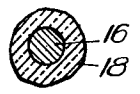
June 15, 1965 H. A. WAYNE 3,188,828

PHOTO-ELECTRIC ICE DETECTING DEVICE

Filed Dec. 4, 1961

2 Sheets-Sheet 1

Fig. 1



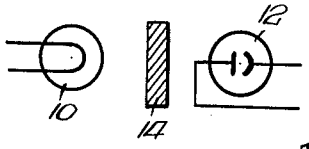
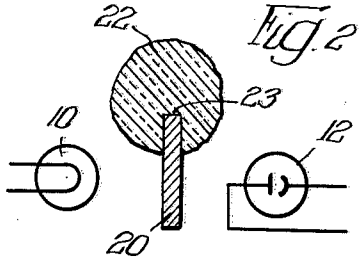


Fig. 3

Fig. 2



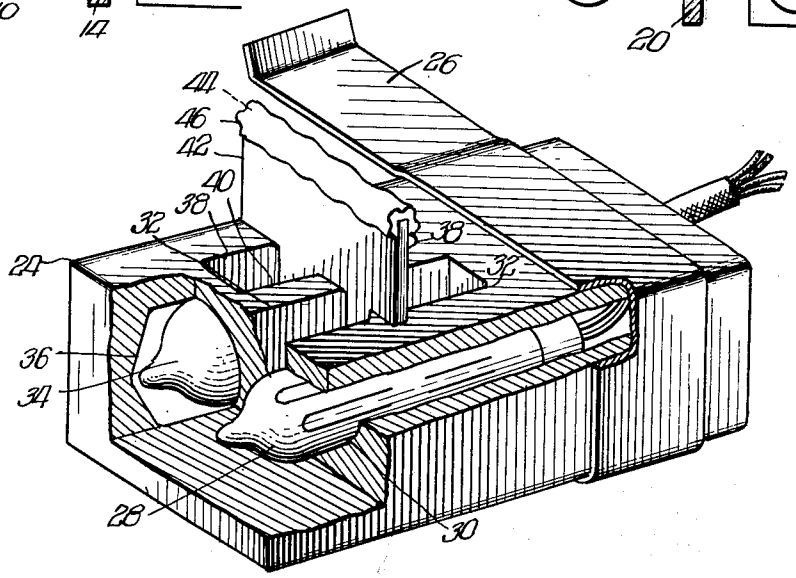
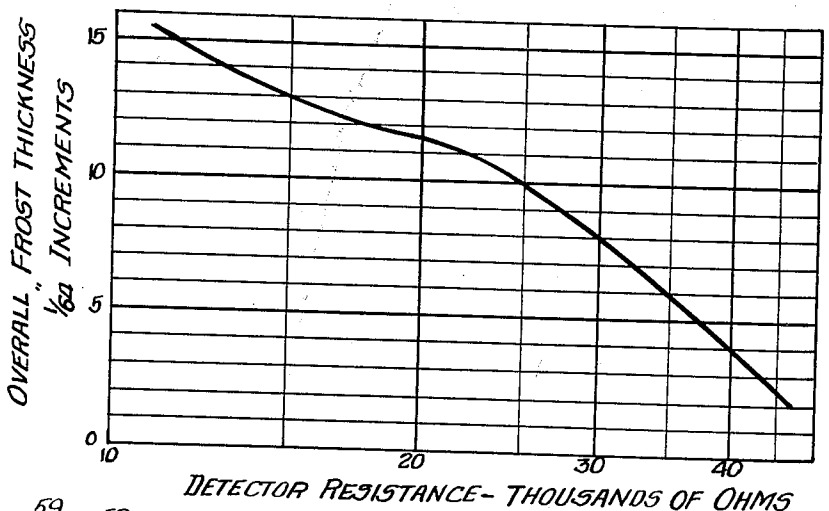


Fig. 4



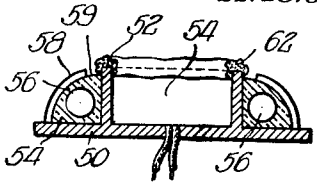


Fig. 5

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2 Sheets-Sheet 2

Fig. 6

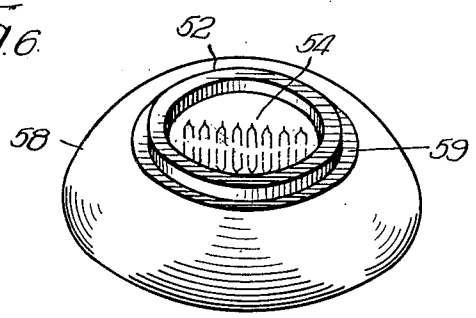


Fig. 7

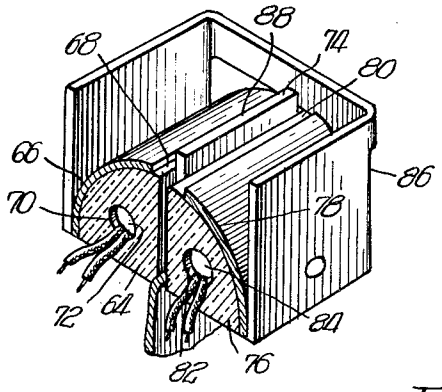


Fig. 8

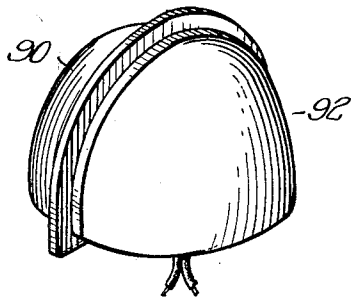
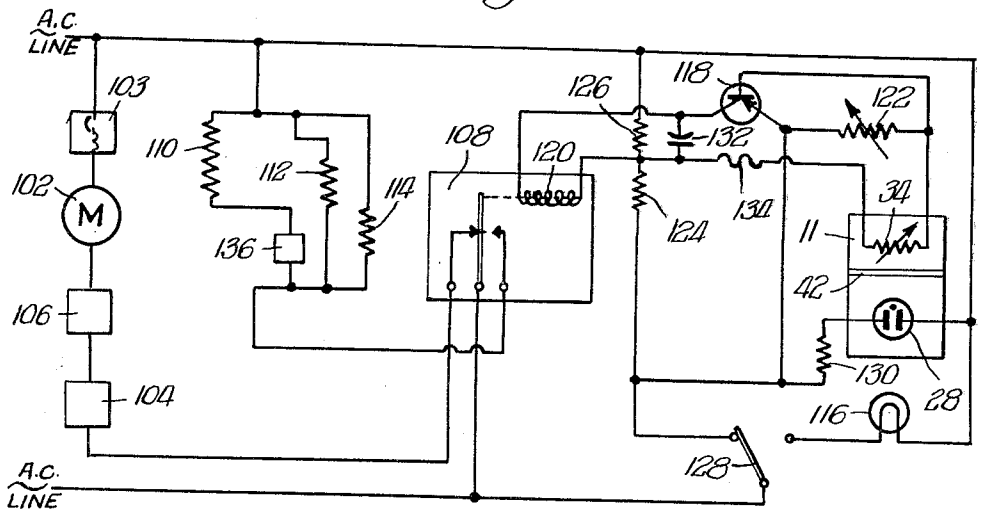


Fig. 9



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3,188,828

PHOTO-ELECTRIC ICE DETECTING DEVICE

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6 Claims. (Cl. 62—140)

This invention relates generally to means for controlling the formation of ice or frost, and more specifically, to means for detecting the presence of ice or frost, and in response thereto generating control signals which will enable an associated device to maintain the ice or frost level at some desired level.

In refrigerating equipment and particularly in modern household refrigerating equipment, the buildup of frost on the evaporator coils of the equipment represents a considerable problem. As the frost and/or ice builds up, it acts to insulate the refrigerated space from the cooling substance flowing through the evaporator with the result that temperatures are not maintained at the desired ambient levels. This in turn causes excessive operation of the pump or compressor motor of the refrigerating equipment in an attempt to maintain the refrigerated space at the desired temperature.

To overcome the problem of excessive motor operation or poor temperature control, many solutions have been proposed and used. One simple method of eliminating frost and/or ice provides a time clock which at some preselected interval shuts off the compressor and turns on a source of heat adjacent to the evaporator coils so as to melt the ice and frost thereon. Still another method similar to the above method but dispensing with the source of heat, shuts off the pump or compressor for a predetermined length of time, which on the average is long enough to permit the temperature inside of the refrigerated space to rise high enough to result in the melting of the frost and ice covering the evaporator coils. Another method which has been used to detect and eliminate frost and/or ice, detects the presence of frost or ice by means of a temperature sensing probe placed in the fluid conduit, extending from the evaporator, and containing the refrigerating medium. In this method obviously the temperature of the refrigerating medium is lower as the frost and ice buildup increases. Following this method, the change (decrease) in temperature is used to actuate a signaling device, which will in turn signal the refrigerating equipment to provide heat to remove the frost. Still another means of detecting the presence of frost involves the counting of the openings of the door to the refrigerated space, the thought being that the frost or ice buildup is directly proportional to the number of door openings.

From the above it is obvious that the previously known methods of detecting the presence of ice or frost are not completely reliable or desirable. For the cases of the time clocks or counting mechanisms, heat is applied to the refrigerated space, regardless of the amount of ice or frost buildup. With respect to the temperature probe inserted in the refrigerating conduit, while this method does depend upon the buildup of frost and ice, it also requires a very sensitive temperature probe, the temperature of the refrigerant varying only over a very small range, in response to quite large changes in the thickness of the frost or ice build-up on the evaporator coils. It is therefore an object of this invention to provide a means for detecting more exactly than heretofore possible, an ice or frost buildup in a refrigerated space.

The principal object of this invention is to provide a detecting device which has an output proportional to the thickness of ice or frost buildup upon the evaporating surface of the refrigerating equipment.

Still another object of this invention is to provide an

ice or frost detecting device of high reliability and low cost.

Yet another object of this invention is to provide an ice or frost detecting device with an output signal proportional to the thickness of ice or frost buildup over wide extremes.

An important object of this invention is to provide an ice or frost detecting device incorporating a surface on which ice or frost builds up at the same rate as, or proportional to, frost or ice buildup on the evaporator plates of the refrigerating equipment.

A still further object of the invention is the provision of simple low cost control circuit means in combination with the detecting device to produce a highly reliable frost or ice control system.

In attaining the foregoing object, the detecting device of the invention may briefly be described as including a radiant energy source and a radiant energy sensor placed adjacent to each other. Some form of mechanical barrier placed between the radiant energy source and sensor prevents the passage of radiant energy to the sensor during intervals when ice is not present in the refrigerated space. As a special feature of this invention, the barrier between the radiant energy source and sensor is advantageously an evaporator plate of the refrigerating equipment itself although this condition is not mandatory. In embodiments where the barrier strip is an integral part of or at the same temperature as the evaporator, the frost building up on the barrier at its termination between the sensor and source will cause light from the radiant energy source to be conducted to the sensor by one or some combination of the phenomena of reflection, refraction or scattering so that the output of the sensor is varied.

In other embodiments of the detecting device, the barrier strip may not be a portion of the evaporator assembly or even in intimate contact therewith. However, in all embodiments of the detecting device there is incorporated an accumulator surface which is at least in intimate contact with the evaporating surface, if not a part thereof. This accumulator surface may or may not be a portion of the barrier strip, but this surface is the element responsible for the accumulation of ice. The ice in turn causes the radiant energy to be reflected, scattered, refracted, or otherwise transmitted from the radiant energy source to the sensor, the amount of radiant energy thus transmitted being dependent upon the amount of frost or ice buildup on the accumulator.

While the invention is described in terms of detecting ice or frost it is to be understood that it may be used for the detection of any foreign material having light transmission characteristics. By light transmission characteristics it is meant reflection, refraction, light scattering and any other manner for communicating light from one point to another.

In the one embodiment decribed herein, the control circuit of the invention comprises a transistor operating off an A.C. line in conjunction with a relay and other circuit elements. This simple circuit is utilized to effect the switching of the sizeable amounts of power required in an ordinary defrost cycle of refrigerating equipment.

The invention both as to its features and advantages will best be understood upon reading of the specification with reference to the following drawings.

In the drawings:

FIGURE 1 is a schematic illustrating the principles employed in the detecting devices of the invention.

FIGURE 2 is a schematic illustrating an alternate configuration for detecting devices employing the principles of the invention.

FIGURE 3 is a perspective view, partly in section, illustrating one embodiment of the detecting device of the invention.

FIGURE 4 is a graph illustrating the sensitivity of the detecting device of FIGURE 3 to a buildup of frost or ice.

FIGURES 5 and 6 illustrate in section and perspective, respectively, still another embodiment of the detecting device of the invention.

FIGURE 7 illustrates yet another embodiment of the detecting device of the invention with FIGURE 8 being a modified form of the embodiment of FIGURE 7.

FIGURE 9 is an electrical schematic illustrating a typical method for employing the detecting devices of the invention in refrigeration equipment.

While this invention is especially suited for use with refrigerating equipment, it is to be understood that the invention has numerous other uses. For this reason, the references made to refrigerating equipment in this specification are merely by way of example and are not to be construed as limitations. As a matter of fact, it will be apparent that this invention has many applications in other fields, e.g., the field of process control.

Referring now to FIGURE 1, there is shown in schematic form an embodiment of the ice and frost detecting device of the invention. The detecting device is comprised of a light source 10, and a photocell 12. Positioned between the light source 10 and the photocell 12 is an opaque barrier strip 14 of sufficient length and height to prevent the light emanations of source 10 from directly reaching the photocell 12. Positioned above the barrier strip 14 is an accumulator 16. The accumulator 16 advantageously may be a part of the refrigeration equipment's evaporating surface, but alternately this accumulator may be a separate piece in intimate contact with the evaporating surface. As illustrated in FIGURE 1, the accumulator consists of a simple wire, although it will be appreciated by those skilled in the pertinent arts that flat plates or fins, both of which are frequently utilized in the refrigeration industry, may be equally well employed.

The accumulator 16 is drawn oversize to facilitate its illustration. In the absence of ice or frost on accumulator 16, approximately the same amount of light falls on photocell 12 as would fall if accumulator 16 were not present. However, as ice or frost builds up around accumulator 16, light from the radiant energy source 10 is principally reflected but may also be refracted or scattered by the ice 18 so as to impinge upon the photocell 12. The photocell 12 in response to the increase in radiant energy falling thereon, generates suitable changes in its output.

As will be self-evident to those skilled in the detector art, the photocell 12 may be of any type suitable to detect radiant energy of the type emitted by source 10. In most of the embodiments constructed to date, the cell has been a photoconductive type cell constructed of cadmium sulfide, which type cells are preferred because of their superior sensitivity and low cost. Another obvious modification of the schematic of FIGURE 1 is achieved when accumulator 16 is positioned transverse the position in which it is there illustrated. Such a modification is made use of in FIGURE 3 described further hereinbelow.

FIGURE 2 illustrates in schematic form the construction of an alternate type of the ice and frost detecting device. Here also a radiant energy source 10 is separated from a photocell 12 by means of an opaque barrier strip. This barrier strip 20 is of such size and so positioned that during periods when ice is not present on the detecting device, it prevents the transmission of the majority of radiant energy emitted by source 10 to the photocell 12. Unlike the device illustrated in FIGURE 1, the barrier strip 20 provides both the function of barrier strip and accumulator. The barrier strip 20 desirably is a contiguous portion of the evaporator of the refrigerating mechanism, but may alternately be a separate piece positioned in intimate contact therewith. In this embodiment as ice or frost 22 builds up on the accumulator surface 23, light from the radiant energy source 10 is principally refracted or scattered but may also be reflected by the ice 22 so as to impinge on the photocell 12.

FIGURE 3 illustrates in perspective and partly in section, the construction of a particular embodiment of the detecting device of the invention. A block of material 24, of high thermal conductivity, e.g., copper, is maintained in close contact with the evaporating surface of a refrigerator by means of spring clip 26. A radiant energy source 28 is positioned in a cavity 30 of the block 24 and transmits radiant energy to the exterior of the block by means of the square inclined openings 32. Although the openings 32 are shown as being empty, they may be filled with some transparent material such as methacrylate type plastic for the purpose of sealing the radiant energy source from the ambient surrrounding and thus preventing the entry of dirt or moisture into the cavity 30.

A photocell 34 is positioned in a second cavity 36 within block 24. Radiant energy is permitted entry to the cavity 36 and thus to impinge upon the photocell 34 by means of two square openings 38. As with the openings 32, advantageously the square openings 38 are sealed with some clear plastic to prevent dirt or moisture from reaching the cavity 36 and the photocell 34.

As may be readily seen from the drawings, the wall 40 separating the square holes 32 and 38 functions as a barrier strip to prevent the light emitted by the radiant energy source 28 from impinging directly upon the photocell 34. An accumulator surface 42 of high thermal conductivity extends from and is contiguous with block 24. In an alternate construction, the accumulator strip 42 is constructed separately from the block 24 and is secured mechanically to the block 24 as by brazing. As frost or ice forming conditions occur within the refrigerated space, the ice tends to form first on the outer termination 44 of the accumulator strip 42. As the buildup of ice and/or frost 46 continues on the strip 42, increasing quantities of the radiant energy emanating from the source 28 are reflected from the ice or frost 46 through the two square openings 38 effecting a change in the output signal of the photocell 34. Depending on the composition of the ice or frost 46, it may, under the influence of the source 28, take on the appearance of a luminous body because of refraction and/or scattering occurring within it. The ice taking on the appearance of a luminous body affects changes in the output of the photocell 34 similar to those which occur due to reflection. Since in either event the amount of radiant energy striking the photocell 34 is related to the size of the buildup of the ice or frost, it can be seen that a device has been provided that is quantitatively responsive to the buildup of frost and ice.

FIGURE 4 illustrates in graphic form the sensitivity of the device of FIGURE 3 to various amounts of ice or frost upon its accumulator strip 42. In the graph of FIGURE 4 the resistance of the photocell 34 is plotted as the abscissae, and the ordinates represent the thickness of frost on the accumulator strip 42 measured in increments of $\frac{1}{64}$". As can be seen by inspection of the figure, the cell resistance is quite linear with respect to frost depth over a range of approximately $\frac{1}{32}$" to $\frac{1}{4}$" of frost or ice. This condition of linear cell output is highly desirable when constructing a control circuit to be operated by the detecting device.

FIGURES 5 and 6 illustrate the construction of another embodiment of the detecting device of the invention. A base plate 50 is provided, which base plate advantageously is constructed of a material having good thermal conductivity. In use, the base plate 50 is mounted in intimate contact with the evaporating surface of the refrigeration apparatus. An annular ring 52 of some material also having good heat conducting properties is secured to, or contiguous with, the base plate 50. A photocell 54 of any suitable type is positioned within the annular

ring 52 and sealed from contact with the surrounding by means of a clear plastic such as those of methacrylate type. Surrounding the annular ring 52 is a light source annular ring 54 comprised of a light conducting substance such as a clear plastic of the methacrylate type. Within the annular ring 54 are positioned one or more light sources 56, which advantageously may be of the neon type and have in actual practice been of the type commercially available under the number NE–51H. An opaque coating 58 blocks the emergence of light from all but a narrow annular slot 59 of the light source annular ring 54. Desirably, at least the interior surface of opaque coating 58 is reflective to assist in increasing the intensity of the light transmitted through the slot 59.

As conditions favorable to the formation of ice and frost develop within the refrigerated space, ice builds up on annular ring 52. In this embodiment the annular ring 52 functions both as an ice or frost accumulator and as a barrier strip. As ice 62 builds up on the accumulator strip 52, light from the source 56 is transmitted by one or some combination of the phenomena of reflection, refraction, or scattering from or within ice 62 to the cell 54, which in turn responds with appropriate changes in its output characteristics. The device of FIGURES 5 and 6 is well adapted to work in any environment where ambient illumination is low. A particular advantage of the device of FIGURES 5 and 6 occurs when the photocell and slot 59 are visible to the user of the refrigerated space. This advantage is an unusual appearance reminiscent of cat's eyes which is produced and which lends itself well to certain types of sales advertising campaigns.

FIGURE 7 illustrates in perspective and partly in section the construction of yet another embodiment of the detecting device of the invention. This embodiment of the invention is quite similar to what would be attained if the embodiment of FIGURES 5 and 6 were laid out in a straight line. A piece of light conducting material 64 having an opaque coating 66 on all but the surface 68 and containing a recess 70 into which a light source 72 is positioned, is placed adjacent to the accumulator-barrier strip 74. In the embodiment of FIGURE 7 the accumulator-barrier strip 74 is advantageously a part of the refrigerator's evaporator surface. A light conducting block 76 coated with an opaque material 78 on all but one surface 80 thereof, and containing a recess 82 in which is positioned a photocell 84 is positioned adjacent to but on the opposite side of the accumulator-barrier strip 74 to that occupied by the block 64. The two blocks 64 and 76 are held in position with respect to each other and the accumulator-barrier strip 74 by means of the spring clamp bracket 86. As frost or ice builds on the surface 88 of the accumulator-barrier strip 74, light from the source 72 transmitted through the block 64 and emerging through the surface 68 thereof is either reflected, refracted, or scattered, depending on the type of ice or frost, to enter the block 76 through the uncoated surface 80, and thereupon impinge upon the cell 84.

The detecting device embodiment illustrated in FIGURE 8 is almost exactly the same as the embodiment of FIGURE 7, but due to the half-hemisphere shape of each of the blocks 90 and 92, provides considerably longer uncoated surfaces than the uncoated surfaces 68 and 80 of the device of FIGURE 7. Because of these longer uncoated surfaces, and also the increased length of the accumulator-barrier strip, the detecting device of FIGURE 8 is considerably less sensitive than the device of FIGURE 7 to foreign matter such as water droplets, dirt, etc., since the over-all illumination of the photocell is changed proportionately less by the foreign matter.

FIGURE 9 is an electrical schematic illustrating a control circuit employing the detecting device of the invention and useful for controlling the frost buildup of a typical household refrigerator. As a normal practice in such a refrigerator, a compressor motor 102 with an overload breaker 103 is connected across an A.C. line and is controlled by a thermostat 104 through a starting relay 106. It will be noted from an examination of FIGURE 9 that the motor 102 is not connected directly across the A.C. line but instead is connected to the line through a control relay 108. The relay 108 is so connected that alternately the compressor motor may be operated or the various defrost heaters 110, 112 and 114 activated. The method of defrosting employed with this illustrative control circuit utilizes resistive type heaters to raise the temperature of the refrigerated space and thus accomplish defrosting. Equally as practicable would be the substitution of solenoid controlled valves for the defrost heaters. When such valves are employed, evaporator temperature is or may be raised by means of reverse cycling of the refrigerant fluid.

The control relay 108 is actuated to disconnect the compressor motor and connect the defrost heaters, whenever frost or ice buildup at a preselected location in the refrigerated space reaches some preselected thickness. This frost or ice buildup is detected by the detecting device indicated at 11 and which advantageously may be the detecting device illustrated in FIGURE 3. As can be seen in FIGURE 9, the entire control circuit for the relay 108 is actuated by the door switch 128 which connects the control circuit across the A.C. line only when the door to the refrigerated space is closed. For some embodiments of the inventive detecting device, such a connection of the control circuit is desirable, since, when the door is open, the refrigerator light 116 or the ambient light on the exterior of the refrigerator may saturate the detecting photocell rendering a false indication of frost or ice buildup at least possible.

A transistor 118, utilized both as an amplifier and half wave rectifier, has its emitter connected through the door switch 128 to one side of the A.C. line. The collector of the transistor 118 is connected to one terminal of the coil 120 of the control relay 108 and the base is connected to the center point of a voltage divider comprised of the detecting device's photocell 34 and a variable resistor 122. The variable resistor 122 is employed for the purpose of adjusting the triggering level (switching action) of the transistor 118 and hence the selected thickness of ice or frost to which the control circuit will respond. The second terminal of both the photocell 34 and the relay coil 120 is a common point at the center of a voltage divider comprised of the resistors 124, 126 and, which are in term, connected across the A.C. line through the door switch 128.

In operation, whenever the door to the refrigerated space is closed, the door switch 128 connects the control circuit to the A.C. line energizing the neon light source 28 through the resistor 130 and providing bias to the photoconductive cell 34. As ice or frost builds up on the accumulator strip 42, increasing amounts of light from source 28 are transmitted to the cell 34 whose resistance drops proportionately. As the resistance of the cell 34 drops, the voltage at the base of the transistor 118 increases. When the ice has increased to the point where the resistance of the cell 34 is low enough and the voltage at the base of the transistor high enough, sufficient current flows through the coil 120 of control relay 108 to energize it. This conduction is only for alternate half cycles of the supply frequency so the condenser 132 is provided to prevent chattering of the relay 108. As explained above, closing the relay disconnects the compressor motor and connects the defrosting means. Defrosting continues until thermostat 134 opens interrupting the control circuit and reconnecting the compressor motor to the line. In the majority of applications of the control circuit that have thus far been used, it has been found advantageous to have this thermostat actuate at 70° F, although the actual temperature of actuation to be used depends on the frost or ice thickness initially tolerated, thermostat location, etc. As a safety factor to prevent

damage to the interior of the refrigerated space, a second thermostat 136 may be connected in the heater circuit to interrupt power to the main defrost heaters whenever box temperature rises to unsafe levels. Obviously both of the thermostats 134 and 136 may in some applications be completely dispensed with and frost control made completely dependent on operation of the detecting device.

While several embodiments of the detecting device and control circuit of the invention have been shown and described, it is obvious that many further variations will be brought to mind by the foregoing. As a result, it is not my intention to be limited to only those embodiments described but to be limited only by the scope of the following claims.

I claim:

1. A control device employing a source of electrical power for maintaining within preselected limits, the build-up on a surface of a foreign material having light transmission characteristics comprising:

a source of radiant energy connected to said power source,

sensor means connected to said power source, said sensor means being adapted to detect the presence of radiant energy emanating from said source and provide a control signal proportional to the amount of radiant energy detected,

barrier means disposed between said source and said sensor for preventing direct irradiance of said sensor by radiant energy emanating from said source,

means for accumulating said foreign material, said foreign material increasing the transfer of radiant energy from said source to said sensor in proportion to the amount of said foreign material accumulated,

relay means connected to said power source,

switching means connected to said sensor means and said relay means for energizing said relay means in response to said control signal,

means responsive to electric power to increase the buildup of said foreign material on said surface,

means responsive to electric power to decrease the buildup of foreign material on said surface,

and contact means actuatable by said relay means for alternately connecting said electrical power source to said means for increasing the buildup of said foreign material or to said means for decreasing the buildup of said foreign material.

2. A control device employing a source of electrical power for maintaining within preselected limits, the build-up on a surface of a foreign material having light transmission characteristics comprising:

a source of radiant energy connected to said power source,

sensor means for detecting the presence of radiant energy emanating from said source and providing a control signal in response thereto, said electrical power source being connected to said sensor means for providing bias thereto,

barrier means disposed between said source and said sensor for preventing direct irradiance of said sensor by radiant energy emanating from said source,

means for accumulating said foreign material, said foreign material increasing the transfer of radiant energy from said source to said sensor in proportion to the amount of said foreign material accumulated,

relay means connected to said electrical power source,

switching means connected to said sensor means and said relay means for energizing said relay means in response to said control signal,

means responsive to electric power to increase the buildup of said foreign material on said surface,

means responsive to electric power to decrease the buildup of said foreign material on said surface,

contact means actuatable by said relay means for alternately connecting said electrical power source to said means for increasing the buildup of said foreign material or to said means for decreasing the buildup of said foreign material,

and selectively adjustable bias means biasing said switching means for affecting changes in the limit of foreign material buildup in response to which said sensor energizes said switching means.

3. A control device employing a source of electrical power for maintaining within preselected limits, the build-up on a surface of a foreign material having light transmission characteristics comprising:

a source of radiant energy connected to said power source,

sensor means for detecting the presence of radiant energy emanating from said source and providing a control signal in response thereto, said electrical power source being connected to said sensor means for providing bias thereto,

barrier means disposed between said source and said sensor for preventing direct irradiance of said sensor by radiant energy emanating from said source,

means for accumulating said foreign material, said foreign material increasing the transfer of radiant energy from said source to said sensor in proportion to the amount of said foreign material accumulated,

said means being positioned in intimate contact with said surface,

relay means connected to said electrical power source,

switching means connected to said sensor means and said relay means for energizing said relay means in response to said control signal,

means responsive to electric power to decrease the buildup of said foreign material on said surface,

and contact means actuatable by said relay means for connecting said electrical power source to said means for decreasing the buildup of foreign material.

4. A control device employing a source of electrical power for maintaining within preselected limits, the build-up on a surface of a foreign material having light transmission characteristics comprising:

a source of radiant energy connected to said power source,

sensor means connected to said power source, said sensor means being adapted to detect the presence of radiant energy emanating from said source and provide a control signal proportional to the amount of radiant energy detected,

barrier means disposed between said source and said sensor for preventing direct irradiance of said sensor by radiant energy emanating from said source,

means for accumulating said foreign material, said foreign material increasing the transfer of radiant energy from said source to said sensor in proportion to the amount of said foreign material accumulated,

relay means connected to said power source,

switching mans connected to said sensor means and said relay means for energizing said relay means in response to said control signal,

means responsive to electric power to increase the buildup of said foreign material on said surface,

and contact means responsive to the energization of said relay means for disconnecting said electrical power source from said means for increasing the buildup of foreign material.

5. A device for detecting the presence of a light dispersing and/or reflecting material such as ice on a surface comprising: a source of radiant energy, sensor means for detecting the presence of radiant energy from said source, an opaque barrier means between said source and said sensor for obstructing substantially all irradiance of said sensor by radiant energy emanating from said source when said material to be detected is not present on said device, and means for accumulating said material at a position optically visible to both said source and said sensor means, said accumulating means itself having substantially no effect on the output of said sensor means

and being spaced from said source, said sensor means, and said barrier and positioned so that any accumulated material thereon is at least partially in the path of the radiant energy emanating from said source whereby the light impinging on said material is transmitted across said barrier with a portion thereof being radiated onto said sensor means.

6. A device for detecting the presence of a light dispersing and/or reflecting material such as ice on a surface comprising: a source of radiant energy sensor means for detecting the presence of radiant energy from said source, an opaque barrier means between said source and said sensor for obstructing substantially all irradiance of said sensor by radiant energy emanating from said source when said material to be detected is not present about said device and means for accumulating said material at a position optically visible to both said source and said sensor means, said accumulating means itself having substantially no effect on the output of said sensor means, and being spaced from said source, said sensor means and said barrier and is positioned so that any accumulated material thereon is at least partially in the path of the radiant energy emanating from said source whereby the light impinging on said material is transmitted across said barrier with a portion thereof being radiated onto said sensor means, said accumulating means forming a continuous part of said surface.

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ROBERT A. O'LEARY, *Primary Examiner.*

MEYER PERLIN, *Examiner.*