

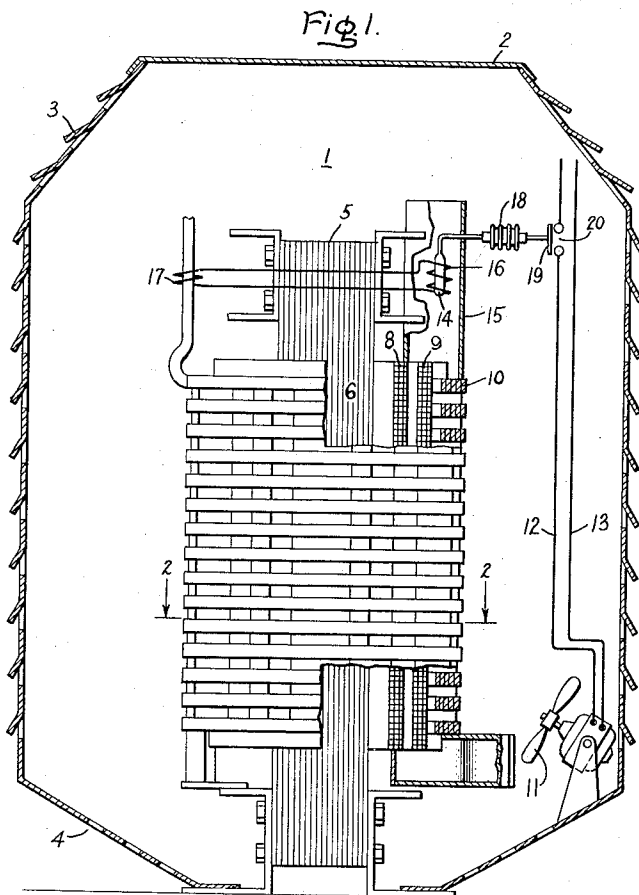
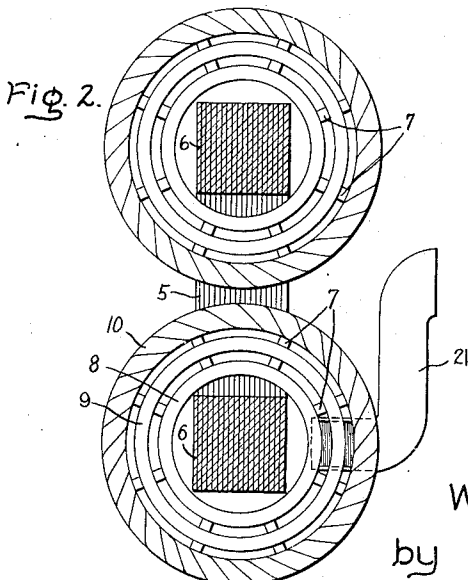
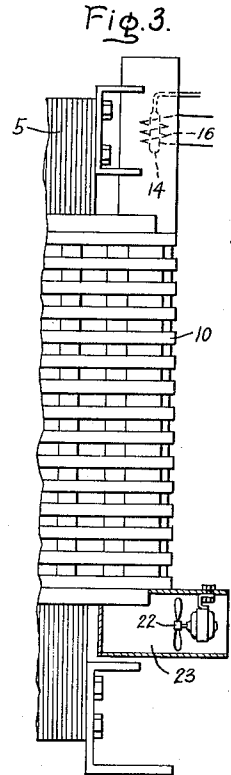
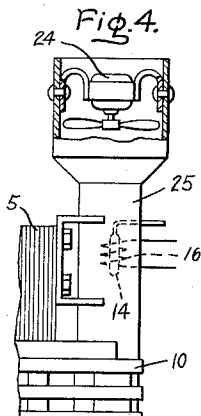
Aug. 28, 1956

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THERMAL PROTECTION FOR NATURAL AND FORCED
DRAFT DRY-TYPE TRANSFORMERS

2,761,101

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2 Sheets-Sheet 1



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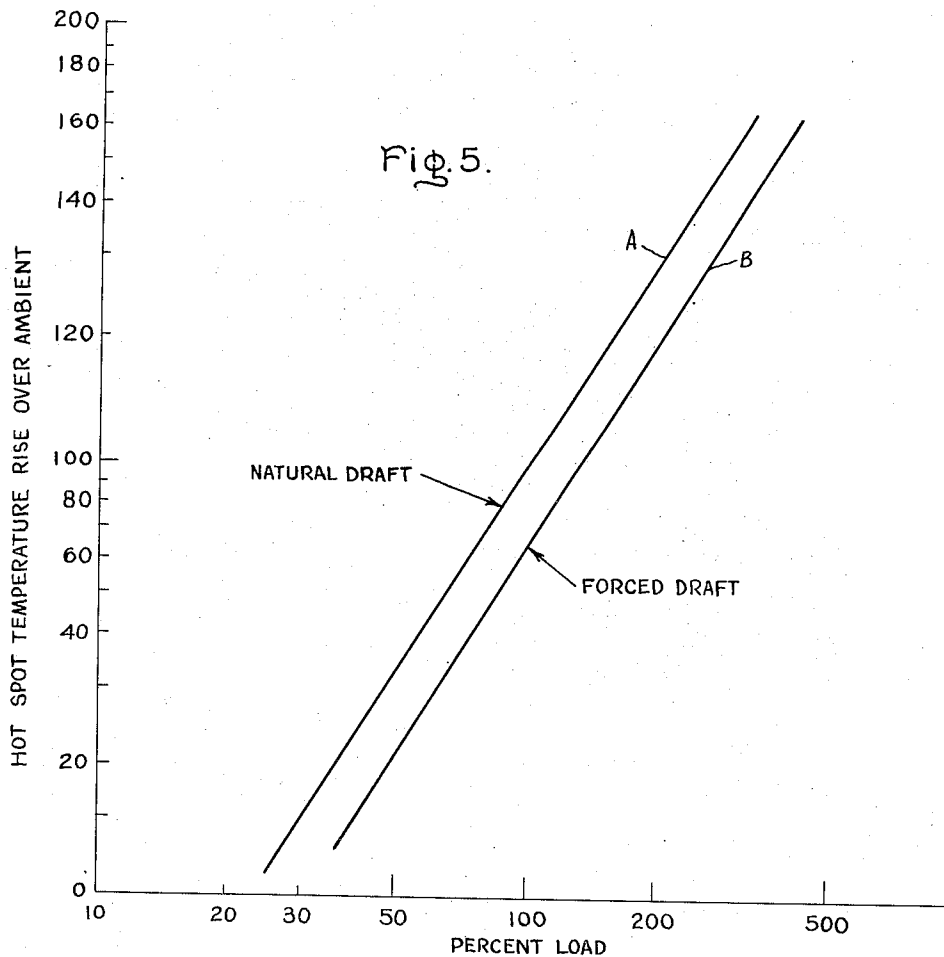
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THERMAL PROTECTION FOR NATURAL AND FORCED DRAFT DRY-TYPE TRANSFORMERS

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11 Claims. (Cl. 323—44)

This invention relates to stationary electrical induction apparatus and more particularly to temperature control devices for gas-cooled stationary electrical induction apparatus.

Certain types of gas-cooled stationary electrical induction apparatus, such as power transformers, are self-cooled at low loads, using the natural convection draft to provide circulation of the gas, while at higher loads the same transformer operates under forced cooling provided by suitably positioned electric fan gas circulating devices.

Hereinafter in this specification, the gaseous insulating medium will be referred to as air. However, it will be understood that this invention is equally applicable with any other type of gaseous insulating medium. Also, the stationary electrical induction apparatus with which our invention is used will be referred to as a transformer. However, it will be understood that our invention may be used with any type of stationary electrical induction apparatus.

Transformers of the forced-cooled type are provided with thermal indicators whose function it is to indicate correctly the hottest spot temperature of the winding under any condition of cooling, and to switch on cooling fans when a predetermined temperature has been reached. The hottest spot temperature of the winding under consideration is equal to the sum of the following temperatures: (a) ambient temperature (b) temperature rise of the air surrounding the windings over the ambient (c) maximum temperature rise of any part of the windings over the surrounding air. The temperature responsive device usually consists of a temperature responsive bulb containing an expansible fluid and an indicator operated by the change in volume of the fluid in the bulb. The indicator operates switches which are used to actuate cooling fans and to give an alarm when a predetermined temperature is exceeded.

In very low voltage transformers, the temperature responsive bulb can be located very nearly directly at the hot spot of one of the windings. The readings of the indicator in this case will be correct under all conditions of loading and methods of cooling.

In relatively high voltage transformers, it is necessary to insulate the bulb from the windings, and it is preferable in the case of high voltage transformers to use the indirect method of measuring the hot spot temperature of the transformer. By the indirect method of hot spot temperature measurement, the bulb of the indicator is inserted in a coil which is heated by a current furnished by the secondary winding of a current transformer, the primary of the current transformer being in series with one of the windings of the power transformer under discussion. In this way, the heating coil is energized in proportion to the load current on the transformer and, if the air circulation conditions about the heating coil are the same as about the transformer windings, the temperature sensitive element will give a good indication of the temperature condition of the transformer winding.

Dry type transformers have a supplementary higher

load rating when the gaseous cooling medium is forced through the windings since, for a given load, the hot spot temperature rise of one of the windings of the transformer is higher when the transformer is self-cooled than when it is forced cooled. Thus, for example, at 100 percent load, the hot spot temperature rise of one of the windings may be approximately 100 degrees centigrade, whereas for the same temperature rise over ambient under forced draft conditions, the load may be, for example, 133 per cent of full load. In order for the hot spot indicator to duplicate the temperature conditions under both natural draft and forced draft, it is necessary that the heating coil of the indicator be cooled in the same manner as the windings of the transformer.

One difficulty which has been observed in the case of temperature responsive devices used with transformers which are both self-cooled and forced cooled is that the temperature responsive device is sometimes unreliable under forced cooled conditions, and indicates higher than the true temperature. This is due to the fact that only a relatively small proportion of the air circulated by the fan normally reaches the heating coil of the temperature sensitive device, with the result that the temperature sensitive device indicates a temperature which is higher than the true temperature.

Accordingly, it is an object of this invention to provide an arrangement whereby the temperature indicator for an air cooled transformer will provide a correct temperature indication under both natural and forced draft conditions.

It is a further object of this invention to provide an arrangement whereby a temperature indicator which indirectly measures the hot spot temperature of a dry type transformer will provide correct temperature indications under both natural and forced draft conditions.

It is a still further object of this invention to provide an arrangement whereby a temperature responsive device used to indirectly measure the winding temperature of an air cooled transformer will be subjected to conditions which simulate the conditions at the windings under both natural and forced draft conditions.

In accordance with these objectives, this invention provides a duct arrangement by means of which a forced draft is conducted to the heating coil of the temperature sensitive element, such as a thermometer bulb in proportion to the forced cooling of the transformer in such manner that the temperature responsive device will correctly indicate the temperature conditions of the transformer under the forced draft condition as well as under the natural draft condition.

The features of this invention which we believe to be novel are set forth with particularity in the appended claims. Our invention itself, however, both as to its organization and use, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 represents an elevation view, partially cut away, of a transformer embodying a temperature indicating arrangement in accordance with our invention; Fig. 2 is a sectional view taken along line 2—2 of Fig. 1; Fig. 3 is an elevation view, partially cut away, of a modified temperature indicating arrangement using an auxiliary air circulating device in accordance with our invention; Fig. 4 is an elevation view, partially cut away, of a still further modification of our invention in which the auxiliary air circulating device is positioned in close proximity to the temperature-sensitive device; while Fig. 5 is a graph indicating the temperature rise over ambient temperature of a typical dry type transformer, under both natural and forced draft conditions.

Referring now to the drawing, there is shown in Fig. 1

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a dry type air insulated transformer indicated generally at 1 and enclosed in a casing 2 provided with louver openings 3 along its top and sides and unlouvered ventilation slots 4 in the lower part of the casing. The transformer comprises a magnetic core 5 having two winding legs 6. Upon each of the winding legs 6 are mounted a low voltage winding and a high voltage winding. The low voltage winding comprises two coaxial barrel type windings 8 and 9, with winding 8 being positioned radially inwardly of winding 9. The high voltage winding 10 is of the disk type and comprises a plurality of superposed disk like winding layers spaced radially outwardly of low voltage barrel winding 9. The layers of disk winding 10 are separated from each other in an axial direction by suitable radially extending spacer members. Insulating cylinders, not shown in the drawing, may be interposed between the respective low voltage barrel windings and between the radially outermost barrel winding and the disk type high voltage winding. Axially-extending spacer members 7 are positioned at circumferentially-displaced locations in the ducts between the respective barrel type windings and between the radially outermost barrel winding and the disk winding in order to radially space these respective windings from each other.

The low voltage and high voltage winding arrangements just described are duplicated on each of the winding legs 6. While we have shown a magnetic core with two winding legs, it is obvious that the number of winding legs is immaterial as far as the operation of our invention is concerned.

To provide forced draft cooling of the transformer windings, a fan 11 is positioned radially outwardly of the winding structure and is centrally located between the two winding legs on the transformer. The fan is energized by suitable power leads 12 and 13.

Means are provided for indirectly indicating the temperature of the transformer windings comprising a thermometer bulb 14 which is positioned above the low voltage and high voltage windings in such manner as to be influenced by the discharge air temperature from both the high and low voltage windings. While we have shown a temperature sensitive element of the bulb type, it will be understood that any other type of temperature sensitive element may be used. The temperature sensitive bulb 14 is positioned in a box-like air collector 15 which is open at both its upper and lower ends, and which has its lower end resting over the duct between low voltage windings 8 and 9 and also over the duct between the radially outer low voltage winding 9 and the disk winding 10. Thus, the temperature sensitive element is influenced by the temperature of the air coming from both the high voltage and low voltage air ducts. A heating coil 16 surrounds the bulb 14, coil 16 being in series with secondary winding of a current transformer 17, the primary of the current transformer being in series with the current from either the high or low voltage winding. The temperature sensitive bulb 14 is connected to a bellows member 18 which operates a switch 19 in such manner as to open and close contacts 20 in series with power supply line 12 to fan 11.

In order to insure a supply of cooling air to the heating coil of the temperature sensitive bulb 14 in proportion to the supply of cooling air provided to the transformer windings, we have provided in accordance with our invention a duct arrangement which conveys air to the heating coil of the temperature sensitive bulb whenever fan 11 is in operation. Duct 21 extends in a horizontal direction from a position intermediate of the two core legs 6, where it is provided with an inlet opening for air circulated by fan 11, to the bottom portion of the windings surrounding one of legs 6. Duct 21 is provided with an outlet adjacent the lower end of the axial duct between low voltage windings 8 and 9 and the axial duct between radially outer low voltage winding 9 and

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high voltage winding 10. Thus, the air which passes into the duct 21 at the opening adjacent fan 11 is carried by the duct 21 to the bottom edge of the axial ducts between the low voltage windings and between the radially outer low voltage winding and the high voltage winding in such manner as to feed the circulated air from the fan up into the axially-extending ducts between windings 8 and 9 and between windings 9 and 10. The circumferentially-displaced axially-extending spacer members 7 which are positioned along the respective axially-extending ducts in the region to which the outlet of duct 21 is connected aid in directing the flow of air through the axially-extending ducts between the windings directly to the air collector 15 at the upper end of the winding ducts. Thus the air passes up these axial ducts and impinges upon the heating coil of the temperature sensitive bulb 14.

There is shown in Fig. 3 a modified embodiment of our invention in accordance with which the heating coil of the temperature sensitive bulb is cooled by a small auxiliary fan 22, rather than by the large fan which cools the transformer windings. Fan 22 is positioned in a duct 23 at the bottom of the winding assembly and communicates with the lower end of the axial ducts between the respective windings in a manner similar to that described in connection with the embodiment of Fig. 1. The air circulated by fan 22 passes up through the axial ducts to the air collector at the top of the windings in the same manner as previously described in connection with Fig. 1. Auxiliary fan 22 is connected in parallel electrical relation with the large fan 11 which cools the windings. An auxiliary fan 22, such as is shown in Fig. 3, would ordinarily be used where it would be impractical to extend a duct, such as duct 21 of Figs. 1 and 2, to the intake position intermediate of the winding legs. Duct 23 extends only in a radially outward direction and is not provided with an extension running to the position intermediate of the winding legs, as in the embodiment of Figs. 1 and 2.

There is shown in Fig. 4 a still further modification of our invention in which an auxiliary fan 24 is positioned above and in communication with the top air collector 25. The fan 24 is connected in parallel electrical relationship with the large fan which cools the windings and operates whenever the large fan is in operation. Fan 24 causes a circulation of air about the heating coil of the temperature sensitive bulb in such manner as to simulate the circulation of air about the transformer windings caused by the large fan 11.

In the embodiments shown in Figs. 3 and 4 the speed of the fans 22 and 24 can be so calibrated as to correctly reproduce the air circulation conditions of the winding hot spot.

There is shown in Fig. 5 a graph in which hot spot temperature rise of the transformer windings over the ambient temperature is plotted logarithmically against per cent load. Curve A represents the temperature condition with natural draft, while curve B represents the temperature condition with forced draft. It will be noted that for a given load with natural draft the temperature rise of the transformer windings over ambient is always greater than with forced draft. If the indicator is initially calibrated to follow curve A and if the air collector placed at the top of the coil stack does not receive additional air from the cooling fans when the transformer is cooled by forced draft, then the indicator will essentially follow curve A and therefore its reading will be too high. Use of special cooling arrangements for the heating coil of the temperature sensitive device in accordance with our invention causes the device to indicate the correct temperature under both natural and forced draft conditions.

It can be seen that we have provided an arrangement to insure a circulation of air about the temperature sensitive element whenever the electrical windings themselves are being cooled by forced air circulation, thereby insur-

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ing that the heating coil of the temperature sensitive element will be subjected to the same air circulation conditions as the windings. This insures that the hot spot temperature indication given by the temperature sensitive device will properly reproduce the hot spot temperature conditions of the windings.

While there have been shown and described particular embodiments of our invention, it will be obvious to those skilled in the art that 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 our invention.

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

1. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and a plurality of radially-displaced electrical windings on said core and axially-extending ducts between adjacent windings, with fan means positioned radially outwardly of said windings for directing said gas against said windings, means for indirectly indicating the temperature of said windings comprising a temperature sensitive element positioned above said windings in communication with a portion of said ducts between said windings, a heating coil in thermal communication with said temperature sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, with flow directing means for separately directing a forced gas flow toward said heating coil so that the gas flow through said portion of said ducts in communication with said temperature sensitive element is greater than the gas flow through other portions of said ducts whenever said fan means is in operation, said flow directing means including a conduit positioned in flow directing relationship with respect to said temperature sensitive element for conveying said gas flow to said heating coil.

2. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and a plurality of radially-displaced electrical windings on said core and axially-extending ducts between adjacent windings, with fan means positioned radially outwardly of said windings for directing said gas against said windings, means for indirectly indicating the temperature of said windings comprising a temperature sensitive element positioned above said windings in communication with a portion of said ducts between said windings, a heating coil in heat exchange relation with said temperature sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, a conduit means having an opening into which gas is directed by said fan means, said conduit means positioned at least in flow directing relationship with respect to said temperature sensitive element and extending from closely adjacent said fan means into communication with said axially-extending ducts between said windings so that the gas flow through said portion of said ducts in communication with said temperature sensitive element is greater than the gas flow through other portions of said ducts whenever said fan means is in operation, said axially-extending ducts communicating said gas flow from said conduit means to said heating coil.

3. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and at least one low voltage electrical winding and at least one high voltage electrical winding positioned on said core in radially-displaced relation with respect to each other, with axially-extending ducts between successive radially-displaced windings, and gas circulating means positioned radially outwardly of said winding for directing said gas against said windings, means for indirectly indicating the temperature of said windings, comprising a gas collector positioned above said windings, one end of said gas

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collector being in communication with a portion of at least one of said axially-extending ducts the opposite end of said gas collector being open to permit free passage of gas therethrough, a temperature sensitive element positioned interiorly of said gas collector in heat exchange relation with gas passing through said collector, a heating coil in heat exchange relation with said temperature sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, with flow directing means for separately directing a forced gas flow toward said heating coil so that the gas flow through said portion of said one duct is greater than the gas flow through other portions of said one duct whenever said gas circulating means is in operation, said flow directing means including a conduit positioned in flow directing relationship with respect to said gas collector for conveying said gas flow to said heating coil.

4. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and at least one low voltage electrical winding and at least one high voltage electrical winding positioned on said core in radially-displaced relation with respect to each other, with axially-extending ducts between successive radially-displaced windings, and gas circulating means positioned radially outwardly of said winding for directing said gas against said windings, means for indirectly indicating the temperature of said windings, comprising a gas collector positioned above said windings, one end of said gas collector being in communication with a portion of at least one duct leading to a high voltage winding and a portion of at least one duct leading to a low voltage winding, the opposite end of said gas collector being open to permit free passage of gas therethrough, a temperature sensitive element positioned interiorly of said gas collector in heat exchange relation with gas passing through said collector, a heating coil in heat exchange relation with said temperature sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, with flow directing means for separately directing a forced gas flow toward said heating coil so that the gas flow through said portions of said one high voltage winding duct and one low voltage winding duct is greater than the gas flow through other portions of said ducts whenever said gas circulating means is in operation, said flow directing means including a conduit positioned in flow directing relationship with respect to said gas collector for conveying said gas flow to said heating coil.

5. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and at least one low voltage electrical winding and at least one high voltage electrical winding positioned on said core in radially-displaced relation with respect to each other, with axially-extending ducts between successive radially-displaced windings, and fan means positioned radially outwardly of said windings for directing said gas against said windings, means for indirectly indicating the temperature of said windings, comprising a gas collector positioned above said windings, one end of said gas collector being in communication with a portion of at least one of said axially-extending ducts, a temperature sensitive element positioned interiorly of said gas collector in heat exchange relation with gas passing through said collector, a heating coil in heat exchange relation with said temperature sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, a conduit means having an opening into which gas is directed by said fan means, said conduit means positioned in flow directing relationship with respect to said gas collector and extending from closely adjacent said fan means into communication with the lower end of said axially-extending ducts between said windings so that the gas flow through said portion of said at least one duct is greater than the gas

flow through other portions of said at least one duct when said fan means is in operation, said axially-extending ducts communicating said gas flow from said conduit means to said heating coil.

6. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and at least one low voltage electrical winding and at least one high voltage electrical winding positioned on said core in radially-displaced relation with respect to each other, with axially-extending ducts between successive radially-displaced windings, and gas circulating means positioned radially outwardly of said winding for directing said gas against said windings, means for indirectly indicating the temperature of said windings, comprising a gas collector positioned above said windings, one end of said gas collector being in communication with a portion of at least one of said axially-extending ducts, a temperature-sensitive element positioned interiorly of said gas collector in heat exchange relation with gas passing through said collector, a heating coil in heat exchange relation with said temperature-sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, with auxiliary fan means positioned in flow directing relationship with respect to said gas collector for separately directing a forced gas flow toward said heating coil whenever said gas circulating means is in operation so that the gas flow through said portion of said at least one duct is greater than the flow through other portions of said at least one duct whenever said gas circulating means is in operation.

7. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and at least one low voltage electrical winding and at least one high voltage electrical winding positioned on said core in radially-displaced relation with respect to each other, with axially-extending ducts between successive radially-displaced windings, and gas circulating means positioned radially outwardly of said winding for directing said gas against said windings, means for indirectly indicating the temperature of said windings, comprising a gas collector positioned above said windings, one end of said gas collector being in communication with a portion of at least one of said axially-extending ducts, a temperature-sensitive element positioned interiorly of said gas collector in heat exchange relation with gas passing through said collector, a heating coil in heat exchange relation with said temperature-sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, with auxiliary fan means for separately directing a forced gas flow toward said heating coil whenever said gas circulating means is in operation, said auxiliary fan means being positioned adjacent the lower end of said windings, with conduit means positioned in flow directing relationship with respect to said gas collector for conducting gas flow from said auxiliary fan means to an axially-extending duct in communication with said gas collector so that the gas flow through said portion of said at least one duct in communication with said gas collector is greater than the gas flow through other portions of said at least one duct when said fan means is operating.

8. In a stationary electrical induction apparatus cooled by an insulating gas and having a magnetic core and at least one low voltage electrical winding and at least one

high voltage electrical winding positioned on said core in radially-displaced relation with respect to each other, with axially-extending ducts between successive radially-displaced windings, and gas circulating means positioned radially outwardly of said winding for directing said gas against said windings, means for indirectly indicating the temperature of said windings, comprising a gas collector positioned above said windings, one end of said gas collector being in communication with a portion of at least one of said axially-extending ducts, a temperature-sensitive element positioned interiorly of said gas collector in heat exchange relation with gas passing through said collector, a heating coil in heat exchange relation with said temperature-sensitive element, means for energizing said heating coil in proportion to the load current of said stationary electrical induction apparatus, with auxiliary fan means for separately directing a forced gas flow toward said heating coil whenever said gas circulating means is in operation, said auxiliary fan means being positioned above said windings in flow directing relationship with respect to said gas collector so that the gas flow through said portion of said at least one axially extending duct is greater than the gas flow through other portions of said at least one axially extending duct when said gas circulating means is operating.

9. An electrical apparatus cooled by an insulating gas, said apparatus having a component which contains cooling duct means extending therethrough, said component normally being subject to temperature variations, fan means positioned adjacent said component and adapted for directing said gas against said component and into said duct means, means for indirectly indicating the temperature of said component comprising a temperature-sensitive element positioned above said component and in communication with a portion of said duct means, a heating coil in thermal communication with said temperature-sensitive element, means for energizing said heating coil in proportion to the load current of said apparatus, and flow-directing means for directing a forced gas flow toward said heating coil whenever said fan means is in operation, said flow-directing means including a conduit positioned in flow directing relationship with respect to said temperature sensitive element for conveying said forced gas flow to said heating coil and being arranged so that the gas flow through said portion of said duct means in communication with said temperature sensitive element is greater than the gas flow through other portions of said duct means.

10. The apparatus of claim 9 being further characterized by said conduit extending from closely adjacent said fan means into communication with said duct means.

11. The apparatus of claim 9 being further characterized by said temperature indicating means comprising a gas collector positioned about said temperature-sensitive element, and said gas collector being in communication with said duct means.

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