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PROTECTIVE SYSTEM

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Fig. 1.

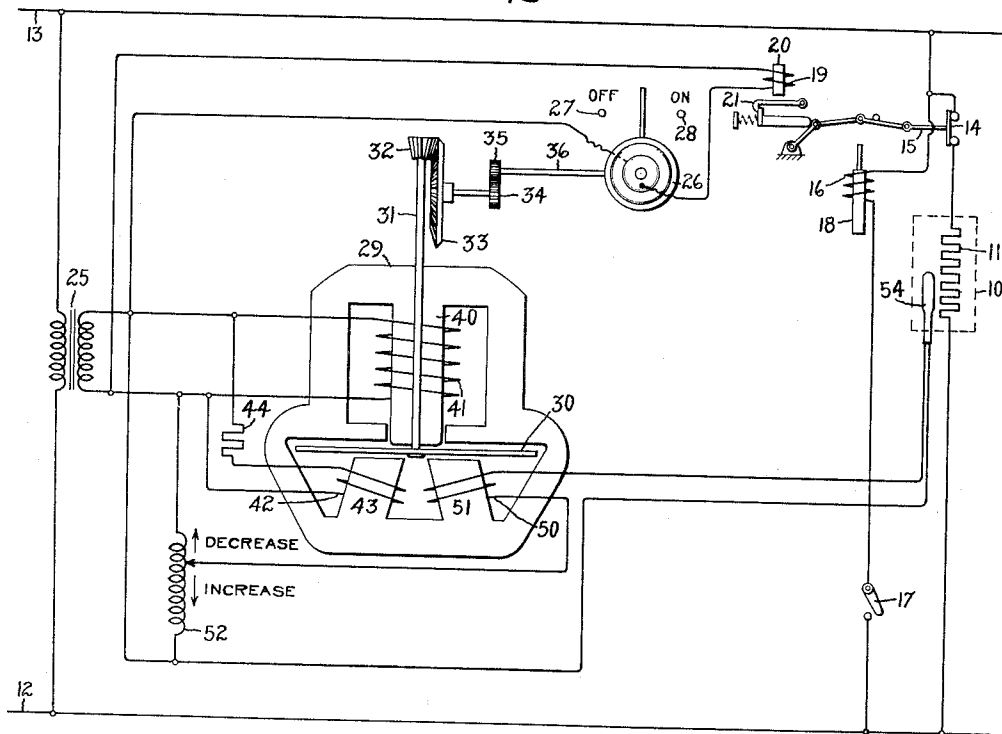
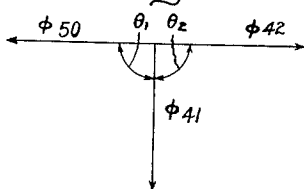


Fig. 2.



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UNITED STATES PATENT OFFICE

2,285,202

PROTECTIVE SYSTEM

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9 Claims. (Cl. 175—294)

My invention relates to condition responsive protective systems in general, and particularly to inductively operated protective systems responsive to temperature and the like.

For example, it is common practice to provide over-temperature protective control of some sort with most furnaces whether domestic or industrial and whether electric or fuel burning. This type of protection is particularly important in industrial furnaces such as ovens, melting pots and the like, which may be heated either electrically or otherwise. Over-temperature protective systems and devices now available for this purpose are quite generally expensive and are not altogether as dependable as might be desired. The lack of accuracy and dependability in prior systems is due largely to their dependence upon voltage and frequency; that is, variations of voltage or frequency will cause errors in the setting of the condition being controlled or indicated.

It is therefore an object of my invention to provide an inexpensive protective system which is dependable and accurate.

It is a further object of my invention to provide a protective system operated by alternating current but independent of variations in voltage and frequency.

It is a further object of my invention to provide a condition-responsive protective system which is simple and efficient and may be constructed largely of standard parts.

A specific object of my invention is the provision of an inductively operated temperature-responsive protective system which is readily adjustable to afford protection over a wide range of temperatures.

By way of example, my invention may be carried out in one form by arranging a contact making device for operation by a modified induction type of electrical instrument. Such an induction relay may be provided with an exciting coil, an operating coil and a restraining coil. To rotate the contact device to its "off" position the restraining coil may be energized to set up a magnetic flux displaced from the exciting flux by substantially ninety electrical degrees; while rotation in the opposite direction may be produced by energizing the operating coil with a current having a magnitude proportional to the value of a desired condition and a phase position displaced by substantially one hundred and eighty electrical degrees from the current in the restraining coil, and therefore by substantially ninety degrees from the exciting flux.

For a more complete understanding of my invention, and for a further appreciation of its objects and advantages, reference may now be had to the following specification taken in conjunction with the accompanying drawings, in which Fig. 1 is a simplified circuit diagram of connections for an induction over-temperature protective system embodying my invention, and Fig. 2 is a vector diagram representing the relation of the various magnetic fluxes existing in the induction relay schematically represented in Fig. 1.

Referring now to the drawings, and particularly to Fig. 1, I have shown a condition changing means, represented by way of example as an electric furnace 10 provided with a resistance heating element 11. The heating element 11 is connected for energization from a pair of line conductors 12 and 13 through the contact 14 of a circuit breaker 15. A closing coil 16, energized from the line conductors 12 and 13 through a manually operated switch 17, is arranged to cooperate with a plunger 18 to actuate the circuit breaker 15 to circuit making position. A trip coil 19 and associated armature 20 are adapted to actuate a latch 21 to trip the breaker 15. The trip coil 19 is shown as energized from the secondary winding of a control transformer 25 through a suitable contact making device 26, which preferably takes the form of a rotatable mercury button of the type described and claimed in Patents 2,101,092 and 2,101,093, issued December 7, 1937, to J. H. Payne and assigned to the same assignee as the present application.

For rotating the mercury button 26 to "off" and "on" positions against a pair of stops 27, 28, respectively, my invention comprises an induction relay 29 having a multiple pole core structure, as indicated. A rotatable aluminum induction disk 30 of the relay 29 is connected to a shaft 31 carrying a bevel gear 32 which cooperates with the second bevel gear 33. Through a pair of spur gears 34 and 35 the bevel gear 33 is arranged to drive a shaft 36 carrying the mercury button 26.

Wound upon the central pole 40 of the relay 29 is a highly inductive potential coil 41 which is energized directly from the secondary winding of the control transformer 25. Due to the high inductance of the coil 41, the flux set up in the relay core by this coil is ninety electrical degrees out of phase with the secondary voltage of the control transformer 25. This flux lags behind the transformer secondary voltage and may be represented by the vector ϕ_{41} of Fig. 2. For co-

operation with the coil 41 to produce a torque in one direction upon the disk 30, a coil 42 is arranged upon a pole 43 of the relay 29. The coil 42 is substantially non-inductive relative to the coil 41 and is connected for energization from the secondary winding of the control transformer 25 through a substantially non-inductive resistor 44. Because of the non-inductive nature of the circuit of the coil 42 the magnetic flux set up by the coil 42 is substantially in phase with the voltage of the secondary winding of the transformer 25. This flux therefore leads the flux of the coil 41 by substantially ninety electrical degrees and may be represented by the vector ϕ_{42} in Fig. 2.

For producing a torque in the opposite direction upon the disk 30 to a coil 50, similar to the coil 42 but reversely wound, is positioned a pole 51 of the relay 29. The coil 50 is energized from a voltage divider 52 or other suitable voltage varying device. The voltage divider 52 is connected for energization across the secondary terminals of the control transformer 25. The circuit of the coil 50 is primarily resistive and includes a temperature sensitive resistance varying element 54. The temperature sensitive element 54 comprises a resistor having a marked negative temperature coefficient of resistance and is preferably of the type described and claimed in my copending application Serial No. 327,901, filed April 4, 1940, and assigned to the same assignee as the present application. As described in my copending application the element 50 comprises an outer electrode in the form of a tube, an inner electrode centrally located in the tube, and a sintered mass of granular resistance material within the tubular electrode embedding the lower end of the inner electrode. One such sintered granular resistance material may comprise magnesium oxide, sodium silicate and copper oxide. The flux set up by the coil 50 is substantially one hundred and eighty electrical degrees out of phase with the voltage of the secondary winding of the control transformer 25 due to the reversed winding of the coil 50. Thus it will be evident that the time phase of the flux set up by the coil 50 will differ from that of the flux set up by the coil 42 by approximately one hundred and eighty electrical degrees, and will differ from that of the coil 41 by approximately ninety electrical degrees. The flux of the coil 50 may be represented by the vector ϕ_{50} of Fig. 2 and will be seen to lag the flux ϕ_{41} of the coil 41 by approximately ninety electrical degrees.

If desired the one hundred and eighty degree phase shift between the fluxes ϕ_{42} and ϕ_{50} may be produced by winding the coil 50 in the same direction as the coil 42 and energizing the voltage divider 52 from the secondary of the control transformer 25 through an insulating transformer which may have a 1 to 1 ratio.

Each of the fluxes ϕ_{42} and ϕ_{50} interacts with the constant exciting flux ϕ_{41} to produce a torque upon the disk 30. Each torque depends for its direction upon the direction of phase angular shift between the two fluxes producing it, and for its magnitude upon the magnitudes of the fluxes and the magnitude of the phase angle between them. For example, consider the various torques established. Most of the flux set up in the central pole 40 by the coil 41 passes across the narrow air gaps above the disk 30 and returns without cutting the disk. Some of the exciting flux however cuts the disk 30 and returns through the radially displaced poles 43 and 51. 75

This portion of the exciting flux sets up circulating currents in the conducting disk which lag behind the flux ϕ_{41} by substantially ninety electrical degrees. Since these circulating currents are in phase with the flux ϕ_{50} and one hundred and eighty degrees out of phase with the flux ϕ_{42} , their magnetic fields are acted upon by the fluxes ϕ_{42} and ϕ_{50} to produce oppositely directed torques. Similarly, the fluxes in the radially displaced poles set up by the coils 42 and 50 pass through the disk 30 and return through the radial core portions above the disk. These fluxes ϕ_{42} and ϕ_{50} establish circulating currents in the disk which are respectively in phase and one hundred and eighty degrees out of phase with the flux ϕ_{41} . Therefore the flux ϕ_{41} acts upon the magnetic fields of the circulating currents set up by the fluxes ϕ_{42} and ϕ_{50} to produce oppositely directed torques. Inspection will show that the torque produced by the flux ϕ_{42} acting upon the currents set up by the flux ϕ_{41} is in the same direction as the torque produced by the flux ϕ_{41} acting upon the currents set up by the flux ϕ_{42} . The same is true of the fluxes ϕ_{41} and ϕ_{50} . The torque relations may be expressed as:

$$T_1 = \phi_{41}\phi_{42} \sin \theta_2$$

$$T_2 = \phi_{41}\phi_{50} \sin \theta_1$$

It will now be apparent that, when the three magnetic fluxes ϕ_{41} , ϕ_{42} and ϕ_{50} exist simultaneously in the core of the relay 29, two oppositely directed torques will be acting upon the rotatable disk 30. The interaction of the fluxes ϕ_{41} and ϕ_{42} produce a torque in one direction, for example counterclockwise; while the interaction of fluxes ϕ_{41} and ϕ_{50} produce an oppositely directed torque, for example in the clockwise direction. Assuming that the angle θ_1 equals the angle θ_2 in Fig. 2, the magnitudes of the opposing torques will be directly proportional to the magnitudes of the fluxes ϕ_{42} and ϕ_{50} . When ϕ_{50} is less than ϕ_{42} the resultant torque will be in the counterclockwise direction and will maintain the mercury button 26 positioned against the stop 27. If, on the other hand, the flux ϕ_{50} is greater than the flux ϕ_{42} the resultant torque will be in the clockwise direction, and the mercury button 26 will be rotated against its stop 28. Clockwise rotation of the mercury button 26 completes an energizing circuit for the trip coil 19 of the circuit breaker 15. The magnitude of the flux ϕ_{42} is fixed. The magnitude of the flux ϕ_{50} is determined by the ampere turns of the coil 50, which in turn is determined by the setting of the voltage divider 52 and the temperature of the temperature sensitive element 54.

In operation, if it is desired to protect the furnace 10 against an over-temperature of a predetermined value, the voltage divider 52 is so adjusted that, with the temperature sensitive element 54 at the predetermined temperature, the ampere-turns of the coil 50 are sufficient to set up a flux ϕ_{50} slightly greater than the flux ϕ_{42} . The flux ϕ_{50} will then produce rotation of the mercury button 26 in the clockwise direction to complete an energizing circuit for the tripping coil 19. Under normal operating conditions of the furnace 10, however, the temperature will be below the predetermined value and, therefore, the resistance of the temperature sensitive element 54 will be proportionately increased. The increased resistance of the element 54 will so decrease the number of ampere turns of the coil 50 that the flux ϕ_{50} will normally be smaller than the flux ϕ_{42} . The resultant torque exerted upon

the disk 30 will therefore normally be counter-clockwise in direction and will maintain the mercury button 26 against its "off" stop 27. Only under conditions of increased temperature within the furnace 10 will the resistance of the temperature sensitive element 54 be sufficiently diminished to enable the coil 50 to rotate the disk 30 in the clockwise direction.

Since the magnitude of the flux ϕ_{42} is fixed, the flux ϕ_{50} must have a predetermined magnitude to trip the relay. That is, regardless of the temperature setting of the apparatus the tripping value of ϕ_{50} is always the same. Thus it will be apparent that the temperature setting of the apparatus may be adjusted by operation of the voltage divider. For example, if the voltage applied to the coil 50 by the voltage divider is decreased, the resistance of the element 54 will have to be less than formerly in order that the relay will trip. Lower resistance of the element 54 means higher temperature in the furnace. Similarly, if the voltage applied to coil 50 by the voltage divider is increased, the relay will trip at a lower furnace temperature.

It will now be observed that one of the outstanding advantages of my invention is its independence of voltage and frequency variations. Since the operating and restraining torques are both derived from the same voltage and frequency, the critical value remains unchanged over a wide range of values of these two variables.

I would like to have it understood that I have shown an electric furnace 10 by way of example only. It will of course be evident to those skilled in the art that temperature sensitive element 54 will respond to changes in any temperature, whether it be a furnace temperature, the temperature of an electric apparatus, the temperature of a conditioned room or other space, or an outside temperature. For example, if the element 54 is located within a space heated by a fuel fired furnace, the circuit breaker 15 may be utilized to disable the energizing circuit for a blower motor or an oil burner motor; or if the furnace be a gas fired furnace the circuit breaker 15 may be operative to shut off a gas valve.

Furthermore, it is within the purview of my invention to substitute for the element 54 an impedance changing device sensitive to any other suitable condition which it is desired to control or indicate. My system also contemplates the variation of the phase rather than the magnitude of the current in the coil 50, since when this current is in phase with the exciting flux no operating force is exerted upon the disk 30.

It will, of course, also be understood by those skilled in the art that my invention is not limited to use in conjunction with a condition responsive element of the particular type illustrated at 54. Any desired type of impedance changing condition responsive element will satisfy the spirit of my invention; such as, for example, a bellows and variable resistor arranged to vary the ampere turns of the coil 50.

Thus, while I have shown one preferred embodiment of my invention, it will be evident to those skilled in the art that I do not wish to be limited thereto, and I, therefore, desire by the appended claims to cover all such modifications as fall within the true spirit and scope of my invention.

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

1. In an over-temperature protective system, an induction relay comprising a rotatable arma-

ture, a pair of relay windings for producing a torque upon said armature independent of temperature, a second pair of relay windings for producing an oppositely directed torque upon said armature, and a resistor having a high negative temperature coefficient of resistance connected in circuit with one winding of said second pair of windings to control the magnitude of said oppositely directed torque, said resistor being so positioned that it is subject to the temperature being controlled.

2. In an over-temperature protective system, a source of alternating voltage, an alternating current induction relay comprising a stationary core structure and a rotatable armature, an exciting coil mounted upon said core structure, an operating coil and a restraining coil likewise mounted upon said core structure, means including said source of voltage for supplying an exciting current to said exciting coil and energizing currents to said operating and restraining coils, said energizing currents differing in phase from said exciting current in opposite senses, control means operated by said relay, and a resistor having a high negative temperature coefficient of resistance connected in circuit with said operating coil to control the energizing current flowing therethrough.

3. In an over-temperature protective system, a source of alternating voltage, an induction relay comprising a stationary core structure and a rotatable armature, an exciting coil mounted upon said core, means operable in conjunction with said source of voltage to provide an exciting current for said exciting coil independent of temperature, an operating coil and a restraining coil likewise mounted upon said core structure, means operable in conjunction with said source of voltage to provide an energizing current for said restraining coil independent of temperature, said energizing current differing in phase from said exciting current in one sense, means providing a second energizing current for said operating coil, said second energizing current differing in phase from said exciting current in an opposite sense, control means operated by said relay, and a resistor having a negative temperature coefficient of resistance connected in series with said operating coil to control said second energizing current.

4. In a protective system, a source of alternating voltage, condition changing means, an alternating current induction relay comprising a stationary core structure and a rotatable disk armature, an exciting coil mounted upon said core structure, means for energizing said exciting coil to establish an exciting flux having a magnitude independent of said condition, an operating coil and a restraining coil likewise mounted upon said core structure, means providing a first energizing current for said restraining coil independent of said condition, said current differing in phase from said exciting flux by substantially ninety electrical degrees, means providing a second energizing current for said operating coil, said second current differing in phase from said first energizing current by substantially one hundred and eighty electrical degrees, contacts operated by said relay and arranged to control said condition changing means, and condition responsive means for controlling the energization of said operating coil.

5. In a protective system, a source of alternating voltage, condition changing means, an alternating current induction relay comprising a

stationary core structure and a rotatable disk armature of electric conducting material, a highly inductive exciting coil energized directly from said source of alternating voltage and mounted upon said core structure, an operating coil and a restraining coil likewise mounted upon said core structure, said operating and restraining coils being relatively non-inductive, a relatively non-inductive circuit for energizing said restraining coil directly from said source of alternating voltage, means for supplying to said operating coil a current differing in phase by substantially one hundred and eighty electrical degrees from said alternating voltage, contacts operated by said relay arranged to control said condition changing means, and condition responsive means arranged to control the magnitude of energization of said operating coil.

6. In a protective system, a source of alternating voltage, condition changing means, an alternating current induction relay comprising a multiple pole stationary core structure and a rotatable disk armature, a highly inductive exciting coil energized directly from said source of alternating voltage and mounted upon a central pole of said core structure, relatively non-inductive operating and restraining coils wound in opposite senses and mounted upon radially displaced poles of said core, means for energizing said operating and restraining coils from said source of alternating voltage through substantially non-inductive circuits, manually operable means for adjusting the magnitude of the voltage applied to said operating coil, contacts operated by said relay arranged to control said condition changing means, and condition responsive means arranged in circuit with said operating coil to control the energization thereof.

7. In an over-temperature protective system, a source of alternating voltage, a temperature changing means, an alternating current induction relay comprising a multiple pole stationary core structure and a rotatable disk armature, a highly inductive exciting coil energized directly from said source of alternating voltage and mounted upon a central pole of said core structure, a relatively non-inductive restraining coil mounted upon a first radially displaced pole of said core structure and energized from said source of alternating voltage through a substantially non-inductive resistance of constant value, a relatively non-inductive operating coil mounted upon a second radially displaced pole of said core structure and wound in a reverse sense with respect to said restraining coil, a voltage divider connected directly across said source of voltage, temperature responsive means comprising an element having a negative temperature coefficient of resistance, means includ-

ing said voltage divider and said element for energizing said operating coil, and a rotatable contact device operated by said relay and arranged to control said temperature changing means.

8. In an over-temperature protective system, a source of alternating voltage, an electric furnace comprising a resistance heating element, switching means connecting said resistance element to said source of alternating voltage, an alternating current induction relay comprising a stationary multiple pole core structure and a rotatable disk armature, a highly inductive exciting coil energized directly from said source of alternating voltage and mounted upon a central pole of said core structure, a relatively non-inductive restraining coil mounted upon a first radially displaced pole of said core structure and energized from said source of alternating voltage through a substantially non-inductive resistance of constant value, a relatively non-inductive operating coil mounted upon a second radially displaced pole of said core structure and wound in a reverse sense with respect to said restraining coil, a voltage divider connected across said source of voltage, temperature responsive means within said furnace comprising an element having a negative temperature coefficient of resistance, means including said voltage divider and said element for energizing said operating coil, and a rotatable contact device operated by said relay to disable said switching means upon the occurrence of a predetermined temperature within said furnace.

9. In an over-temperature protective system, a source of alternating voltage, temperature changing means, an alternating current induction relay comprising a multiple-pole stationary core structure and a rotatable disk armature, a highly inductive exciting coil energized directly from said source of alternating voltage and mounted upon a central pole of said core structure, a relatively non-inductive restraining coil mounted upon a first radially displaced pole of said core structure and energized from said source of alternating voltage through a substantially non-inductive resistance of constant value, a relatively non-inductive operating coil mounted upon a second radially displaced pole of said core structure, an insulating transformer having primary and secondary windings, a voltage divider connected across said secondary winding, temperature responsive means comprising an element having a negative temperature coefficient of resistance, means including said voltage divider and said element for energizing said operating coil, and a rotatable contact device operated by said relay and arranged to control said temperature changing means.

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