

UNITED STATES PATENT OFFICE

2,530,980

CONTROL SYSTEM FOR WINDOW HEATERS

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Application March 1, 1949, Serial No. 79,053

3 Claims. (Cl. 219—20)

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This invention relates to control systems, and in particular to control systems for providing over-temperature protection for windows which are to be heated.

Recently systems have been developed for controlling the temperature of windows, such as in aircraft, to prevent the frosting of the windows. Such systems have in general been used in conjunction with window panes formed of laminated sections of plastic and glass in which the surface of one or more panes of glass is coated with a transparent conducting material which, when connected in a suitable electrical circuit, will act as a resistor and dissipate heat within the window. A sensing element is used in conjunction with such windows to give an indication of the temperature of the window.

If the lead to the sensing element should become shorted in the case of a positive temperature coefficient element or if the sensing element circuit opens in the case of a negative temperature coefficient element, there is a possibility that the known systems may cause overheating of the windows with accompanying damage to the aircraft. It is also possible, where only one sensing element is employed in controlling the temperature of a plurality of windows, that if the power supply to the window with which the sensing element is associated, should fail, that particular window becomes cold and the control therefore fails as the control will operate to supply more power to the other windows in which there are no sensing elements with the result that the other windows become overheated.

An object of this invention is to provide, in a system for heating windows, for preventing the overheating of the windows.

Another object of this invention is to provide, in a system for heating windows, for interrupting the power supply to all of the windows upon the occurrence of a predetermined temperature in any one of certain of the windows.

Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawing, the single figure of which is a diagrammatic view of apparatus and circuits involving the teachings of this invention.

Referring to the drawing, this invention is illustrated by reference to a system for preventing the overheating of a plurality of window panes 10, 12 and 14, such as in an airplane (not shown). The window panes 10 and 14 are located in different sections of the airplane. For example, the window pane 10 can be located in the front of the airplane whereas the window panes 14 can be positioned in the side wall or panel thereof. The purpose of the location of the window panes 10 and 14 will be explained more fully hereinafter.

Each of the window panes 10, 12 and 14 is of similar construction being formed of a layer

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16 of plastic sandwiched between two layers of glass 18, one layer of glass having a coating 20 thereon formed of conductive material which will function as a resistor element therebetween. Such a window pane is more fully described in Technical Glass Bulletin No. 15 of the Pittsburgh Plate Glass Company. The composition of layers 16, 18 and 20 may be of many different materials so long as the combination acts as a transparent window pane, and the conductive layer 20 functions as a resistor element in the combination.

In order to supply current to the layer 20 of conductive material to effectively heat the window panes 10, 12 and 14, the layer 20 of each of the window panes is connected across conductors 22 and 24 which are connected to be supplied from a transformer 26 the primary windings of which are disposed to be connected, by a main or line contactor 28 to a suitable power source such as an inverter (not shown).

The main contactor 28 is provided with a movable contact member 30 and a winding 32 which when energized effects the actuation of the contact member 30 into a circuit closing position to effect the energization of the transformer 26 whereby current flows through the heating elements or conductive layers 20 of the window panes. In order to control the energization of the main contactor 28, a pair of secondary contactors 34 and 36 are provided having contact members 38 and 40, respectively, disposed to be actuated to circuit closing positions when the energizing windings 42 and 44, respectively, of the contactors are energized. When the contact members 38 and 40 are both in the circuit closing position, the energizing winding 32 of the main contactor 28 is connected to be energized whereas if either of contact members 38 or 40 is in an open circuit position the energizing circuit for the winding 32 is interrupted.

In order to control the energization of the secondary contactors 34 and 36, polarized relays 46 and 48 are associated with contactors 34 and 36, respectively. The polarized relays 46 and 48 are similar, each being provided with a movable armature contact member 50 disposed to be held in the neutral or open circuit position illustrated or to be actuated into engagement with the fixed contact members 52 and 54 associated with the windings 42 and 44, respectively, depending upon the energization of the polarized relays 46 and 48, respectively. As illustrated, if the movable armature contact members 50 are moved to the left, a circuit is established for each of the windings 42 and 44 to effectively energize contactors 34 and 36, respectively, to establish the energizing circuit for the main contactor 28.

The polarized relays 46 and 48 are disposed to be normally connected across similar resistance bridges 56 and 58, respectively, the resistance balance of which is determined by the tempera-

ture of the window panes 10 and 14, respectively, with which the bridges 56 and 58 are associated. As illustrated, each of the resistance bridges 56 and 58 comprise two legs, the one leg being formed of resistors 60 and 62 and the other leg being formed of resistors 64 and 66, the two legs being connected at their intermediate points 68 and 70 to a suitable source of power represented by the positive and negative signs. In both cases, the energizing winding of the polarized relays 46 and 48 is connected to intermediate taps 72 and 74 in the legs of the associated resistance bridge.

In the embodiment illustrated, the resistor 62 is utilized as a sensing element. The resistor 62 is formed of any suitable material having a high temperature coefficient of resistance such as nickel wire and is positioned closely adjacent to the window pane with which it is associated, being imbedded in the plastic layer 16 of the window pane where possible. This is to insure that the resistance of the resistor 62 will vary directly as the temperature of the window pane varies. The resistors 60, 64 and 66 are preferably formed of a material having a low temperature coefficient of resistance, such as advance, the resistor 62 also preferably being positioned so that the leads to the resistors will be approximately equal to eliminate errors in the resistance within the bridge itself. The resistance bridge can be initially balanced by adjusting the resistor 64 so that for a given temperature in the window panes 10 and 14, the polarized relays 46 and 48, respectively, are energized to maintain the armature contact members 50 thereof in the open circuit position illustrated. For temperatures below the given or predetermined temperature which in the case of airplane windows it is desired to not exceed, the polarized relays 46 and 48 are energized to actuate the armature contact members 50 thereof into circuit closing position with the co-operating fixed contact members.

In operation, assuming that the window panes 10 are located in the front of the airplane, and the window pane 14 is located in the side of the airplane, as referred to hereinbefore, and with the system as illustrated, when the temperatures of the window panes 10 and 14 are below the predetermined temperature beyond which it is undesirable to heat the window panes, then the bridge circuits 56 and 58 are unbalanced to so energize the polarized relays 46 and 48 that the armature contact members 50 thereof are actuated into engagement with the fixed contact members 52 and 54, respectively, to effect the energization of the windings 42 and 44, respectively, of the secondary contactors 34 and 36, respectively. When the contactors 34 and 36 are thus energized the contact members 38 and 40, respectively, are actuated to circuit closing positions to effect the energization of the winding 32 of the main contactor 28 and actuate the contact member 20 thereof into circuit closing position. The contact member 30 thus establishes the energizing circuit for the transformer 26 whereby power is supplied to the conductive layers 20 of all of the window panes connected across the conductors 22 and 24. In practice, the window pane 10 is only one of several in the front panel of the airplane and the window pane 14 is one of several in the side panels of the airplane.

As is well known, under dry-air flying conditions the side windows of an airplane are usually cooled at a faster rate than the front window panels. Thus, the bridge circuit 58 associated with the window pane 14 would be maintained unbalanced to effect the energization of the sec-

ondary contactor 36 for a longer period than the resistance bridge 56 associated with the window pane 10. Thus the temperature of the window pane 10, as well as the other window panes positioned in the front of the airplane, would be heated to the predetermined temperature which must not be exceeded in a shorter period of time than the window pane 14 and the other window panes positioned in the sides of the airplane.

Under such conditions, when the predetermined temperature which must not be exceeded is reached in the window pane 10, the bridge circuit 56 becomes balanced and the polarized relay 46 is then so energized that the armature contact member 50 thereof assumes the neutral position shown with the result that the energizing circuit of the winding 42 of the secondary contactor 34 is interrupted and the contact member 38 drops to a circuit interrupting position to interrupt the energizing circuit of the winding 32 of the main contactor 28. The power supply to the transformer 26 is thus interrupted and current ceases to flow in the conducting layers 20 of all of the windows connected across the conductors 22 and 24. Thus, even if the contactor 36 is energized to a circuit closing position so that the control associated with the window pane 14 is still operating to call for a power supply to the conductive layer thereof, the bridge circuit 58 associated with the window pane 10 so controls the secondary contactor 34 as to prevent the flow of current to the conductive layer of the window pane 14 and the windows associated therewith.

If, during flying, the airplane encounters wet conditions, it is found that the front panel of the airplane is cooled at a faster rate than the side panel of the airplane with the result that a lower temperature is maintained in the front window pane 10 than is maintained in the side window pane 14. Under such flying conditions, the window pane 14 will therefore tend to over-heat before the front window pane 10 becomes over-heated with the result that when the predetermined temperature which must not be exceeded is encountered in the window pane 14 the bridge circuit 58 becomes balanced and the polarized relay 48 is so energized that the armature contact member 50 thereof interrupts the energizing circuit for the winding 44 of the secondary contactor 36 with the result that the contact member 40 thereof drops to a circuit interrupting position. Thus, even if the contactor 34 is energized to a circuit closing position, the control of the contactor 36 is sufficient to interrupt the energizing circuit to the winding 32 of the main contactor 28 to interrupt the energizing circuit of the transformer 26 and prevent the flow of current to the conductive layers 20 of all of the windows connected across the conductors 22 and 24.

With the circuit as shown, it is seen that even if one of the window heaters should fail, or if the connections to the individual window should become interrupted through failure of a conductor, the bridge circuit associated with that particular window would be unbalanced since the predetermined temperature is not reached due to the failure of the heating element to function and the secondary contactor associated therewith would always be biased under such conditions to a circuit closing position. Thus, the control associated with the other window pane would assume control of the heating of the remaining windows connected across the conductors 22 and 24 whereby a measure of control

would be afforded for all of the remaining windows even though it permitted some overheating of certain of the windows.

The system is very efficient in operation, being composed of standard components which can be readily replaced where necessary. As will be appreciated, a separate sensing element 62 and control can be provided for each of the windows in the front and side panels of the airplane where desired, but the system illustrated having only two window panes 10 and 14, with the controls associated therewith, is sufficient for providing good protection with a minimum number of parts. This is evident for the possibility of both sensing elements or both window panes in which the sensing elements are located failing simultaneously is remote, except in the case of a complete failure of the system which is not likely unless the entire controls of the airplane fail.

I claim as my invention:

1. In a system for preventing the overheating of a pair of windows each of which has a heating element associated therewith disposed to be supplied from a transformer, the heating elements being connected in parallel circuit relation with one another, in combination, a main contactor having a winding disposed to be energized and a contact member disposed to be actuated into circuit relation with the transformer when the winding is energized for controlling the supply to the parallel connected heating elements, a resistance bridge circuit for each of the windows, each of the bridge circuits having a resistor disposed to be responsive to the temperature of the associated window whereby the resistance of the resistor varies as the temperature of the associated window varies, a polarized relay for each of the bridge circuits connected to be responsive to the balance of the associated bridge circuit, each of the relays being disposed for operation to an open circuit position when the temperature of the resistor of the associated bridge circuit reaches a predetermined value and to a contact making position when the temperature of the resistor of the associated bridge circuit is below the predetermined value, a secondary contactor disposed to be energized when an associated polarized relay is in a contact making position, each of the secondary contactors having a contact member disposed to be actuated when the secondary contactor is energized to connect the main contactor to be energized, the contact members of the secondary contactors cooperating to prevent the energization of the main contactor and the parallel connected heating elements supplied from the transformer when either of the polarized relays is in an open circuit position.

2. In a system for preventing the overheating of a pair of windows each of which has a heating element associated therewith, the heating elements being connected in parallel circuit relation with one another, in combination, a transformer disposed to be energized to supply current to each of the parallel connected heating elements, a line contactor disposed when energized to connect the transformer to a power source, a pair of resistance bridge circuits for the pair of windows, each of the bridge circuits having a resistor for cooperating with an associated window whereby the resistance of the resistor varies as the temperature of the associated window varies, a pair of polarized relays associated with the pair of bridge circuits, each of the polarized relays being

disposed for operation to a contact making position when the resistor of the bridge circuit is heated at a temperature below a predetermined value and to an open position when the temperature of the resistor reaches the predetermined value, a pair of secondary contactors associated with the pair of polarized relays, each of the secondary contactors having a contact member disposed to be actuated to a circuit closing position in series circuit relation to each other and the line contactor when the associated relays are in contact making positions to control the energization of the line contactor, the secondary contactors thereby effecting the deenergization of the line contactor when the contact member of either of the secondary contactors is in a circuit opening position to prevent a flow of current to the parallel connected heating elements of the windows.

3. In a system for preventing the overheating of a pair of windows each of which has a heating element associated therewith disposed to be supplied from a transformer, the heating elements being connected in parallel circuit relation with one another, in combination, a main contactor having a winding disposed to be energized and a contact member disposed to be actuated into circuit relation with the transformer when the winding is energized for controlling the supply to the parallel connected heating elements, a resistance bridge circuit for each of the windows, each of the bridge circuits having a resistor disposed to be responsive to the temperature of the associated window whereby the resistance of the resistor varies as the temperature of the associated window varies, a polarized relay for each of the bridge circuits connected to be responsive to the balance of the associated bridge circuit, each of the relays being disposed for operation to an open circuit position when the temperature of the resistor of the associated bridge circuit reaches a predetermined value and to a contact making position when the temperature of the resistor of the associated bridge circuit is below the predetermined value, a secondary contactor associated with each of the polarized relays, each of the secondary contactors having a winding therefor disposed to be energized when the associated relay is in a contact making position, each of the secondary contactors having a contact member disposed to be actuated into a circuit closing position when the secondary contactor is energized, the contact members of the secondary contactors being disposed, when in circuit closing position, in series circuit relation with each other and the winding of the main contactor to connect contactor to be energized, the secondary contactors thereby cooperating when one of the polarized relays is in an open circuit position to prevent the energization of the main contactor and the contact member thereof is actuated to a position to interrupt the supply to the parallel connected heating elements.

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