

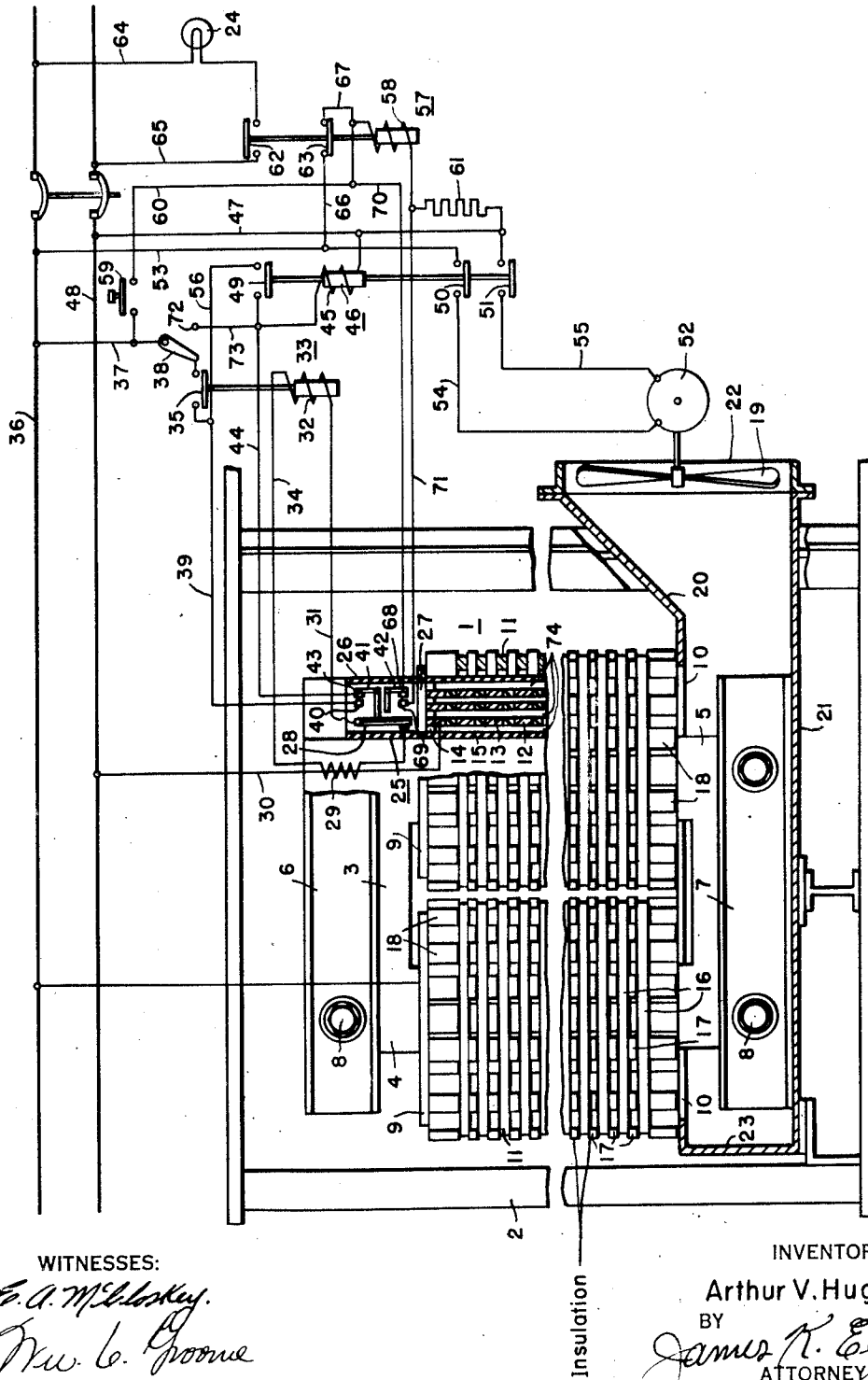
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TRANSFORMER COOLING SYSTEM CONTROL

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TRANSFORMER COOLING SYSTEM
CONTROL

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The invention relates to transformers, and, more particularly, to means for protecting air-cooled, air-insulated transformers, from excessive temperatures.

In Patent No. 2,223,530 issued to H. V. Putnam and assigned to the same assignee as the present application, protective means is provided for electrical apparatus such as a transformer, the protective means including a control device responsive to predetermined operating conditions of the apparatus. More specifically, the control device operates to actuate an indicating device when the operating condition of the transformer has attained a predetermined value and operates to disconnect the transformer from the line when the operating condition of the transformer has attained a slightly higher predetermined value. Such protective device is commonly employed in oil-cooled transformers.

Where attempts have been made to employ such protective devices in air-cooled transformers to control the operation of a cooling fan, it has been found that the thermal variations encountered produced an irregular operation of the cooling fan. For example, if a transformer is operating under overload conditions, the thermally responsive means, which is ordinarily a bimetal element incorporated within the control device, will operate to move in a predetermined direction for actuating the fan. The operation of the fan will impart a cooling effect not only to the winding of the coils, but also to the thermally responsive device, thereby effecting an actuation of the bimetal element in the opposite direction to effect the deenergization of the fan. Since the transformer will not have been sufficiently cooled by the short operation of the fan, the thermally responsive device will immediately be actuated once more to its predetermined position for again effecting the operation of the fan. This cycle of operation will, therefore, continue indefinitely, resulting in the improper operation of the device thereby reducing the effectiveness of the forced cooling and increasing the switching duty on the circuit controlling contact members.

An object of the invention is to provide an air-cooled, air-insulated electrical transformer having protective means including a control device operative in response to predetermined conditions of the transformer for selectively actuating a plurality of safety and indicating devices disposed for preventing damage to and indicating operating conditions of the transformer.

Another object of the invention is to provide

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protective means for air-cooled, air-insulated electrical transformers, including a control device operative in response to predetermined conditions of the transformer for actuating a cooling means upon the occurrence of a predetermined operating condition of the transformer and thereafter actuating a signalling device upon the occurrence of other predetermined operating conditions of the transformer.

A further object of the invention is to provide an air-cooled, air-insulated electrical transformer having protective means, including a control device responsive to operating conditions of the transformer to control the sequential operation of a plurality of contactors and thereby control the operation of a cooling device and indicating means associated with the transformer and to provide for thereafter maintaining the contactors in operating position independently of the operation of the control device in response to the operation of the cooling device.

Other objects of the invention will become apparent from the following description when taken in conjunction with the accompanying drawing, the single figure of which is a view in side elevation and partly in section and partly diagrammatic, of apparatus and circuits illustrating an embodiment of this invention.

Referring to the drawing, this invention is illustrated by reference to an air-cooled, air-insulated transformer 1 which is of the general construction described and claimed in Patent No. 2,295,415 to G. R. Monroe, issued September 8, 1942, and assigned to the same assignee as this application. As illustrated, the transformer comprises a casing 2 which may have wire mesh side walls (not shown) for providing free access of the surrounding air to contact a core structure 3 and winding structure thereon, disposed within the casing. The core structure 3 is provided with two vertically positioned winding legs 4 and 5 connected by two horizontal yoke portions clamped between channel members 6 at the top of the structure and between channel members 7 at the bottom of the structure, respectively, and held in position by bolts 8 for clamping the channel members together. A pair of upper pressure plates or rings 9 and a pair of lower support members 10, respectively, are provided for assisting in holding a high-voltage winding 11 and a low-voltage winding 12 disposed internally thereof in their proper positions about the winding legs 4 and 5 of the core structure 1. The rings 9 and support members 10 are of a spider construction (not shown) to facilitate pas-

sage of air therethrough to and from the windings 12 and 11.

The low-voltage winding 12 comprises a plurality of cylindrical coils 13 separated by spacers 14 and wound about a central tube 15, the tube 15 and coils 13 extending from the lower support members 10 to the upper pressure plates 9. The high-voltage winding 11 comprises a plurality of flat or disk-type coils 16 separated by spacers 17 of insulating material, such as porcelain, the spacers 17 being arranged in vertical columns between adjacent coils and the spacers 16 being arranged in horizontal rows between adjacent coils. The spacers 17 and 14 are spaced about the circumference of the windings 11 and 12, respectively, in a manner to provide openings in the windings 11 and 12 radially between the adjacent coils, the spacers 14 providing openings 14 between the coils 13 of the winding 12 which extend from the lower support members 10 to the upper pressure plates 9 for permitting the free movement of air currents upwardly between the coils 13. The windings 11 are positioned between blocks 18 between the support members 10 and the lower end of the windings 11 and between the pressure rings 9 and the upper end of the windings 11 to assist in clamping the coils of the windings 11 firmly in place between the members 5 and 10.

In order to provide for forced cooling of the core and coil assembly, a fan 19 is disposed at one end of a housing 20 for operation when the transformer 1 is operating under a predetermined overload condition. As illustrated, the housing 20 is positioned beneath the coil assembly of the transformer 1, the upper horizontal surface of the housing 20 constituting the support members 10 extending below the coil assembly for supporting the coil assembly as described hereinbefore, the lower horizontal surface of the housing 20 constituting a lower plate member 21 for supporting the channel member 7, one end of the housing 20 terminating in an opening 22 for receiving the fan 19, the housing 20 being enclosed by supporting side walls 23. The plate member 21 is formed with a central opening (not shown) for receiving the lower ends of the winding legs 4 and 5 of the core structure 3, as viewed in the drawing, this opening in cooperation with the spider construction (not shown) of the plate 10 permitting air currents forced upwardly by operation of the fan 19 to enter into the region occupied by the coil assembly for circulation thereabout to cool the coil assembly.

In order to control the operation of the fan 19, which is disposed for actuation upon the occurrence of a predetermined operating condition of the transformer 1 for cooling the coil assembly thereof, and to also control the operation of a signalling device 24, which may be a light, bell or other suitable device disposed for actuation thereafter to indicate predetermined operating conditions of the transformer 1, a control device 25 is disposed within a casing 26 which is preferably mounted atop the coil assembly of the transformer 1 on one of the pressure plates 9 and over one of the spider openings 21 therein. The control device 25 is of the general construction of and operates similarly to the device described and claimed in Patent No. 2,169,586 to M. G. Leonard, issued August 15, 1939, and assigned to the same assignee as this application.

A thermally responsive bimetal element 28 is included in the control device 25 and comprises

a part of a circuit which extends from one terminal of a current transformer 29 disposed in inductive relation with a conductor 30 of the load circuit of the transformer 1, through the bimetal 28, conductor 31, the energizing winding 32 of a relay 33, and conductor 34 to the other terminal of the current transformer 29. The bimetal 28 is responsive to both the predetermined heating effects of current induced in the winding of the current transformer 29, which is a measure of current flowing in the load circuit of the transformer 1, and the predetermined temperatures of air currents which move upwardly from the coil assembly of the transformer 1 into the casing 26 of the control device 25.

The heating of the bimetal 28 due to current flow therethrough that is proportional to the load current on the transformer 1 reflects immediately in the control device 25 any change in the loading of the transformer 1 which might overheat and endanger the transformer 1. Thus the bimetal 28 is disposed for movement to predetermined positions to the right when the low-voltage winding 12 has become overheated by the presence of dangerous overloads on the transformer 1 which cause currents of heated air to rise upwardly between the coils 13 into the casing 26 of the thermally responsive control device 25.

In order to provide for proper operation of the fan 19, the energizing winding 32 of the relay 33 is included in the circuit described hereinbefore. The winding 32 is, therefore, responsive to current which is proportional to the load current of the transformer 1 and is designed and adapted to be so energized thereby when the load current of the transformer 1 attains a value slightly higher than the value of the rated full load current of the transformer 1 as to actuate the contact member 35 thereof to a circuit closing position. When the contact member 35 is actuated to the circuit closing position, a circuit is established which extends from the power line conductor 36 through conductor 37, an automatic-manual selector switch 38 shown as being in the automatic position, contact member 35, and conductor 39 to a fixed contact member 40 of the control device 25.

In order to control the sequential operation of a plurality of contactors to thereby control the operation of the fan 19 and the signal device 24, a pair of pivotally mounted switch operating members 41 and 42 are included in the control device 25 within the casing 26. The member 41 is disposed to be engaged by the bimetal 28 upon the occurrence of a predetermined movement of the bimetal 28 to the right to effect movement of the free end of the member 41 to the left. A contact member 43 carried by the member 41 at the free end thereof is thereby moved into engagement with a cooperating fixed contact member 40 for establishing a circuit extending from power line conductor 36 through conductor 37, switch 38, contact member 35, conductor 39, contact members 40 and 43, conductor 44, the energizing winding 45 of a contactor 46 and conductor 47 to the power line conductor 48. The winding 45 of the contactor 46 is, therefore, connected across the power line conductors 36 and 48 and is thereby energized to simultaneously effect movement of a plurality of contact members 49, 50 and 51 thereof to circuit closing positions.

Movement of the contact members 50 and 51 to circuit closing positions effects energization of the fan motor 52 through a circuit extending

from power line conductor 36 through conductor 53, contact member 50, conductor 54, fan motor 52, conductor 55, contact member 51 and conductor 47, to the power line conductor 43, thus effecting the energization of the fan motor 52 to operate the fan 19. Movement of the contact member 49 effects establishment of a holding circuit for the winding 45 of the contactor 46 which is disposed to thereafter maintain the energization of the fan motor 52. Such holding circuit extends from the power conductor 36, through conductor 37, switch 38, contact member 35, conductor 56, contact member 49, energizing winding 45 of contactor 46 and conductor 47 to the line conductor 48.

The holding circuit is necessary for the effective operation of the protective device for, as the fan 19 begins operation, air is forced upwardly thereby from the housing 20 and is circulated about the area occupied by the overheated low-voltage windings 12 to force the air heated by the windings 12 upwardly into the casing 26 for not only cooling the low-voltage windings 12 but for also cooling the thermally responsive bimetal element 28. It is readily apparent that such a result is inevitable, for the air actuated by the fan 19 rises upwardly from the low-voltage windings 12 into the casing 26 to effect such cooling of the bimetal element 28. The thermal action of the cooler air on the bimetal element 28 tends to cause the bimetal element 28 to operate to reverse the initial sequence of operations whereby the free end of the switch operating member 41 tends to move to the right to disengage the contact members 40 and 43 and interrupt the energizing circuit for the energizing winding 45 of the contactor 46. However, since the holding circuit for the energizing winding 45 has been established, the contactor 46 is maintained in its energized circuit closing position to thereafter maintain operation of the energizing circuit for the fan motor 52 independently of the position of the bimetal element 28. However, when the load current on the transformer 1 is reduced to a predetermined value which permits safe operation of the transformer 1, the current flow through the winding 32 of the relay 33 is insufficient to maintain the relay 33 in a circuit closing position and the contact member 35 drops to a circuit interrupting position to interrupt the holding circuit for the winding 45 of contactor 46.

In order to control the operation of the signal device 24 another contactor 57 having an energizing winding 58 is included in the control circuits for the protective means. When the transformer 1 is initially "set up" for operation, the winding 58 is placed in a normally energized condition by manual actuation of a start-reset switch 59 to a circuit closing position for establishing a circuit extending from line conductor 36 through conductor 37, switch 59, conductor 60, winding 58 of the contactor 57, resistor 61 and conductor 47 to line conductor 43 to thereby connect the winding 58 across the line conductors 36 and 43 for energizing the winding 58. Such energization of the winding 58 effects the movement of a pair of contact members 62 and 63 of the contactor 57 to circuit interrupting and circuit closing positions, respectively. Movement of contact member 62 to a circuit interrupting position interrupts a signal circuit extending from line conductor 36 through conductor 64, signal device 24, contact member 62 and conductor 65 to line conductor 48 to thereby

maintain the signal device 24 in an inoperative condition until predetermined operating conditions of the transformer 1 effect the energization thereof. Movement of contact member 63 to a circuit closing position establishes a circuit extending from line conductor 36 through conductors 53 and 66, contact member 63, conductor 67, winding 58 of the contactor 57, resistor 61 and conductor 47 to line conductor 43 to thereby maintain the energization of the winding 58 of the contactor 57 until such time when operating conditions of the transformer 1 effect de-energization of the winding 58 for effecting the energization of the signal device 24 by means of an operation which will be described hereinafter.

In order to effect the deenergization of the contactor 57, the pivotally mounted switch operating member 42 is disposed to be actuated by a further predetermined movement of the bimetal 28 to the right for effecting movement of the free end of the member 42 to the left. A contact member 68 carried by the pivoted member 42 at the free end thereof is thereby moved into engagement with a fixed contact member 69. The engagement of contact members 68 and 69 establishes a circuit extending from power line conductor 36 through conductors 53 and 66, contact member 63 normally disposed in the circuit closing position as described hereinbefore, conductors 67 and 70, closed contact members 68 and 69, conductor 71, resistor 61 and conductor 47 to power line conductor 43. This circuit is disposed for shunting the normally energized winding 58 of the contactor 57 to effect the de-energization of the winding 58, thereby causing contact members 63 and 62 to drop to circuit interrupting and circuit closing positions, respectively. Movement of contact member 62 to the circuit-closing position establishes the signal circuit for energizing the signal device 24, and movement of the contact member 63 to the circuit interrupting position interrupts the energizing circuit for the energizing winding 58 of the contactor 57 to thereafter maintain the deenergization of the winding 58 and the energization of the signal device 24. When it is desired to deenergize the signal device 24, the switch 59 may be manually actuated to the circuit closing position as was described hereinbefore.

A brief description of operation of the protective device will serve to illustrate the advantages thereof. Assuming that the transformer load has increased to a value slightly above the rated full load value of the apparatus and that the protective device is properly "set up" for normal operation, that is, the automatic-manual switch 38 has been manually actuated to the automatic position and the start-reset switch 59 has been manually actuated to a position for energizing the winding 58 of the contactor 57, the winding 32 of the relay 33 is so energized by a current flowing therethrough which is proportional to the load current of the transformer 1 as to actuate the contact member 35 to a circuit closing position.

As the load on the transformer 1 increases, air heated by the overloaded low-voltage windings 12 rises into the casing 26 and, by thermal action, effects movement of the bimetal element 28 toward the switch operating member 41 for engagement therewith to move the contact member 43 into engagement with the contact member 49, thereby establishing the energizing circuit for the winding 45. Such operation effects the

movement of contact members 40, 50 and 51 to circuit closing positions for simultaneously establishing the holding circuit for the winding 45 and the energizing circuit for the fan motor 52, respectively.

As the fan motor 52 begins operation, the fan 19 is rotated thereby for forcing air currents upwardly from the housing 23 into the casing 28 of the control device 25 to thereby effect a cooling of the bimetal element 29 by thermal action for moving the bimetal 28 away from the member 41 whereby the contact member 43 is actuated to a circuit interrupting position. The fan motor 52 continues to operate the fan 19, however, since the holding circuit for the winding 45 has been established to maintain the energization of the winding 45 of the contactor 43 to thereby maintain the energizing circuit for the fan motor 52 independently of the position of the bimetal element 29.

When the load current on the transformer 1 decreases to a safe predetermined value, the winding 32 of the relay 33, is so deenergized as to actuate the contactor 35 thereof to a circuit interrupting position to interrupt the holding circuit for the winding 45 of the contactor 43 thus causing the contact members 50 and 51 thereof to drop for interrupting the energizing circuit for the fan motor 52 whereby operation of the fan 19 is discontinued.

If for any reason the fan 19 fails to operate, or is operating inefficiently, the low-voltage winding 12 continues to heat up, resulting in a movement of the bimetal element 29 to a predetermined position further to the right for engaging the switch operating member 42 to move the contact member 38 carried thereby into engagement with the fixed contact member 39. Engagement of contact members 38 and 39 effects the establishment of the circuit which shunts the normally energized winding 58 of the contactor 57 to effect the deenergization of the winding 52 whereby the contact members 63 and 62 drop to circuit interrupting and circuit closing positions, respectively, for simultaneously interrupting the holding circuit for the winding 58 and establishing the circuit disposed for energizing the signal device 24. The signal device 24 reveals to anyone in the vicinity the fact that the transformer 1 is overloaded and that the load should be reduced or the transformer should be disconnected from the line and replaced by one having a higher rating. If the transformer 1 is disconnected, the signal device 24 may be made inoperative only by manual actuation of the start-reset switch 59 to the reset position, which operation establishes the circuit disposed for energizing the winding 58 whereby the contact members 62 and 63 are actuated simultaneously to effect the interruption of the signal circuit and the establishment of the holding circuit for the winding 58, respectively.

If it is found necessary to operate the fan 19 in an emergency situation such as, for example, in the event of failure of operation of the relay 33 or the bimetal element 29, or the indicating device 24, the automatic-manual switch 34 may be manually actuated to a position where it engages a fixed contact member 72. Such actuation of the switch 38 effects the establishment of a circuit extending from power line conductor 35 through conductor 37, switch 38, conductor 73, winding 45 of the contactor 43 and conductor 47 to line conductor 48 to thereby energize the winding 45 for effecting the establishment of the energizing circuit for the fan motor 52.

Advantages of the protective means are apparent from the description of operation of the device. For example, if it be so desired, a transformer may be operated under overload conditions for a considerable time without danger of overheating the coil assembly. Such operation is made possible by means of operation of the control device 25 and the protective circuits associated therewith to operate the fan 19 for cooling the coil assembly when the load becomes excessive. The holding circuit for the winding 45 of the contactor 43 is disposed for maintaining operation of the fan motor 52 independently of the position of the bimetal element 29 to prevent a rapid cycling or hunting of the fan 19 caused by alternating movement of the bimetal 29, thereby reducing the switching duty on the contact members and increasing the efficiency of the forced air cooling. If the fan 19 fails to operate, or is operating inefficiently, or if the energizing winding 58 of the contactor 57 becomes deenergized by means of failure of the winding 52 or failure of the power lines 38 and 43, the signal device 24 is energized to warn of impending danger to or of the failure of the apparatus and remains in such condition until the start-reset switch 59 is manually actuated to a circuit closing position. The fan 19 may be turned on at any time, if so desired, by manual actuation of the automatic-manual switch 34. This feature of the protective device provides for operation of the fan 19 in the event of failure of the bimetal element 29, the relay 33 or any part of the circuit not associated with the circuit operable upon such actuation of the switch 38. Many modifications of the structure illustrated and described may be made within the spirit of the invention.

I claim as my invention:

1. In electrical apparatus, the combination of a housing, a transformer core and coil assembly disposed therein, air cooling means disposed for operation to effect the cooling of the coil assembly, a signalling means disposed for operation for indicating a predetermined overload operating condition of the transformer, a control device disposed to be operated in response to predetermined temperatures of air currents rising from the coil assembly and predetermined heating effects of current flowing through the coils of the transformer, the control device including a thermally responsive means disposed for movement through two switching positions in response to variations in said temperatures and heating effects, a relay disposed to be energized in response to a predetermined flow of current through the coils and to be deenergized when the current flow through the coils decreases to a value below said predetermined flow of current, a contact member disposed to be actuated to a circuit closing position upon the occurrence of a predetermined movement of the thermally responsive means to one of said switching positions, a cooling means contactor disposed to be energized to effect the operation of the cooling means only after the relay is energized and said contact member is actuated to circuit closing position, the relay when energized cooperating with said contactor to thereafter effect the energization of the cooling means independently of movement of the thermally responsive means and when deenergized cooperating with said contactor to deenergize the cooling means, another contact member disposed to be actuated upon the occurrence of a further predetermined movement of the thermally respon-

sive means to the other of said switching positions, a normally energized signalling contactor disposed for operation in response to the actuation of said another contact member to effect the operation of the signalling means, said another contact member being disposed when actuated to effect the deenergization of the signalling contactor to thereby effect the operation of the signalling means independently of further movement of the thermally responsive means, and switch means disposed to be manually actuated for operation to energize the signalling contactor to effect the discontinuation of operation of the signalling means.

2. In electrical apparatus, the combination of a housing, a transformer core and coil assembly disposed therein, air cooling means disposed for operation to effect the cooling of the coil assembly, a signalling means disposed for operation for indicating a predetermined overload operating condition of the transformer, a control device disposed to be operated in response to predetermined temperatures of air currents rising from the coil assembly and predetermined heating effects of current flowing through the coils of the transformer, the control device including a thermally responsive means disposed for movement through two switching positions in response to variations in said temperatures and heating effects, a relay disposed to be energized in response to a predetermined flow of current through the coils and to be deenergized when the current flow through the coils decreases to a value below said predetermined flow of current, a contact member disposed to be actuated to a circuit closing position upon the occurrence of a predetermined movement of the thermally responsive means to one of said switching positions, a cooling means contactor disposed to be energized to effect the operation of the cooling means only after the relay is energized and said contact member is actuated to circuit closing position, the relay when energized cooperating with said contactor to thereafter effect the energization of the cooling means independently of movement of the thermally responsive means and when deenergized cooperating with said contactor to deenergize the cooling means, another contact member disposed to be actuated upon the occurrence of a further predetermined movement of the thermally responsive means to the other of the switching positions, a normally energized signalling contactor disposed for operation in response to the actuation of said another contact member to effect the operation of the signalling means, said another contact member being disposed when actuated to effect the deenergization of the signalling contactor to thereby effect the operation of the signalling means independently of further movement of the thermally responsive means, switch

means disposed to be manually operated to control the energization of the cooling means contactor independently of the energization of the relay and the actuation of said contact member, and another switch means disposed to be manually actuated for operation to energize the signalling contactor to effect the discontinuation of operation of the signalling means.

3. In electrical apparatus, the combination of a housing, a transformer core and coil assembly disposed therein, air cooling means disposed for operation to effect the cooling of the coil assembly, a signalling means disposed for operation for indicating a predetermined overload operating condition of the transformer, a control device disposed to be operated in response to predetermined temperatures of air currents rising from the coil assembly and predetermined heating effects of current flowing through the coils, the control device including a thermally responsive means disposed for movement through two switching positions in response to variations in said temperatures and heating effects, a relay disposed to be energized in response to a predetermined flow of current through the coils and to be deenergized when the current flow through the coils decreases to a value below said predetermined flow of current, a contact member disposed to be actuated to a circuit closing position upon the occurrence of a predetermined movement of the thermally responsive means to one of said switching positions, a contactor disposed to be energized to effect the operation of the cooling means only after the relay is energized and said contact member is actuated to circuit closing position, the relay when energized cooperating with said contactor to thereafter effect the energization of the cooling means independently of movement of the thermally responsive means and when deenergized cooperating with said contactor to deenergize to cooling means, another contact member disposed to be actuated to a circuit closing position upon the occurrence of a further predetermined movement of the thermally responsive means to the other of said switching positions, and a signalling contactor disposed for operation in response to the actuation of said another contact member to effect the operation of the signalling means.

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