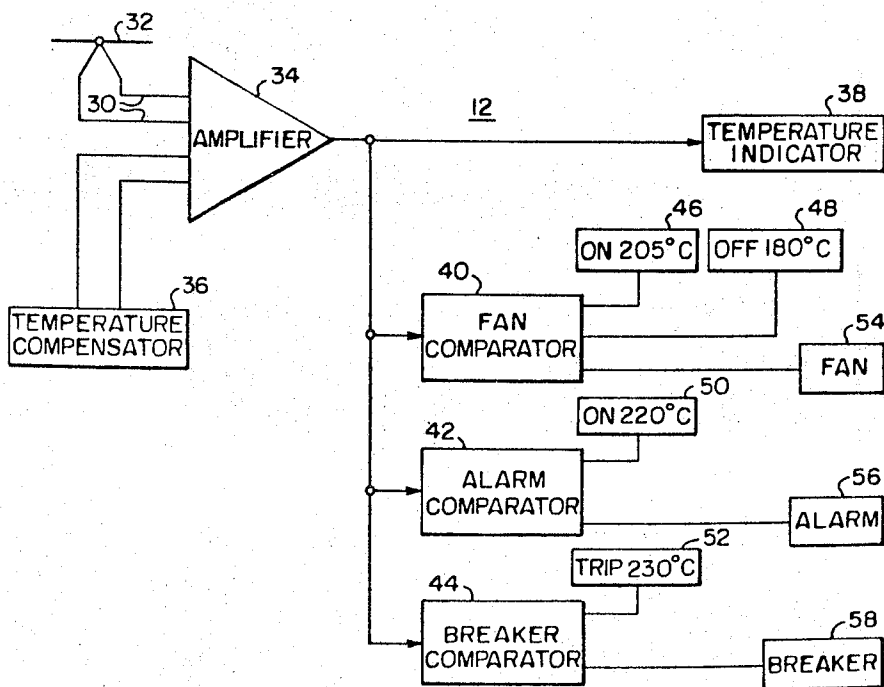
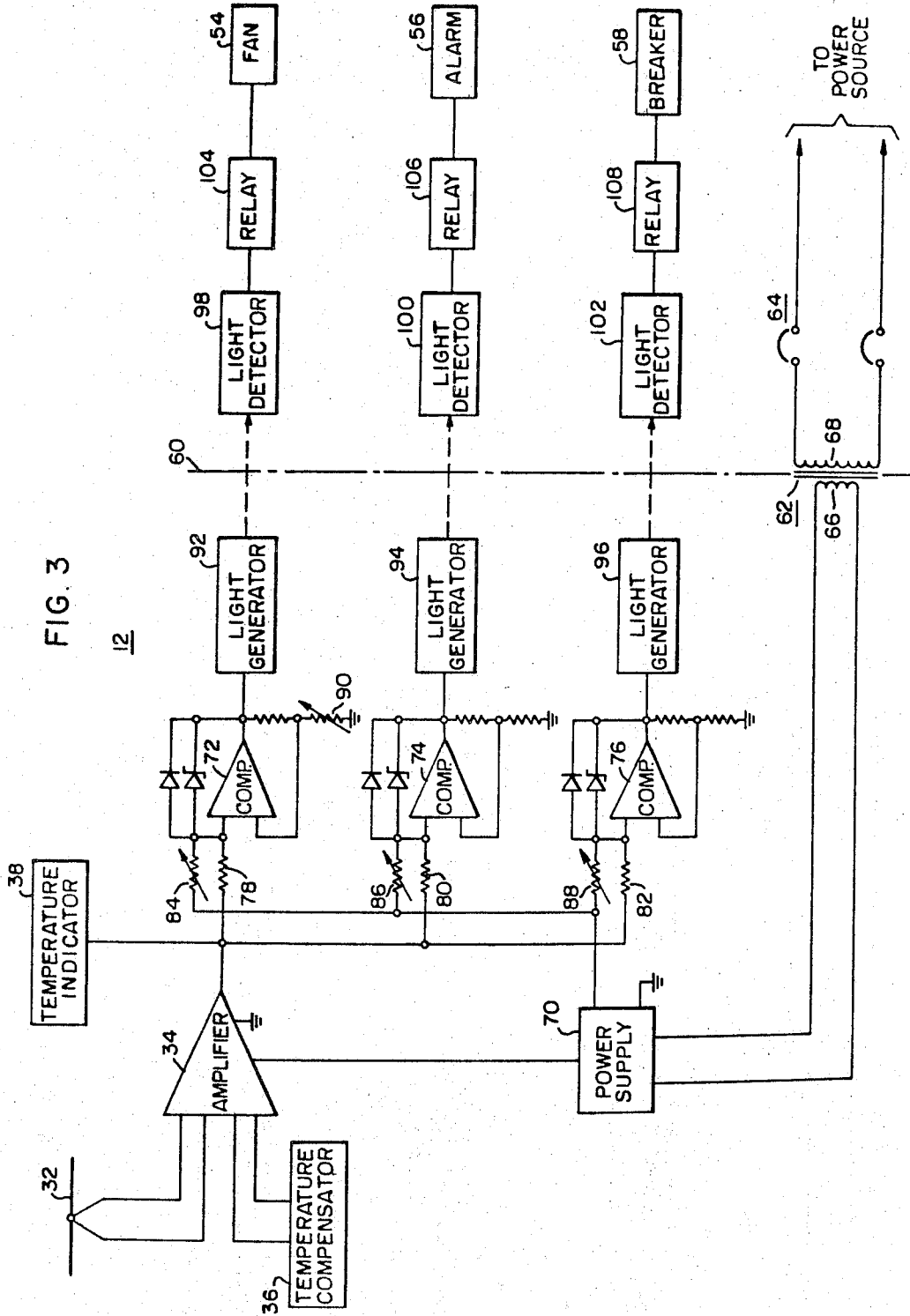


FIG. 2



FLUID-COOLED TRANSFORMER HAVING A TEMPERATURE RESPONSIVE INDICATING AND CONTROLLING DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates, in general, to electrical apparatus and, more specifically to transformers having temperature responsive indicating and controlling means.

2. Description of the Prior Art

Fluid-cooled electrical apparatus, such as air-cooled transformers, frequently have a fluid forcing device, such as a pump or fan, to enhance the flow of the cooling fluid around the heat producing components of the apparatus. It is advantages insome air-cooled transformer applications to monitor a temperature within the transformer, to indicate the monitored temperature, and to control auxiliary apparatus, such as fans, in a predetermined manner dependent upon the monitored temperature. Generally, when the monitored temperature increases to a predetermined value, one or more fans are turned on in an effort to lower the temperature.

Air-cooled transformers have certain regions, called "hot spots," which exhibit a higher temperature than the surrounding regions due to the inherent upward flow of heated air and to the shape of the heated structure. It is the temperature at the hot spot region which determines the upper temperature limit within which the transformer may be safely operated.

Many prior art temperature monitors use capillary tubes placed near the hot spot to measure the temperature. Since the hot spot is usually located within a winding of the transformer, normally in the center winding of threephase transformers at a location which is about one-third of the winding length from the top of the center winding, it is not practical to place the capillary tube exactly at the hot spot. Consequently, the determination of the hot spot temperature must be accomplished by using empirical data which correlates the temperature at the hot spot to that at the position where the capillary tube is located. Thus, some inaccuracies may exist between the indicated hot spot temperature and the true hot spot temperature with the use of the prior art capillary tube arrangements. Therefore, it is desirable, and it is an object of this invention, to provide a transformer having a hot spot indicator with a sensor which may be placed directly into the hot spot region of the transformer.

Indicating the temperature of the hot spot is sufficient in some applications. However, in other applications, simply indicating the temperature is not sufficient to protect the apparatus. Therefore, it is also desirable, an it is a further object of this invention, to provide a hot spot indicator which directly monitors the temperature at the hot spot and which controls various alarms and regulating apparatus.

SUMMARY OF THE INVENTION

There is disclosed herein a new and useful hot spot indicator and controller for use with electrical apparatus. The indicator includes a temperature responsive electrical sensing element which is positioned at the hot spot in the apparatus. The electrical sensing element is connected to an amplifier which processes the temper-

ature responsive signal from the electrical sensing element and applies the processed signal to an indicator and to comparator circuits. The indicator displays the temperature, in degrees, of the hot spot. One comparator governs the temperature at which a cooling fan is turned on and off. Another comparator governs the temperature at which an alarm indicator is turned on. Still another comparator governs the temperature at which a circuit breaker is tripped. The comparators and the heat sensing element are isolated from the controlled auxiliary apparatus to permit the placement of the heat sensing element at or near a high potential in the electrical apparatus without the need for large insulation structures near the hot spot. Isolation from the auxiliary apparatus is provided by light channels across which the control information is transmitted. Isolation from the power source is provided by an isolation transformer. The indicator disclosed herein provides accurate indications of the hot spot temperature and provides programmed control over the operation of auxiliary apparatus, such as fans, alarms, and circuit breakers.

BRIEF DESCRIPTION OF THE DRAWING

Further advantages and uses of this invention will become more apparent when considered in view of the following detailed description and drawing, in which:

FIG. 1 is an elevational view of an air-cooled transformer with a portion of the housing broken away;

FIG. 2 is a schematic block diagram of a temperature responsive indicating and controlling device constructed according to this invention; and

FIG. 3 is a diagram of the device shown in FIG. 2 illustrating the potential isolating circuitry.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Throughout the following description, similar reference characters refer to similar elements or members in all the figures of the drawing.

Referring now to the drawing, and to FIG. 1 in particular, there is shown an air-cooled transformer 10 which is equipped with a temperature responsive indicating and controlling device 12. The transformer 10 includes a ventilated housing 14, a three-phase magnetic core 16, and phase winding structures 18, 20 and 22. Forcing means, such as the fans 24, enhance the circulation of air around and through the core and winding assembly of the transformer 10.

Many prior art temperature responsive devices associated with similar transformers use capillary or bimetallic elements which are not easily placed into the hot spot of the transformer. Such elements usually are placed against a winding lead, such as the bus conductor 26. The temperature responsive device of this invention comprises a temperature responsive electrical sensing element, such as a thermocouple, or a temperature dependent variable resistance element, such as a thermistor. Because of its size and connecting requirements, the temperature responsive element of this invention may be placed directly into the core and winding structure at the location of the hot spot. Although the location of the hot spot in various transformers may be different, the hot spot in the transformer 10 shown in FIG. 1 is located within the phase winding 20 about one-third of the winding length from the top of the winding 20. The temperature responsive element which

is positioned within the winding structure is connected to the control panel 28 by the electrical cable 30. Circuitry located at the control panel 28 properly senses the electrical signals from the temperature responsive element and provides the desired indicating and/or controlling functions.

FIG. 2 is a schematic block diagram of the temperature responsive indicating and controlling device 12 connected to appropriate indicating and controlling components. The thermocouple 32, which is positioned to measure the temperature at the hot spot of the transformer, develops a voltage which is transmitted to the amplifier 34 through the cable 30. The temperature compensator 36 reduces the effect of the ambient temperature on the response of the amplifier 34. Combined amplifiers and temperature compensators are available commercially in a single integrated circuit package for compensated amplification of a thermocouple generated voltage.

The amplified signal from the amplifier 34 is applied to a temperature indicator 38 and to comparators 40, 42 and 44. The temperature indicator 38 may be a suitable current or voltage meter having a scale calibrated in temperature degrees. The comparators 40, 42 and 44 compare the signal from the amplifier 34 with internal reference signals and activate their associated indicators or controls depending upon the adjustment of the comparator circuit parameters.

The blocks 46, 48, 50 and 52 indicate the presence of adjustable circuit parameters for the comparators. For the fan comparator 40, the circuit may be adjusted to cause a signal from the comparator 40 to turn the fan 54 on when the temperature measured by the thermocouple 32 reaches 205°C and to turn the fan 54 off when the temperature decreases to 180°C. For the alarm comparator 42, the circuit may be adjusted to cause a signal from the comparator 42 to turn the alarm 56 on when the temperature reaches 220°C. For the breaker comparator 44, the circuit may be adjusted to cause a signal from the comparator 44 to trip the circuit breaker 58 when the temperature reaches 230°C. It is within the contemplation of this invention that any of the comparators may have on-off control with the proper circuit changes.

The temperatures of operation may be changed without departing from the scope of the invention. Any number of fans may be controlled by the fan comparator 40, or multiple comparators may be used to turn on different fans at different temperatures. The alarm 56 may be any locally mounted device on the transformer, such as a buzzer or light, or a remotely located device. Similarly, the circuit breaker 58 may be contained within the transformer housing 14 or in the housing of associated electrical equipment.

A definite sequence of events may occur with the circuit parameters adjusted to operate the comparators at the temperatures indicated in FIG. 2. The temperature of the hot spot is indicated continuously by the temperature indicator 38. If the temperature increases to 205°C, the fan 54 is turned on to help cool the transformer 10. If the fan lowers the temperature of the transformer to 180°C, the fan 54 is turned off. If the temperature increases after the fan is turned on, the fan continues to run. If the temperature increases to 220°C, the alarm 56 is activated to warn personnel that the transformer is operating in an overheated condition. If the temperature increases to 230°C, the circuit breaker

58 is tripped to de-energize the transformer 10 or to remove the load from the transformer 10, thereby reducing the possibility of damaging the transformer due to overheating.

The thermocouple 32, and some of the circuitry associated therewith, is susceptible to the high potentials appearing on the winding 20, since it is usually undesirable to provide enough insulation around the thermocouple 32 to fully insulate the high voltages to ground. Thus, a form of electrical isolation between the thermocouple 32 and the auxiliary indicating and controlling elements is desirable.

FIG. 3 illustrates circuitry which provides electrical isolation in the temperature responsive device 12. The line 60 schematically indicates the electrical isolation barrier between the circuit components. A source of power is connected to a suitably insulated isolation transformer 62 through the circuit breaker 64. The potential on the secondary winding 66 of the transformer 62 is isolated from the primary winding 68 and from the power source.

A suitable power supply 70 rectifies and filters the AC voltage and provides power to the amplifier 34 and to the comparators 72, 74 and 76. The input voltages are applied across the resistors 78, 80 and 82 to the comparators 72, 74 and 76, respectively. Variable resistors 84, 86 and 88 permit adjustment of the voltage level required to activate the comparators 72, 74 and 76, respectively. The variable resistor 90 permits adjustment of the voltage level required to deactivate the comparator 72 and turn the fan 54 off.

The output signals from the comparators 72, 74 and 76 are applied to the light generators 92, 94 and 96 which emit light energy when the output signals have a sufficient magnitude. Suitable light generators include light emitting diodes and incandescent lamps. The light energy emitted by the light generators 92, 94 and 96 is directed to the light detectors 98, 100 and 102, respectively, by suitable means, such as by a lens arrangement or through optical fibers.

The light detectors 98, 100 and 102 may be constructed of any suitable elements, such as photocells, light sensitive diodes, or light sensitive transistors. The path traversed by the light energy must be sufficiently long enough to provide the desired electrical insulation between the light generator and the light detector. The light detectors 98, 100 and 102 are connected to relays 104, 106 and 108, respectively, which activate the fan 54, the alarm 56, and the circuit breaker 58.

With the circuit illustrated in FIG. 3, high-voltage isolation between the thermocouple 32 and the auxiliary indicators and controls is achieved. Thus the thermocouple 32 may be located within a winding at the hot spot position. Different hot spot temperatures cause different indicating and controlling conditions to be activated. Other isolating arrangements may be used, such as by the use of properly insulated relays.

Since numerous changes may be made in the above described apparatus, and since different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all of the matter contained in the foregoing description, or shown in the accompanying drawing shall be interpreted as illustrative rather than limiting.

I claim as my invention:

1. A fluid-cooled transformer comprising the combination of:

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a core and coil assembly;
 temperature responsive means located within the
 transformer coil;
 means for forcing the cooling fluid around said core
 and coil assembly, said forcing means being con- 5
 trolled by said temperature responsive means;
 a first comparator circuit which is responsive to the
 temperature of said temperature responsive means,
 said first comparator circuit being constructed to
 activate the forcing means at a first predetermined 10
 temperature and to deactivate the forcing means at
 a second predetermined temperature of said tem-
 perature responsive means;
 means for providing an alarm if the temperature in
 the coil becomes excessively high, said indicating 15
 means being activated by said temperature respon-
 sive means;
 a second comparator circuit which is responsive to
 the temperature of said temperature responsive
 means, said second comparator circuit being con- 20
 structed to activate the alarm means at a third pre-
 determined temperature of said temperature re-
 sponsive means;
 means for interrupting the load power delivered by
 the transformer, said interrupting means being acti- 25
 vated by said temperature responsive means; and,
 a third comparator circuit which is responsive to the

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temperature of said temperature responsive means,
 said third comparator circuit being constructed to
 activate the reducing means at a fourth predeter-
 mined temperature of said temperature responsive
 means;
 said temperature responsive means being isolated
 from the forcing, alarm, and interrupting means to
 prevent the transfer of any high voltages existing on
 the temperature responsive means to the forcing,
 alarm or interrupting means.
 2. The fluid-cooled transformer of claim 1 wherein
 the first predetermined temperature is higher than the
 second predetermined temperature, the third predeter-
 mined temperature is higher than the first predeter-
 mined temperature, and the fourth predetermined tem-
 perature is higher than the third predetermined tem-
 perature.
 3. The fluid-cooled transformer of claim 1 wherein
 the forcing, alarm, and interrupting means each include
 a light generator and a light detector which is respon-
 sive to said light generator, with the isolation being pro-
 vided by the light channel between said light generator
 and said light detector.
 4. The fluid cooled transformer of claim 3 including
 an isolation transformer which isolates the power sup-
 plied to the first, second and third comparator circuits
 from the power source.

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