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AUTOMATIC REFRIGERATING DEFROSTING CONTROL

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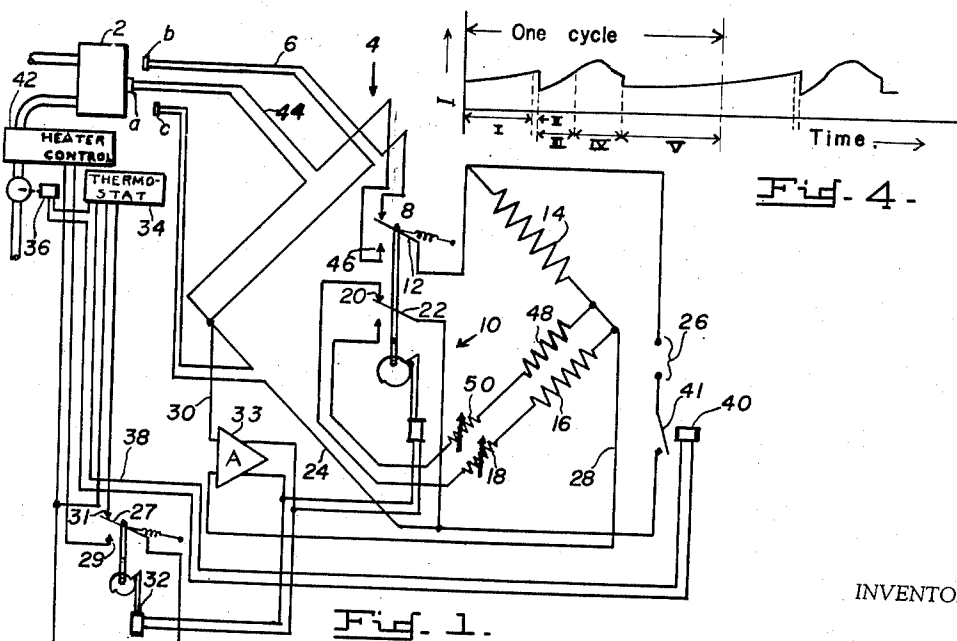
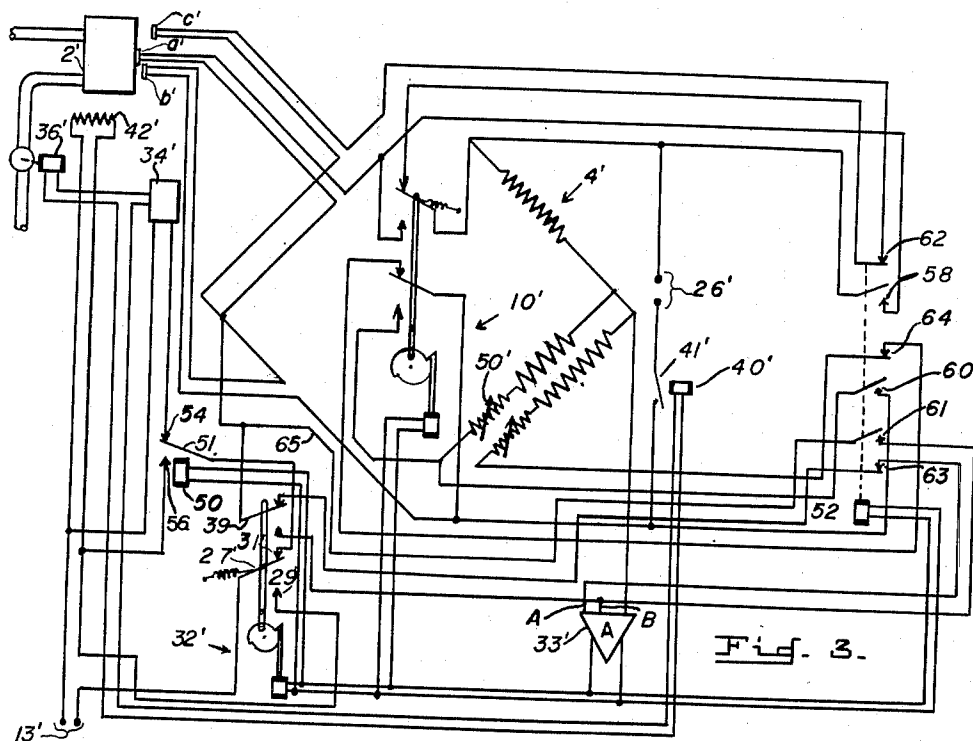


Fig. 4.

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AUTOMATIC REFRIGERATING DEFROSTING CONTROL

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This invention relates to automatic control means for defrosting the cooling element of automatic refrigerators, and has for its primary object the provision of improved means of simple construction and positive operation for accurately proportioning the defrosting action in accordance with the amount of frost which has accumulated so as to insure complete defrosting without excessive shutdown or excessive production of heat which would impair the efficiency of operation of the refrigerator unit.

An automatic defrosting system must include some means for detecting an accumulation of frost at which it is desired to commence defrosting, means for initiating a defrosting action when this accumulation of frost is detected, and means to end the defrosting action when the object has been accomplished. It is known in the art to detect frost accumulation by such devices as measurement of the physical thickness of ice accumulation by a mechanical mechanism; by detecting the change in temperature, in terms of gas pressure, produced at a specified distance from the cooling unit due to the accumulation of ice reaching to that distance; by detecting the interruption of a beam of light produced by ice accumulation and by noting the response to increased current flow to the motor of a fan which blows air across the evaporator due to increased pressure drop caused by accumulation of ice. More naive systems utilize a timer which initiates and ends defrosting at arbitrarily predetermined time periods, or else count the number of door openings.

For the system not to be too inefficient, it is necessary that the defrosting action must be ended when the defrosting has been satisfactorily accomplished. Various methods have been resorted to in order to accomplish this, the simplest of which is the use of a pre-set period of defrosting. While this is generally satisfactory, it is, of course, not as efficient, especially when operating temperature is changed, as a system which accurately determines when the cooling unit has been completely defrosted and initiates cessation of defrosting action at that time.

The defrosting itself may be accomplished in various ways. Among these are the flow of the hot gas or liquid through the evaporator; the use of a water or other liquid spray; the use of two evaporators which are alternately defrosted; the use of an electric heater in conductive contact with the surface of the cooling unit; the use of hot air directed over the evaporator and the reverse flow of the refrigerant,

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wherein the evaporator is used as a condenser. In addition to the above, it is, of course, also possible to merely stop the flow of refrigerant, but this is slow and generally unsatisfactory. It has been found that the use of local heating applied to the cooling unit can quickly and satisfactorily accomplish defrosting without appreciably interfering with the normal operation of the refrigerator.

All of the prior methods of defrosting of which I am aware are subject to certain disadvantages. They either employ relatively complicated mechanical parts which are a source of trouble, or else are unduly expensive, or else will be very difficult to adjust to various operating conditions, if they are not possessed of the required degree of adjustability and flexibility. Many of the methods do not completely melt the frost. It will be apparent that each of the systems described above is subject to certain obvious disadvantages.

It is a primary object of my invention to provide a simple, relatively inexpensive defrosting system which is not subject to the above disadvantages. I accomplish this by the use of temperature-sensitive resistance elements placed at different distances from the cooling unit, corresponding to the desired distances at which the various actions take effect. In the absence of frost, both or all of the temperature-sensitive units will be at approximately the same temperature, or a predetermined difference in temperature will exist due to the different distances from the cooling unit of the elements. If the elements are suitably arranged in a bridge circuit so that, in effect, the differences in temperatures of the elements are detected by the circuit, then it is possible to balance the bridge circuit so that the operation is not affected by normal variation in temperature of the air within the refrigerator. That is, the refrigerator can be set to operate at various temperatures without being affected by or affecting the operation of the frost detecting elements. However, when frost formed around the cooling unit reaches one of the elements, its temperature will be drastically lowered as compared to an element set at a slightly greater distance from the cooling unit which has not yet been reached by the frost formation. This difference in temperature may then be used to initiate the defrosting action. The cessation of defrosting action may be accomplished if desired by means of a timing unit known to the art. Alternatively, a more sophisticated system for ending defrost-

ing is shown wherein the control is transferred to a second set of temperature-sensitive resistors after defrosting action has been initiated, and said second set of elements controls the defrosting accurately in accordance with actual conditions on the surface of the cooling unit.

The specific nature of the invention, as well as other objects and advantages thereof, will clearly appear from a description of a preferred embodiment thereof as shown in the accompanying drawings, in which:

Fig. 1 is a schematic diagram showing the invention applied to an internal defrosting system;

Fig. 2 is a chart showing graphically the normal frosting and defrosting cycle of Fig. 1;

Fig. 3 is a schematic diagram showing the invention applied to an external defrosting system, and

Fig. 4 is a chart showing graphically the normal frosting and defrosting cycle of Fig. 3.

Referring to Fig. 1, adjacent to the evaporator unit or cooling unit 2 there are placed three temperature sensitive resistance elements *a*, *b*, and *c*, of which element *a* is placed very close to the cooling unit, or if desired, in contact therewith, and elements *b* and *c* are respectively spaced at increasing distances from the surface of the cooling unit 2. For this purpose, commercially available thermistors are used, although any suitable temperature sensitive resistance elements having a large temperature coefficient of resistivity may be used. These resistance elements are connected to a double Wheatstone bridge arrangement generally indicated at 4, which is actually two separate Wheatstone bridges having some common elements and so connected by means of switches as will be described below that one or the other of them is in the circuit at any given time. The normal frosting and defrosting cycle of the refrigerator is indicated graphically in Fig. 2, wherein the ordinate represents current flow across the bridge as the latter becomes unbalanced, and the abscissa represents time. The circuit of Fig. 1 is shown in the normal condition during normal operation of the freezer which is arbitrarily represented as zero time in Fig. 2. At this time resistors *b* and *c* are connected in the circuit as can be seen by following lead 6 from thermistor *b* to contact 8 of stepping relay 10, through switch arm 12 to arm 14 of the bridge. The bridge circuit continues through fixed resistance 16 and adjusting resistance 18 of a third arm of the bridge to contact 20 of switch arm 22 of stepping relay 10, thence to the fourth arm 24 of the bridge. Inserted in this fourth arm is thermistor *c*. It will thus be seen that with the arrangement shown thermistors *b* and *c* constitute two arms of the Wheatstone bridge, resistance 14 constituting a third arm and resistances 16 and 18 constituting a fourth arm. The input of the bridge is provided at terminals 26 by any suitable source, and the output of the bridge is carried by leads 28 and 30 to a suitable amplifier 32, the amplified output being fed to stepping relays 10 and 32. The usual thermostat for controlling the temperature of the interior of the refrigerator is indicated at 34. The operation of this thermostat controls solenoid actuated valve 36 or any other conventional elements whose operation controls the condition of refrigeration, such controlling circuits being no part of the present invention. The thermostat also controls, through leads 38, relay 40 which in turn controls the power input to the Wheatstone

bridge through terminals 26. The circuit of Fig. 1 is intended for use with an internal-type defroster system, that is, one wherein the defrosting operation is accomplished by heating the evaporator 2 from within. This may be accomplished by any of a number of well known methods, one of which is to flow hot gas or liquid through the evaporator, while another is to reverse the flow of refrigerant so that the evaporator is used as a condenser, and still more common is the use of electric heating by thermal conduction. My invention is not concerned with the type of defrosting employed, but only with provision of a control system therefor. However, different circuits are required for internal defrosting as above described, and for external defrosting of the type wherein an external heating element near the evaporator is used to accomplish the defrosting. The arrangement of Fig. 1 is for defrosting control in the former instance, while Fig. 3 shows a control system for external defrosting.

Relay 40 is provided for control by thermostat 34 so that there will be no possibility of the Wheatstone bridge circuit going into operation to initiate defrosting while the thermostat is still calling for more cold, that is, for continued operation of the refrigerating system. Thus it will be seen that when the thermostat energizes solenoid 36 (or any other control device) to cause operation of the refrigeration system, relay 40 will also be actuated to hold open switch 41 and thus insure that the Wheatstone bridge circuit remains deenergized. During the normal operation of the refrigerator, as is well known, frost accumulates on the evaporating unit 2. However, as long as the frost accumulation does not actually contact element *b*, this element and element *c* will both be at a temperature substantially determined by conditions in the interior of the refrigerator. Element *b* will be a little cooler because it is closer to the evaporator unit 2. However, the resistance 18 of the bridge can be so adjusted that under these conditions of operation the bridge is balanced and stepping relays 10 and 32 remain in the condition shown in Fig. 1. This is the condition represented at stage I of Fig. 2. As the actual frost coating creeps closer and closer to thermistor *b* the temperature difference between *b* and *c* increases continually, until when the coating actually contacts element *b*, this temperature difference rises to such a point that the resultant unbalance of the Wheatstone bridge due to the change of resistance element *b* causes operation of stepping relays 10 and 32, marking the end of stage I and the beginning of stage II as shown in Fig. 2. At this point, if thermostat 34 is calling for more cold, relay 40 will hold switch 41 open and nothing will happen. However, as soon as the thermostat deenergizes its outgoing circuits, switch 41 closes and the unbalanced Wheatstone bridge is energized to operate relays 10 and 32. Of course, if the beginning of this unbalance found switch 41 closed, the relays would be actuated immediately. Operation of relays 10 and 32 will move all of the switch arms affected by these relays from the upper contact position shown in Fig. 1 to the lower contact position. Relay 32 thereby cuts out thermostat 34 and actuates heater control 42 to initiate the internal defrosting operation. Switch arm 12 of relay 10 disconnects element *b* from the bridge and connects instead element *a*, the circuit being from element *a* through lead 44, contact 46, switch arm 12 to arm 14 of the

bridge. At the same time, switch arm 22 of relay 10 disconnects the arm including resistances 16 and 18 and substitutes the arm including resistance 48 and variable resistance 50, as will be obvious from inspection of the circuit. The bridge is now under control of elements *a* and *c*, instead of *b* and *c*, as heretofore. Since the relays are not directional, it will be understood that their operation will be dependent only upon the magnitude of the current flow due to unbalance, and therefore it does not matter, as far as the relays are concerned, which one of the elements is colder and which warmer. At the moment of defrosting, represented by the beginning of stage II of Fig. 1, there will, of course, also be a large temperature difference between element *a* and element *c*. However, rheostat 50 of the bridge is so adjusted that this difference does not cause sufficient unbalance to operate the relay. As heating commences, the temperature inside of evaporator 2 rises rapidly and element *a* becomes warmed so that there is now a temperature difference in the opposite sense from before, as shown in stage II. However, as long as there is ice surrounding the evaporator unit, element *a* cannot rise in temperature to a point sufficiently high to cause operation of the relays. After all of the ice is melted, the temperature of element *a* very rapidly rises, causing sufficient unbalance of the bridge to operate the stepping relays to restore the initial condition shown in Fig. 1. This is the beginning of stage III, which is, of course, the same as stage I, and the cycle is now repeated.

One important advantage of my invention as exemplified by the above system is that the bridge can be so adjusted that its operation is not affected by even a fairly radical change in the operating temperature of the refrigerator as determined by the customary manual setting of the thermostat 34. Since the operation depends upon the difference in temperature initially in elements *b* and *c*, a change in the absolute temperature of the interior of the refrigerator in which both *b* and *c* are located will not materially affect this state of balance, and it is not until the approach of actual frost to element *b* changes its condition in a very different manner from that of element *c* that the balance of the bridge is disturbed sufficiently to cause operation. Of course, it will be understood that due to the temperature gradient in the refrigerator at different distances from the evaporator unit 2, there will be a temperature difference between element *b* and element *c* so that a change in the operating temperature will, in most cases, tend to produce a different change in the resistivity of the two elements, thereby causing some small unbalance. However, this unbalance can easily be kept small enough, and the sensitivity of the circuit so adjusted by means of variable resistances 18 and 50, respectively, that normal variations in operating temperature will not cause unwanted operation of the defroster unit.

It will be seen that the above system produces defrosting strictly in accordance with the formation of frost upon the evaporator unit, and terminates the defrosting when the ice has become completely melted. The heating operation is continued for no longer a period than is essential to accomplish the desired result, yet it is never terminated while there is still frost left on the evaporator unit and the job is thus not completely finished.

In the case where an external heater unit is

employed, the conditions of melting are obviously somewhat different, and the system of control shown in Fig. 1 would not be adequate under these conditions. Therefore certain changes and additions are necessary as shown in Fig. 3. Most of the elements in Fig. 3 are very similar to those in Fig. 1 and are represented by the same reference characters with a prime added. Additional relays 50' and 52' are provided which are of the ordinary type; that is, when they are energized their switch arms are drawn down toward the coil and when deenergized, their switch arms move away from the coil; in the case of relay 50', arm 51' will move down when the relay is energized from contact 54' to contact 56'. In the case of relay 52', when it is energized, the circuit will be made at contacts 58', 60' and 61' and simultaneously opened at contact 62', 63' and 64'; and this condition will be maintained as long as the relay is energized. When the relay is deenergized, the original condition shown in Fig. 3 will recur. Referring to Fig. 4, stage I corresponds to stage I of Fig. 2 and initially represents normal operation of the refrigerator with frost continually accumulating on the evaporator unit 2'. At this time thermistor elements *b'* and *c'* are in control of the Wheatstone bridge, as can be readily seen by tracing the circuits. The end of stage I occurs when frost reaches element *b'*, thereby setting up the required temperature difference between elements *b'* and *c'*; and when thermostat 34' stops calling for cold, thereby closing solenoid valve 36' and deenergizing relay 40' to close switch arm 41' and thus energize the bridge as before. As the bridge is now unbalanced, the various relays controlled by the output of amplifier 33' are actuated, these being relays 10', 32', 50' and 52'. At this point, it will be convenient to represent the various stages which occur due to the unbalance becoming sufficiently large as stage II, although actually stage II represents only the very brief period when changes occur due to this unbalance. In this stage II, stepping relay 10' will switch the control from elements *b'* and *c'* to elements *a'* and *b'*; stepping relay 32' will start the heater 42'; relay 50' will cut off power to thermostat 34'; although the lead to the thermostat has also been opened at contact 31' of stepping relay 32' (the reason for this will be shown below); ordinary relay 52' is energized to open the various circuits at contacts 62', 63' and 64' and simultaneously close the circuits at contacts 58', 60' and 61', and ordinary relay 40' remains deenergized so that switch arm 41' remains closed. Stage III of Fig. 4 has now begun. The control having been transferred to elements *a'* and *b'*, both of which are in contact with the ice formation on the evaporator unit, the temperature difference between these two units is adjusted by variable resistor 50' so that the current flow across the bridge is reduced sufficiently to deenergize the various relays. Therefore, the contacts of ordinary relays 50' and 52' return to their original positions shown in Fig. 3. Stepping relays 10' and 32', however, remain in the down position, since it requires a second actuation of these relays to return them to their original position. The heater 42', therefore, continues to defrost as it is supplied from power terminals 13', through switch arm 27', contact 29', to the heater. As the heat is external, element *b'* is warmed up very much more quickly than element *a'*, and the temperature difference rapidly rises to the point where the unbalance of the bridge is sufficient to again cause actuation thereof. This is the end of stage

III and the beginning of stage IV. The resultant actuation causes stepping relays 10' and 32' to return to their original positions shown in Fig. 3. However, due to resultant actuation of ordinary relay 52, which remains actuated during this period (stage IV), the circuits at 62, 63 and 64 are now opened and those at 58, 60 and 61 are now closed. Therefore, elements a' and b' still remain operative and the controls do not shift to elements b' and c' even though the stepping relay has operated; moreover, since ordinary relay 50 is also actuated at this time, contact 56 is engaged by arm 51, the thermostat is still cut out of the circuit and heater 42' is still on, its circuit extending through contact 56, arm 51, contact 31', arm 27' out to terminals 13'. This condition (stage IV) continues during the rest of the defrosting operation. As the ice melts from around the unit 2', element a' finally also warms up to the point where the temperature difference between it and element b' is insufficient to hold ordinary relays 50 and 52. This is the end of stage IV and the beginning of stage V. When this occurs, relays 50 and 52 are deenergized and return to the position shown in Fig. 3. One full cycle has now been completed.

It will be noted that in Fig. 3, when stepping switch 32' is energized, it not only changes switch 27' from its upper to its lower position, but also similarly changes switch 39 from initial engagement with its upper contact to engagement with its lower contact. Similarly, contacts 61 and 63 of relay 52 change. This is to change to a stage of smaller amplification, which is sometimes necessary because the current flow in the bridge during defrosting in some arrangements is much greater than before defrosting—with some circuit parameters the latter current flow is from 10 to 40 times as great during defrosting. Switch 39 and contacts 61 and 63 are therefore arranged to cut out a stage of amplification so that the current output of the amplifier during this stage remains of the same order of magnitude as before. The action is as follows: During stage I, the circuit is as shown in Fig. 3, from the left side of the bridge through the upper contact of switch 39, through contact 63 to input A of the amplifier switch, which is the more sensitive stage; during stages II and III, through lower contact of switch 39 direct to input B, cutting out input A and thus attaining less sensitivity; during stage IV from left side of bridge through wire 65 to contact 61, again to input B; and during stage V same as stage I. The above arrangement may not be needed in all installations, and if found not to be necessary, switch 39 and contacts 61 and 63 may be omitted and the circuit to the amplifier may be as shown at 30 in Fig. 1.

It will be understood that in some situations the use of thermistors a and b as well as a and c for terminating defrosting can be used for either means of heating, although the above-described combination is usually the best for each method of heating under the circumstances ordinarily encountered. It will also be understood that during the normal operation stage of the refrigerator unit, represented by stages I and III in Fig. 2 and by stages I and V in Fig. 4, the refrigerator thermostat is alternately operating and releasing relay 40 (or 40') and that the above described current curves of Figs. 2 and 4 ignore the periods when the thermostat causes the bridge to be deenergized since initiation of defrosting cannot occur during such periods.

However, this only delays initiation of defrosting for a relatively short time during which comparatively little additional frost can form, and once the defrosting action is initiated, the thermostat is no longer in control until defrosting is completed.

It will be apparent that the embodiments shown are only exemplary and that various modifications can be made in construction and arrangement within the scope of my invention as defined in the appended claims.

I claim:

1. The method of automatically defrosting of a refrigerator cooling unit upon which ice tends to form which comprises detecting the temperature difference between a first locus removed from the surface of said cooling unit by the maximum distance to which frost is permitted to extend and a second locus, further from said cooling unit, converting said temperature difference into a first electrical parameter; initiating defrosting action when said first electrical parameter attains a predetermined magnitude representing the extension of frost formation to said first locus; detecting the temperature difference between a locus immediately adjacent the surface of said cooling unit and a more remote location from said cooling unit; converting the last said detected temperature difference into a second electrical parameter; transferring control of the defrosting action from said first electrical parameter to said second electrical parameter; ceasing said defrosting action when said second electrical parameter attains a predetermined magnitude representing elimination of frost from said surface; and reestablishing the initial control conditions.

2. The invention defined in the preceding claim wherein the step of defrosting the cooling unit is performed by heating it from within, said second temperature difference being taken between said locus adjacent the cooling unit surface and said second locus.

3. The invention according to claim 2 wherein the step of defrosting the cooling unit is performed by heating it from without, said second temperature difference being taken between said locus adjacent the cooling unit and said first locus.

4. The invention according to claim 3 including the step of deenergizing said defrosting control system whenever the refrigerator temperature is above a predetermined value.

5. An automatic defrosting system comprising three temperature-sensitive electrical elements, one located near a surface upon which frost tends to form, the second at the limit of allowable deposit of frost on said surface and the third beyond the reach of frost formation on said surface, said elements being of such nature that they change an electrical characteristic as a function of temperature, a circuit for balancing said electrical characteristics of said second and third elements, when their temperature difference is within a predetermined range, circuit means controlled by the degree of unbalance produced when their temperature difference exceeds a predetermined amount to initiate defrosting action and also to transfer control of defrosting termination to a circuit for balancing the electrical characteristics of the first and third elements, and means controlled by said last circuit for restoring the original circuit condition upon termination of defrosting.

6. In combination with a refrigerator en-

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closure having a cooling element therein and a thermostatic control system for maintaining a predetermined refrigerator temperature, an automatic defrosting system for said freezing element comprising a first temperature-sensitive electrical element located at a predetermined distance from a surface of said cooling unit upon which frost tends to form; a second temperature-sensitive electrical element located at a further distance from said freezing unit than said first element; a bridge circuit including both said elements for balancing respective electrical characteristics thereof; relay means connected in said bridge circuit; defrosting means for said cooling unit; control means for said defroster means actuated by said relay means upon attainment of a predetermined difference in electrical characteristic between said temperature-sensitive elements; a third temperature sensitive element located adjacent the surface of said cooling unit; a bridge circuit including said last temperature-sensitive element and a temperature-sensitive element more remote from the surface of said cooling unit; switching means controlled by said relay means for transferring control of said defrosting means from said first bridge to said second bridge; means controlled by a predetermined value of the output of said second bridge for restoring the initial circuit condition.

7. In combination with a refrigerator enclosure having a freezing element therein, an automatic defrosting system comprising a first temperature-sensitive electrical element located at a predetermined distance from a surface of the freezing unit upon which frost tends to form; a second temperature-sensitive electrical element located adjacent said surface, said elements being capable of influencing an electrical parameter of an electrical circuit of which they are a part; first and second electric means including each said element respectively; defrosting control

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means for controlling defrosting of said surface; circuit connections between said respective electric circuit means and said defrosting control means, whereby a predetermined temperature difference between said first temperature-sensitive element and the refrigerator enclosure remote from said freezing element changes the circuit parameters to actuate said defrosting means to initiate defrosting action; switching means actuated by the change in electrical parameters resulting from said predetermined difference for transferring control of said defrosting means from said first temperature-sensitive element to said second temperature-sensitive element; circuit connections between said second temperature-sensitive element and said defrosting control means for terminating the defrosting when a predetermined temperature difference between said second temperature-sensitive element and the refrigerator enclosure is attained; and means for restoring the initial circuit connections between said first temperature-sensitive element and said first electrical circuit upon termination of said defrosting action.

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