

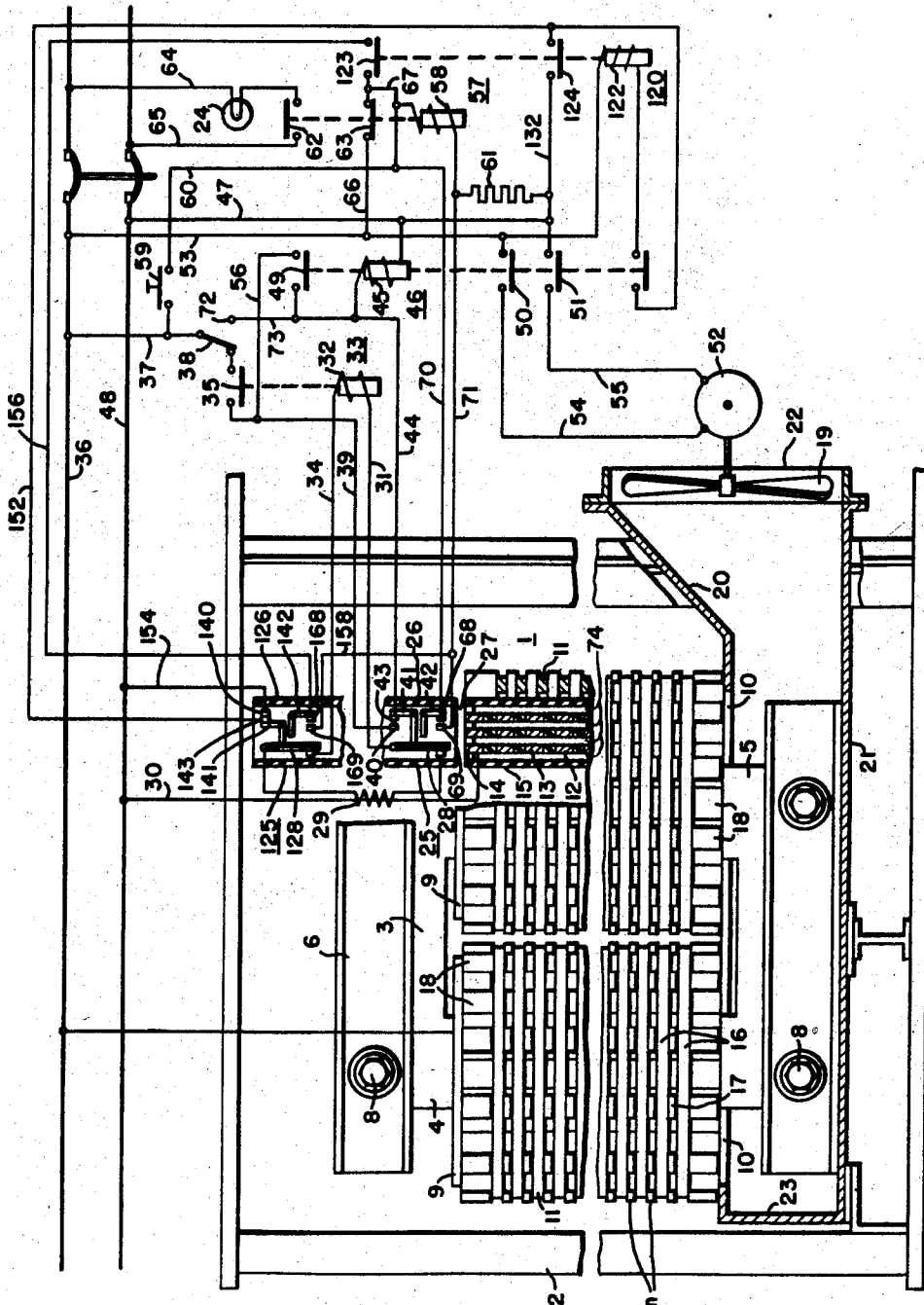
July 21, 1959

R. L. SCHWAB

2,896,152

TRANSFORMER COOLING SYSTEM CONTROL

Filed March 7, 1958



WITNESSES

*John C. Hensley, Jr.*  
*Clement L. Mc Hale*

INVENTOR

Richard L. Schwab

BY

*F. E. Browder*  
ATTORNEY

1

2,896,152

## TRANSFORMER COOLING SYSTEM CONTROL

Richard L. Schwab, Hickory Township, Mercer County, Pa., assignor to Westinghouse Electric Corporation, East Pittsburgh, Pa., a corporation of Pennsylvania

Application March 7, 1958, Serial No. 719,808

8 Claims. (Cl. 323—44)

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

In Patent No. 2,640,101, issued to A. V. Hughes, and assigned to the same assignee as the present application, protective means is provided for electrical apparatus, such as an air-cooled transformer, the protective means including a control device operative in response to predetermined conditions of the transformer for actuating cooling means upon the occurrence of a predetermined operating condition and thereafter actuating a signalling device upon the occurrence of other predetermined operating conditions of the transformer, such as the failure of the cooling means to operate or when the cooling means is operating inefficiently. More particularly, the control device is responsive to both the predetermined heating effects of current flowing in the windings of the transformer and the predetermined temperatures of air currents which pass over the windings of the transformer. A disadvantage of the above protective means is that it does not include means for actuating the signalling device during periods when the cooling means is operating. This is because the temperatures to which the control device in the above protective means responds to actuate the signalling device during self-cooled operation are higher than the temperatures to which the control device responds to actuate the cooling means. In order to provide suitable means for actuating the signalling device during periods in which the cooling means is operating, the means for actuating the signalling device must respond to temperature during the latter periods which are less than the temperatures to which the control device in the above protective means responds to actuate the cooling means. This is because the cooling means imparts a cooling effect not only to the windings of the transformer but also to any thermally responsive control device included in a protective means. It is therefore desirable to provide protective means for a transformer of the type described for controlling the operation of the cooling means and for actuating a signalling device upon the occurrence of predetermined operating conditions of the transformer regardless of whether the cooling means is operating.

An object of this invention is to provide a new and improved air-cooled transformer having protective means for controlling the operation of the cooling means associated with the transformer and for indicating predetermined operating conditions of the transformer.

Another object of this invention is to provide protective means for an air-cooled transformer including thermally responsive devices for actuating cooling means in response to a predetermined operating condition of the transformer and for actuating signalling means in response to other predetermined operating conditions of the transformer both before and after said cooling means is actuated.

Other objects of the invention will, in part, be obvious and will, in part, appear hereinafter.

2

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing in which the single figure is a view in side elevation, partly in section and partly diagrammatic, of circuits and apparatus illustrating one 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 1 comprises a casing 2 which may have ventilated openings in the 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 to 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 the 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 7. The rings 9 and support members 10 are of a spider construction (not shown) to facilitate passage 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 the 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 the spacers 17 of insulating material, such as porcelain, the spacers 17 being arranged in vertical columns between adjacent coils and the spacers 14 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 the 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 9 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 10 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 coopera-

tion 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 the 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 both during self-cooled and fan-cooled operation, a first control device 25 and a second control device 125 are disposed within the casings 26 and 126, respectively, which are preferably mounted adjacent to each other atop the coil assembly of the transformer 1 on one of the pressure plates 9 and over one of the spider openings 27 therein. The first thermally responsive control device 25 and the second thermally responsive control device 125 are of the general construction and operate 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. In general, the first control device 25 is designed to respond to higher temperatures than the second control device 125.

The thermally responsive bimetal elements 28 and 128 are included in the control devices 25 and 125, respectively, and comprise a part of a circuit which extends from one terminal of a current transformer 29 disposed in relation with a conductor 30 of the load circuit of the transformer 1 through the bimetal 28, the conductor 31, the energizing winding 32 of a relay 33, through the conductor 34 and the bimetal 128 to the other terminal of the current transformer 29. The bimetals 28 and 128 are responsive to both the predetermined heating effects of current induced in the winding of the current transformer 29 which is a measure of the 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 casings 26 and 126 of the first control device 25 and the second control device 125, respectively.

The heating of the bimetals 28 and 128 due to the current flow therethrough that is proportional to the load current on the transformer 1 reflects immediately in the control devices 25 and 125 any change in the loading of the transformer, which might overheat and endanger the transformer during self-cooled and fan-cooled operation, respectively. Thus, the bimetals 28 and 128 are 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 during self-cooled and fan-cooled operation respectively of the transformer 1 which cause currents of heated air to rise upwardly between the coils 13 into the casings 26 and 126 of the thermally responsive control devices 25 and 125, respectively.

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 reaches a value slightly higher than the value of the rated full load current of the transformer 1 as to actuate the normally open 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 the conductor 37, an automatic-manual selector switch 38, shown as being in the automatic position, through the contact member 35 and

the conductor 39 to a fixed contact member 40 of the first 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 during both self-cooled and fan-cooled operation of the transformer 1, a pair of pivotally mounted switch operating members 41 and 42 are included in the first control device 25 within the casing 26, and a pair of pivotally mounted switch operating members 141 and 142 are included in the second control device 125 within the casing 126. As the transformer 1 heats up initially, the lower end of the member 141 of the second control device 125 is disposed to be moved by the bimetal 128 upon the occurrence of a predetermined movement of the bimetal 128 to the right to effect movement of the free end of the member 141 to the left. A contact member 143, carried by the member 141 at the free end thereof, is thereby moved away from engagement with a cooperating fixed contact member 140 for opening the circuit which extends from the power line conductor 48 through the conductor 154, the contact members 140 and 143, the conductor 152 to a normally open contact member 150 of the contactor 46 which is connected in series circuit relationship with the energizing winding 122 of the contactor 120. Thus, whenever the contact members 140 and 143 are disengaged, the energizing winding 122 of the contactor 120 will be deenergized for reasons which will be explained hereinafter. As the transformer 1 heats up still further, the pivotally mounted switch operating member 142 is disposed to be actuated by a further predetermined movement of the bimetal 128 to the right for effecting movement of the free end of the member 142 to the left. A contact member 168 carried by the pivoted member 142 at the free end thereof is thereby moved into engagement with a fixed contact member 169. The engagement of contact members 168 and 169 establishes a circuit extending from the conductor 71 at one side of the energizing winding 58 of the contactor 57 through the contact members 169 and 168, through the conductor 156 to a normally open contact member 123 of the contactor 120 for reasons which will be explained hereinafter.

As previously described, the first control device 25 responds to temperatures which are higher than the temperatures to which the second control device 125 responds. As the transformer 1 heats up still further, the switch operating member 41 of the first control device 25 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 fixed contact member 40 for establishing a circuit extending from the power line conductor 36 through the conductor 37, the switch 38, through the contact member 35 whenever the relay 33 is energized, the conductor 39, the contact members 40 and 43, the conductor 44, the energizing winding 45 of a contactor 46 and through the 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 normally open contact members 49, 50, 51 and 150 thereof to circuit closing positions.

The movement of the contact members 50 and 51 of the contactor 46 to circuit closing positions effects energization of the fan motor 52 through a circuit extending from the power line conductor 36 through the conductor 53, the contact member 50, the conductor 54, the fan motor 52, the conductor 55, the contact member 51 and the conductor 47 to the power line conductor 48, thus effecting the energization of the fan motor 52 to operate the fan 19. The 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. The holding circuit extends from the power conductor 36 through the conductor 37, the switch 38, the contact member 35, the conductor 56, the contact member 49, the energizing winding 45 of the contactor 46 and the conductor 47 to the line conductor 48. The movement of the contact member 150 to a circuit closing position permits energization of contactor 120 whenever the contact members 140 and 143 of the second control device 125 are engaged through a circuit which extends from the conductor 36 through the conductor 53, the energizing winding 122 of the contactor 120, through the contact member 150, the conductor 152, the contact members 140 and 143, and through the conductor 154 to the power line conductor 48.

The holding circuit is necessary for the effective operation of the protective means or system 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 heated low voltage windings 12 to force the air heated by the windings 12 upwardly into the casings 26 and 126 for not only cooling the low voltage windings 12 but for also cooling the thermally responsive bimetal elements 28 and 128. 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 casings 26 and 126 to effect such cooling of the bimetal elements 28 and 128, respectively. 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 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 of the relay 33 drops to a circuit interrupting position to interrupt the holding circuit for the winding 45 of the contactor 46.

In similar fashion, after the fan 19 begins operation, the thermal action of the cooler air on the bimetal element 128 after a time delay tends to cause the bimetal element 128 to operate to reverse the initial sequence of operations whereby the free end of the switch operating means 142 tends to move to the right to disengage the contact members 168 and 169 and the free end of the switch operating member 141 tends to move to the right to move the contact member 143 into engagement with the contact member 140, thus energizing the contactor 120 through the circuit which extends from the power line conductor 36 through the conductor 53, the energizing winding 122 of the contactor 120, the contact member 150 of the contactor 46, through the conductor 152, the contact members 143 and 144 and through the conductor 154 to the power line conductor 48. The winding 122 of the contactor 120 is, therefore, connected across the power line conductors 36 and 48, and is thereby energized to simultaneously effect movement of the contact members 124 and 123 thereof to circuit closing positions. The movement of the contact member 124 effects establishment of a holding circuit for the winding 122 of the contactor 120 which extends from the power line conductor 48 through the conductor 47, through the contact member 124 and the contact member 150, through the winding 122 of the contactor 120, through the conductor 53, and back to the power line

conductor 36. The movement of the contact member 123 of the contactor 120 to a circuit closing position has no effect on the operation of the control circuit so long as the contact members 168 and 169 of the second control device 125 are disengaged since the contact member 123 is connected in series circuit relationship with the contact members 168 and 169 of the second control device 125.

In order to control the operation of the signal device 24, another contactor 57 having an energizing winding 58 is included in the control circuit for the protective means or system. When the transformer 1 is initially arranged 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 the line conductor 36 through the conductor 37, the switch 59, the conductor 60, the winding 58 of the contactor 57, the resistor 61 and the conductor 47 to the line conductor 48 to thereby connect the winding 58 across the line conductors 36 and 48 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. The movement of the contact member 62 to a circuit interrupting position interrupts a signal circuit extending from the line conductor 36 through the conductor 64, the signal device 24, the contact member 62, and the conductor 65 to the 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. The movement of the contact member 63 to a circuit closing position establishing a holding circuit extending from the line conductor 36 through the conductors 53 and 66, through the contact member 63, the conductor 67, the winding 58 of the contactor 57, the resistor 61 and the conductor 47 to the line conductor 48 to thereby maintain the energization of the winding 58 of the contactor 57 until such time as the operating conditions of the transformer 1 effect deenergization 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 during the self-cooled operation of the transformer 1, the pivotally mounted switch operating member 42 of the first control device 25 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. The 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 the power line conductor 36 through the conductors 53 and 66, the contact member 63 normally disposed in the circuit closing position as described hereinbefore, the conductors 67 and 70, the closed contact members 68 and 69, through the conductor 71, the resistor 61 and the conductor 47 to the power line conductor 48. This circuit is disposed for shunting the normally energized winding 58 of the contactor 57 to effect the deenergization of the winding 58, thereby causing the contact members 63 and 62 to drop to circuit interrupting and circuit closing positions, respectively. The resistor 61 is provided in order to prevent a short circuit between the power line conductors 36 and 48 whenever the contact members 68 and 69 are engaged. The movement of the contact member 62 to the circuit closing position establishes the signal circuit for energizing the signal device 24, and the 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.

In order to effect the deenergization of the contactor 57 after the fan 19 begins operation, it is necessary that the effect of the thermal action of the cooler air on the bimetal element 128 cause the contact members 140 and 143 of the second control device 125 to return to a circuit closing position and the contact members 168 and 169 to return to a circuit interrupting position as previously described. After the contact members 140 and 143 return to a circuit closing position, the contactor 120 will be energized through a circuit which extends from the power line conductor 36 through the conductor 53, the energizing winding 122 of the contactor 120, the contact member 150 of the contactor 46, the conductor 152, the contact members 143 and 140, and through the conductor 154 to the power line conductor 48. The winding 122 of the contactor 120 is, therefore, connected across the power line conductors 46 and 48 and is thereby energized to simultaneously effect movement of a pair of contact members 124 and 123 of the contactor 120 to circuit closing positions. The movement of the contact member 124 to a circuit closing position effects establishment of a holding circuit for the winding 122 of the contactor 120 which extends from the power conductor 36 through the conductor 53, the winding 122 of the contactor 120, the contact member 150 of the contactor 46, through the contact member 124 of the contactor 120, through the conductors 132 and 47 to the power conductor 48. The contactor 120 remains energized thereafter independently of the operation of the contact members 140 and 143 of the second control device 125. The movement of the contact member 123 of the contactor 120 establishes a closed circuit which extends from one side of the energizing winding 58 of the contactor 57 through the contact member 123 and the conductor 156 to the fixed contact member 168 of the second control device 125.

After the initial effect of the thermal action of the cooler air on the bimetal 128 has returned the contact members 140 and 143 to a circuit closing position and the contact members 168 and 169 of the second control device to a circuit opening position, a further increase in the load on the transformer 1 will cause an increase in the temperature of the air which is heated by the windings of the transformer 1 and rises into the casing 126 of the second control device 125. The thermal action of the heated air will effect movement of the bimetal element 128 to the right to disengage the contact member 143 from engagement with the contact member 140. Such operation will have no effect on the energization of the contactor 120 since a holding circuit will have already been established as previously described. As the transformer 1 heats up still further, however, during fan-cooled operation the pivotally mounted switch operating member 142 is actuated by a further predetermined movement of the bimetal 128 to the right for effecting movement of the free end of the member 142 to the left. The contact member 168 carried by the pivoted member 142 at the free end thereof is thereby moved into engagement with the fixed contact member 169. The engagement of the contact members 168 and 169 now establishes a circuit extending from the power line conductor 36 through the conductors 53 and 66, through the contact member 63 normally disposed in the circuit closing position as described hereinbefore, the contact member 123 of the contactor 120, the conductor 156, the contact members 168 and 169, the conductors 158 and 71, the resistor 61, and through the conductor 47 to the power line conductor 48. This circuit is disposed for shunting the normally energized winding 58 during fan-cooled operation of the transformer 1, thereby causing contact members 62 and 63 to drop to circuit inter-

rupting and circuit closing positions, respectively. As previously described, the movement of the contact member 62 to the circuit closing position establishes the signal circuit for energizing the signal device 24, and the 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.

A brief description of the overall operation of the protective system or means will serve to illustrate the advantages thereof. Assuming that the load is connected to the transformer 1 initially and gradually increased, and that the protective means or system is properly arranged 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 air heated by the windings of the transformer 1 rises into the casings 26 and 126 and by thermal action effects movement of the bimetal element 128 to the right to cause the switch operating member 141 to move the contact member 143 away from engagement with the contact member 140, thereby preventing energization of the contactor 120 until after the fan 19 begins operation and the contact members 140 and 143 have returned to a circuit closing position. As the transformer heats up further, the bimetal element 128 will move to a predetermined position further to the right for engaging the switch operating member 142 to move the contact member 168 carried thereby into engagement with the fixed contact member 169. The engagement of the contact members 168 and 169 will have no effect at this stage of the operation of the transformer 1 since the contactor 120 is deenergized, and the contact member 123 of the contactor 120, which is connected in series circuit relation with the contact members 169 and 168, will be in a circuit interrupting position.

As the load on the transformer 1 increases to a value slightly above the rated full load value of the apparatus, the winding 32 of the relay 33 is energized by a current flowing therethrough which is proportional to the load current of the transformer 1 so as to actuate the contact member 35 of the relay 33 to a circuit closing position. In addition, as the transformer 1 heats up still further, the thermal action of the air rising from the windings of the transformer 1 will effect movement of the bimetal element 28 of the first control device 25 toward the switch operating member 41 for engagement therewith to move the contact member 43 into engagement with the contact member 40, thereby establishing the energizing circuit for the winding 45. Such operation effects movement of the contact members 49, 50, 51 and 150 to circuit closing positions for simultaneously establishing the holding circuit for the winding 45, the energizing circuit for the fan motor 52 and the circuit extending from the winding 122 of the contactor 120 to the contact member 143 of the second control device 125, respectively.

As the fan motor 52 begins operation, the fan 19 is rotated thereby for forcing air currents upwardly from the housing 20 into the casings 26 and 126 of the first and second control devices 25 and 125, respectively, to thereby effect a cooling action of the bimetal elements 28 and 128, respectively, by thermal action. One effect of the thermal action is to move 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 46 to thereby maintain the energizing circuit for the fan motor 52 independently of the position of the bimetal element 28.

A second effect of the thermal action of the cooling air caused by operation of the fan 19 is to move the bimetal element 128 of the second control device 125 to thereby return the contact members 168 and 169 to a circuit interrupting or disengaged position and the contact members 140 and 143 to a circuit closing or engaged position in that order. The return of the contact members 140 and 143 to a circuit closing position energizes the contactor 120 since the contact member 150 is already in a circuit closing position due to the energization of the contactor 46. Such operation effects the movement of the contact members 124 and 123 to circuit closing positions for simultaneously establishing the holding circuit for the winding 122 of the contactor 120 and the circuit which extends from one side of the winding 58 of the signalling contactor 57 to the fixed contact member 168 of the second control device 125 to thereby permit the second control device 125 to control the deenergization of the signalling contactor 57.

If the load on the transformer 1 is further increased during fan-cooled operation, the thermal action of the heated air from the windings of the transformer 1 is to move the bimetal 128 to thereby disengage the contact members 140 and 143. Such operation has no effect since a holding circuit has already been established for the winding 122 of the contactor 120. As the transformer 1 heats up still further during fan-cooled operation, a movement of the bimetal element 128 of the second control device 125 to a predetermined position further to the right engages the switch operating member 142 to move the contact member 168 into engagement with the fixed contact member 169. Engagement of the contact members 168 and 169 effects the establishment of the circuit which shunts the normally energized winding 58 of the contact 57 to effect the deenergization of the winding 58. The contact members 63 and 62 then 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 signalling device 24.

If for any reason the fan 19 fails to operate or is operating inefficiently, the windings of the transformer 1 continue to heat up resulting in a movement of the bimetal element 28 of the first control device 25 to a predetermined position further to the right for engaging the switch operating member 42 to move the contact member 68 carried thereby into engagement with the fixed contact member 69. Engagement of the contact members 68 and 69 effects the establishment of a circuit previously described which shunts the normally energized winding 58 of the contactor 57 to effect the deenergization of the winding 58 during substantially self-cooled operation 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 in a similar manner to that previously described for fan-cooled operation.

The signal device 24 which may be energized either during self-cooled operation or fan-cooled operation 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.

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 contact member 35 thereof to a circuit interrupting position to interrupt the holding circuit for the winding 45 of the contactor 46, thus causing the contact members 50 and 51 thereof to drop out for interrupting the energizing circuit for the fan motor 52 whereby operation of the fan 19 is discontinued.

If it is found necessary to operate the fan 19 in an emergency situation, such as, for example, in the event of failure of the operation of the relay 33 or the bimetal element 28, or the indicating device 24, or the bimetal element 128, the automatic-manual switch 38 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 the power line conductor 36 through the conductor 37, the switch 38, the conductor 73, the winding 45 of the contactor 46 and through the conductor 47 to the line conductor 48 to thereby energize the winding 45 for effecting the establishment of the energizing circuit for the fan motor 52.

In summary, the protective means, as disclosed provides automatic control for the cooling means associated with an air-cooled transformer and for indicating predetermined load conditions of the transformer during substantially self-cooled operation and during the operation of the cooling means. The first control device 25, in general, operates to initiate operation of the fan 19 and to energize the signal device 24 in the event that the fan 19 fails to operate or is operating inefficiently. The second control device 125, in general, is responsive to temperatures which are less than the temperatures to which the first control device 25 responds and operates to control the energization of the signal device 24 after the operation of the fan 19 has been initiated by the operation of the first control device 25 and the relay 33. The relay 33 cooperates with the first control device 25 to maintain energization of the fan 19 after the fan 19 has been energized by the first control device 25 until the load current of the transformer 1 has decreased to a safe predetermined value.

The apparatus and circuits embodying the teachings of this invention have several advantages. For example, if it is desired, a transformer may be operated under overload conditions for a considerable time without danger of overheating the coil assembly or windings of the transformer. Such operation is made possible by means of the operation of the first control device 25 and the protective circuits related thereto to operate the fan 19 for cooling the coil assembly when the load on the transformer becomes excessive. The holding circuit for the winding 45 of the contactor 46 is disposed for maintaining operation of the fan motor 52 independently of the position of the bimetal 28 to prevent a rapid cycling or hunting of the fan 19 caused by alternating movement of the bimetal 28, 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 contact 57 becomes deenergized for any reason, the signal device 24 is then 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. In particular, the protective means, as disclosed, has the additional advantage that the signal device 24 is energized when a dangerous predetermined overload condition results in the transformer after the fan 19 is energized and is operating normally. The later operation of the signalling device 24 is not possible with conventional protective means of this type which include only a single thermally responsive control device since the temperatures at which the second control device 125 respond are less than the temperatures to which the first control device 25 responds.

In addition, the fan 19 may be turned on at any time

if so desired by manual actuation of the automatic-manual switch 38. This feature of the protective system or means provides for operation of the fan 19 in the event of failure of the bimetal element 28, the relay 33, or any part of the circuit in association with the circuit operable upon such actuation of the switch 38.

Since numerous changes may be made in the above-described apparatus and circuits, and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all the matter contained in the foregoing description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In an air-cooled transformer provided with a coil assembly, in combination, cooling means disposed for operation to effect the cooling of the transformer, first and second thermally responsive control devices disposed to be responsive to both the temperature of the air rising from said coil assembly and to the heating caused by the current flowing in said coil assembly, said first control device including first and second contact members arranged to close at different degrees of loading of said transformer, a relay disposed to be energized in response to a predetermined value of current flow in said coil assembly and to be deenergized when the current flow decreases to a value below said predetermined value, first means disposed to be energized to effect the operation of said cooling means only after said relay is energized and the first contact member of said first control device is closed, said relay when energized cooperating with said first means to thereafter effect the energization of said cooling means independently of said first control device and when deenergized cooperating with said first means to deenergize said cooling means, a signalling means disposed for operation for indicating a predetermined load condition of said transformer, second means disposed for operation in response to the closing of said second contact member of said first control device to effect operation of said signalling means, said second control device including first and second contact members arranged to open and close respectively at different degrees of loading of said transformer at temperatures less than the temperatures required for the operation of said first control device and a contactor disposed to be energized only when the first contact member of said second control device has closed after said first means has effected the operation of said cooling means, said contactor when energized cooperating with the second contact member of said second control device to effect operation of said second means and said signalling means in response to the closing of said second contact member of said second control device after said first means has effected the operation of said cooling means and said first contact member of said second control device has closed.

2. In an air-cooled transformer provided with a coil assembly, in combination, cooling means disposed for operation to effect the cooling of the transformer, first and second thermally responsive control devices disposed to be responsive to both the temperature of the air rising from said coil assembly and to the heating caused by the current flowing in said coil assembly, said first control device including first and second contact members arranged to close at different degrees of loading of said transformer, a relay disposed to be energized in response to a predetermined value of current flow in said coil assembly and to be deenergized when the current flow decreases to a value below said predetermined value, first means disposed to be energized to effect the operation of said cooling means only after said relay is energized and the first contact member of said first control device is closed, said relay when energized cooperating with said first means to thereafter effect the energization of said cooling means independently of said first control device and when deenergized cooperating with said first means

to deenergize said cooling means, a signalling means disposed for operation for indicating a predetermined load condition of said transformer, second means disposed for operation in response to the closing of said second contact member of said first control device to effect operation of said signalling means, said second control device including first and second contact members arranged to open and close respectively at different degrees of loading of said transformer at temperatures less than the temperatures required for the operation of said first control device and a contactor disposed to be energized only when the first contact member of said second control device has closed after said first means has effected the operation of said cooling means, said contactor when energized cooperating with the second contact member of said second control device to effect operation of said second means and said signalling means in response to the closing of said second contact member of said second control device after said first means has effected the operation of said cooling means and said first contact member of said second control device has closed, and switch means disposed to be manually operated to control the energization of said first means independently of the energization of said relay and the actuation of said first contact member of said first control device and to effect the operation of said cooling means.

3. In an air-cooled transformer provided with a coil assembly, in combination, cooling means disposed for operation to effect the cooling of the transformer, first and second thermally responsive control devices disposed to be responsive to both the temperature of the air rising from said coil assembly and to the heating caused by the current flowing in said coil assembly, said first control device including first and second contact members arranged to close at different degrees of loading of said transformer, a relay disposed to be energized in response to a predetermined value of current flow in said coil assembly and to be deenergized when the current flow decreases to a value below said predetermined value, first means disposed to be energized to effect the operation of said cooling means only after said relay is energized and the first contact member of said first control device is closed, said relay when energized cooperating with said first means to thereafter effect the energization of said cooling means independently of said first control device and when deenergized cooperating with said first means to deenergize said cooling means, a signalling means disposed for operation for indicating a predetermined load condition of said transformer, a normally energized signalling contactor disposed for operation in response to the actuation of said second contact member of said first control device to effect the operation of the signalling means, said second contact member of said first control device being disposed when actuated to effect the deenergization of said signalling contactor to thereby effect the operation of said signalling means independently of said first control device, said second control device including first and second contact members arranged to open and close respectively at different degrees of loading of said transformer at temperatures less than the temperatures required for the operation of said first control device and a contactor disposed to be energized only when the first contact member of said second control device has closed after said first means has effected the operation of said cooling means, said contactor when energized cooperating with the second contact member of said second control device to effect operation of said second means and said signalling means in response to the closing of said second contact member of said second control device after said first means has effected the operation of said cooling means and said first contact member of said second control device has closed.

4. In an air-cooled transformer provided with a coil assembly, in combination, cooling means disposed for operation to effect the cooling of the transformer, first and

13

second thermally responsive control devices disposed to be responsive to both the temperature of the air rising from said coil assembly and to the heating caused by the current flowing in said coil assembly, said first control device including first and second contact members arranged to close at different degrees of loading of said transformer, a relay disposed to be energized in response to a predetermined value of current flow in said coil assembly and to be deenergized when the current flow decreases to a value below said predetermined value, first means disposed to be energized to effect the operation of said cooling means only after said relay is energized and the first contact member of said first control device is closed, said relay when energized cooperating with said first means to thereafter effect the energization of said cooling means independently of said first control device and when deenergized cooperating with said first means to deenergize said cooling means, a signalling means disposed for operation for indicating a predetermined load condition of said transformer, a normally energized signalling contactor disposed for operation in response to the actuation of said second contact member of said first control device to effect the operation of the signalling means, said second contact member of said first control device being disposed when actuated to effect the deenergization of said signalling contactor to thereby effect the operation of said signalling means independently of said first control device, said second control device including first and second contact members arranged to open and close respectively at different degrees of loading of said transformer at temperatures less than the temperatures required for the operation of said first control device and a contactor disposed to be energized only when the first contact member of said second control device has closed after said first means has effected the operation of said cooling means, said contactor when energized cooperating with the second contact member of said second control device to effect operation of said second means and said signalling means in response to the closing of said second contact member of said second control device after said first means has effected the operation of said cooling means and said first contact member of said second control device has closed, 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.

5. In an air-cooled transformer provided with coil assembly, in combination, cooling means disposed for operation to effect the cooling of the transformer, first and second thermally responsive control devices disposed to be responsive to both the temperature of the air rising from said coil assembly and to the heating caused by the current flowing in said coil assembly, said first control device including first and second contact members arranged to close at different degrees of loading of said transformer, a relay disposed to be energized in response to a predetermined value of current flow in said coil assembly and to be deenergized when the current flow decreases to a value below said predetermined value, first means disposed to be energized to effect the operation of said cooling means only after said relay is energized and the first contact member of said first control device is closed, said relay when energized cooperating with said first means to thereafter effect the energization of said cooling means independently of said first control device and when deenergized cooperating with said first means to deenergize said cooling means, a signalling means disposed for operation for indicating a predetermined load condition of said transformer, second means disposed for operation in response to the closing of said second contact member of said first control responsive device to effect operation of said signalling means, said second control device including first and second contact members arranged to open and close respectively at different degrees of loading of said transformer at tem-

14

peratures less than the temperatures required for the operation of said first control device and a contactor disposed to be energized only when the first contact member of said second control device has closed after said first means has effected the operation of said cooling means, said contactor when energized cooperating with the second contact member of said second control device to effect operation of said second means and said signalling means in response to the closing of said second contact member of said second control device after said first means has effected the operation of said cooling means and said first contact member of said second control device has closed, and switch means disposed to be manually operated to control the energization of said first means to effect the operation of said cooling means independently of said relay and the actuation of said first contact member of said first control device.

6. In an air-cooled transformer provided with a coil assembly, in combination, cooling means disposed for operation to effect the cooling of the transformer, first and second thermally responsive control devices disposed to be responsive to both the temperature of the air rising from said coil assembly and to the heating caused by the current flowing in said coil assembly, said first control device including first and second contact members arranged to close at different degrees of loading of said transformer, a relay disposed to be energized in response to a predetermined value of current flow in said coil assembly and to be deenergized when the current flow decreases to a value below said predetermined value, a cooling means contactor disposed to be energized to effect the operation of said cooling means only after said relay is energized and the first contact member of said first control device is closed, said relay when energized cooperating with said first means to thereafter effect the energization of said cooling means independently of said first control device and when deenergized cooperating with said first means to deenergize said cooling means, a signalling means disposed for operation for indicating a predetermined load condition of said transformer, second means disposed for operation in response to the closing of said second contact member of said first control responsive device to effect operation of said signalling means, said second control device including first and second contact members arranged to open and close respectively at different degrees of loading of said transformer at temperatures less than the temperatures required for the operation of said first control device and a contactor disposed to be energized only when the first contact member of said second control device has closed after said first means has effected the operation of said cooling means, said contactor when energized cooperating with the second contact member of said second control device to effect operation of said second means and said signalling means in response to the closing of said second contact member of said second control device after said first means has effected the operation of said cooling means and said first contact member of said second control device has closed.

7. 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 load operating condition of the transformer, a first and a second control device each 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, each of said control devices including a thermally responsive means disposed for movement through two switching positions in response to variations in said temperatures and heating effects, the thermal responsive means of said second control device being arranged to respond to lower temperatures than the thermal responsive means

15

of said first control device, 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 below said predetermined flow of current, a first contact member of said first control device disposed to be actuated to a circuit closing position upon the occurrence of a predetermined movement of the thermally responsive means of said first control device to one of said switching positions, a first contactor disposed to be energized to effect the operation of the cooling means only after said relay is energized and said first contact member is actuated to circuit closing position, the relay when energized cooperating with said contactor to thereafter effect the energization of said cooling means independently of the movement of the thermally responsive means of the first control device and when deenergized cooperating with said contactor to deenergize said cooling means, a second contact member of said first control device disposed to be actuated to a circuit closing position upon the occurrence of a further predetermined movement of the thermally responsive means of said first control device to the other of said switching positions, a signalling contactor disposed for operation in response to actuation of said second contact member of said first control device to effect the operation of the signalling means, a first contact member of said second control device disposed to be actuated to a circuit opening position upon the occurrence of a predetermined movement of the thermally responsive means of said second control device to one of said switching positions, a second contact member of said second control device disposed to be actuated to a circuit closing position upon the occurrence of a further predetermined movement of the thermally responsive means of said second control device, and a second contactor disposed to be deenergized in response to actuation of the first contact member of said second control device, said signalling contactor disposed for operation in response to actuation of said second contact member of said second control device after said first contact member of said second control device has been actuated first to a circuit opening position and returned to a circuit closing position following the energization of said first contactor to effect the operation of said cooling means.

8. 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 load operating condition of the transformer, a first and a second control device each 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, each

16

of said control devices including a thermally responsive means disposed for movement through two switching positions in response to variations in said temperatures and heating effects, the thermal responsive means of said second control device being arranged to respond to lower temperatures than the thermal responsive means of said first control device, 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 below said predetermined flow of current, a first contact member of said first control device disposed to be actuated to a circuit closing position upon the occurrence of a predetermined movement of the thermally responsive means of said first control device to one of said switching positions, a first contactor disposed to be energized to effect the operation of the cooling means only after said relay is energized and said first contact member is actuated to circuit closing position, the relay when energized cooperating with said contactor to thereafter effect the energization of said cooling means independently of the movement of the thermally responsive means of the first control device and when deenergized cooperating with said contactor to deenergize said cooling means, a second contact member of said first control device disposed to be actuated to a circuit closing position upon the occurrence of a further predetermined movement of the thermally responsive means of said first control device to the other of said switching positions, a signalling contactor disposed for operation in response to actuation of said second contact member of said first control device to effect the operation of the signalling means, a first contact member of said second control device disposed to be actuated to a circuit opening position upon the occurrence of a predetermined movement of the thermally responsive means of said second control device to one of said switching positions, a second contact member of said second control device disposed to be actuated to a circuit closing position upon the occurrence of a further predetermined movement of the thermally responsive means of said second control device, and a second contactor disposed to be deenergized in response to actuation of the first contact member of said second control device, said signalling contactor disposed for operation in response to actuation of said second contact member of said second control device after said first contact member of said second control device has been actuated first to a circuit opening position and returned to a circuit closing position following the energization of said first contactor to effect the operation of said cooling means, and switch means disposed to be manually actuated for operation to cause said signalling contactor to effect the discontinuation of operation of said signalling means.

No references cited.