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Otaki

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[45] **Dec. 11, 1973**

[54] **DEFROSTING METHOD AND APPARATUS**

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[52] **U.S. Cl.** **62/81,** 62/156, 62/160

[51] **Int. Cl.** **F25d 21/06**

[58] **Field of Search** 62/140, 156, 80, 62/81, 22, 160

[56] **References Cited**

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Primary Examiner—Meyer Perlin

Attorney—John J. McGlew et al.

[57] **ABSTRACT**

In a method of defrosting a first heat exchanger, on the heat source side of refrigerating apparatus having a second heat exchanger on the utilization side and a fluid flow circuit interconnecting the two heat exchangers, the maximum temperature difference between the inlet fluid temperature and the outlet fluid temperature of the second heat exchanger is determined. During operation of the refrigeration apparatus, the difference between the inlet and outlet fluid temperatures of the second heat exchanger is detected and, when the ratio of the detected temperature difference to the maximum temperature difference decreases below a preset value, due to icing or frosting of the first heat exchanger, defrosting of the first heat exchanger is initiated. The apparatus includes temperature sensing means detecting the inlet fluid temperature and the outlet fluid temperature of the second heat exchanger and conjointly controlling swinging of a first lever about a pivot. In moving toward the maximum temperature difference, the first lever carries with it a second lever which is pivoted coaxially with the first lever. When the temperature difference decreases, the first lever moves in the reverse direction with the second lever being retained in its position and, after a preselected movement of the first lever relative to the second lever, a switch means is operated to initiate the defrosting operation, with the defrosting operation being terminated upon return of the first lever to the position of the second lever.

10 Claims, 11 Drawing Figures

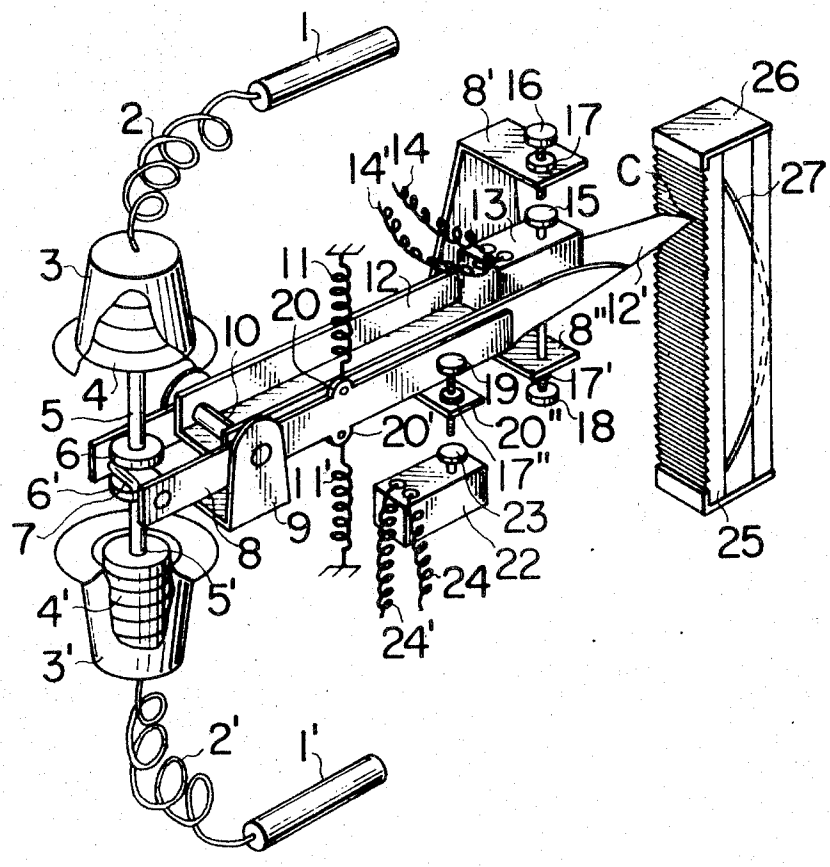


FIG. 1

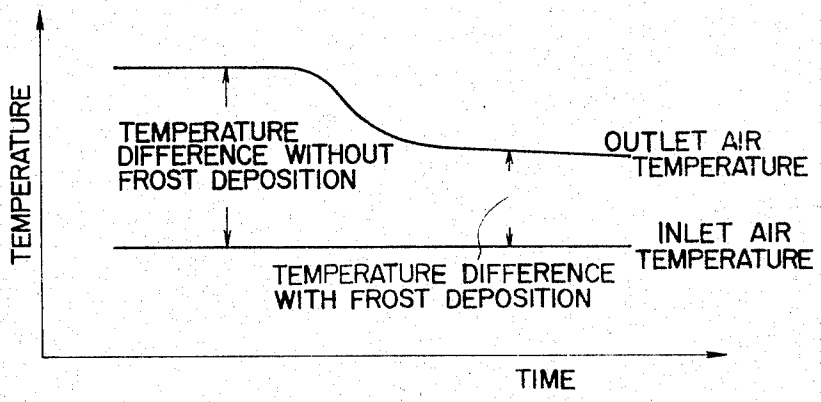

TEMPERATURE
TEMPERATURE DIFFERENCE WITHOUT FROST DEPOSITION
OUTLET AIR TEMPERATURE
INLET AIR TEMPERATURE
TEMPERATURE DIFFERENCE WITH FROST DEPOSITION
TIME

FIG. 2

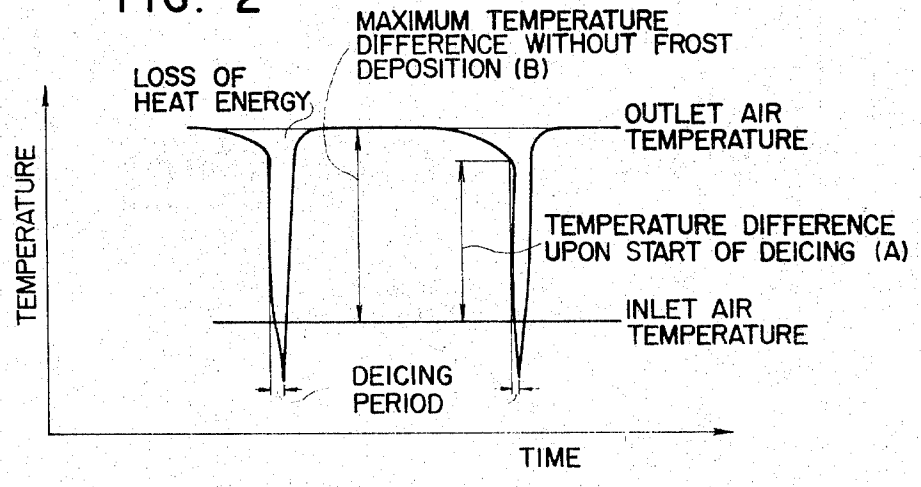

MAXIMUM TEMPERATURE DIFFERENCE WITHOUT FROST DEPOSITION (B)
LOSS OF HEAT ENERGY
OUTLET AIR TEMPERATURE
TEMPERATURE DIFFERENCE UPON START OF DEICING (A)
INLET AIR TEMPERATURE
DEICING PERIOD
TEMPERATURE
TIME

FIG. 3

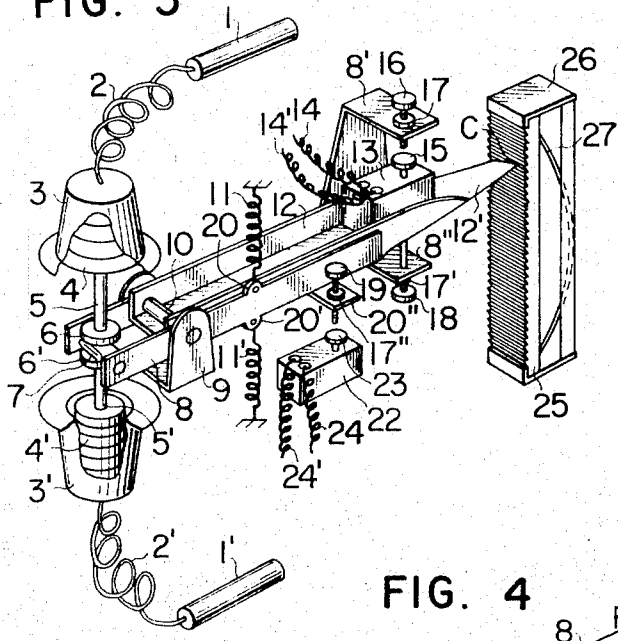


FIG. 3A

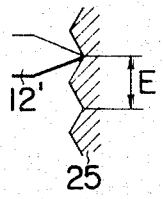


FIG. 4

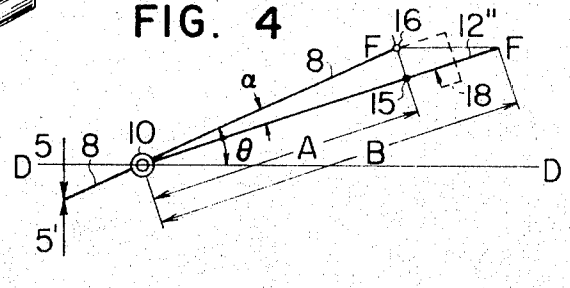


FIG. 5

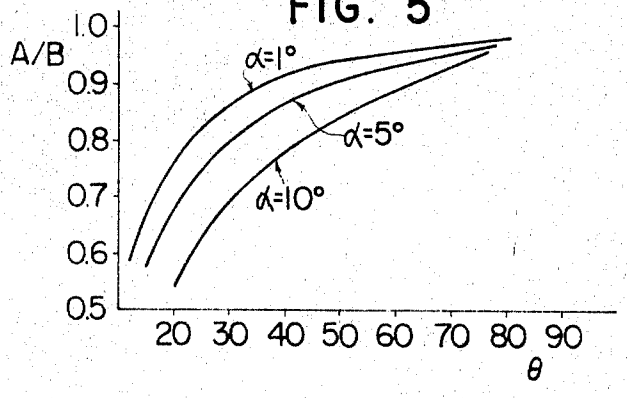


FIG. 6

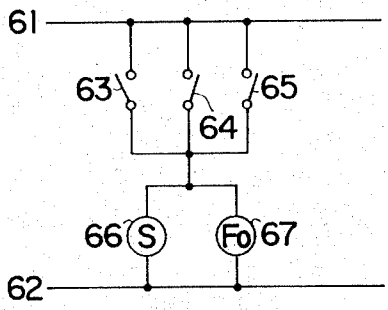


FIG. 7

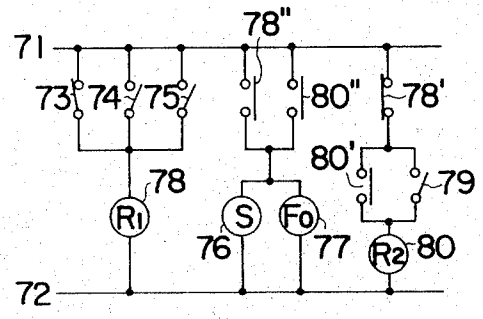
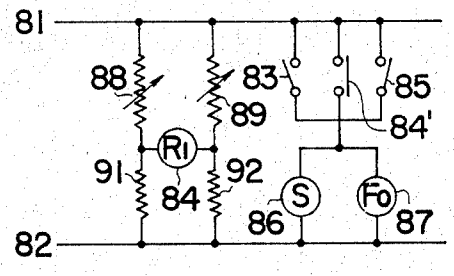


FIG. 8



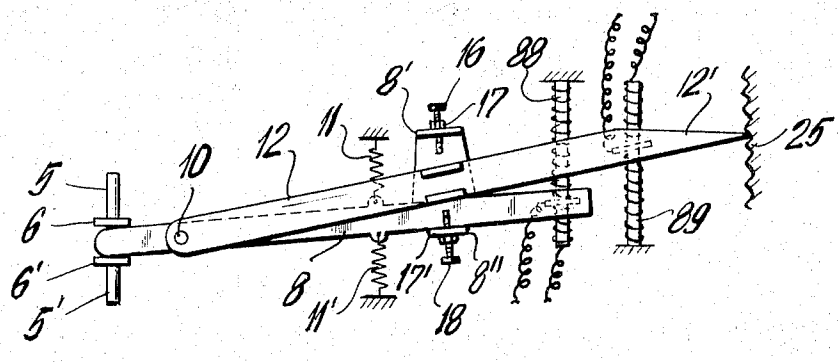

16
8'
17
88
12'
11
12
10
5
6
6'
5'
8
11'
17'
18
8''
89
25

FIG.9

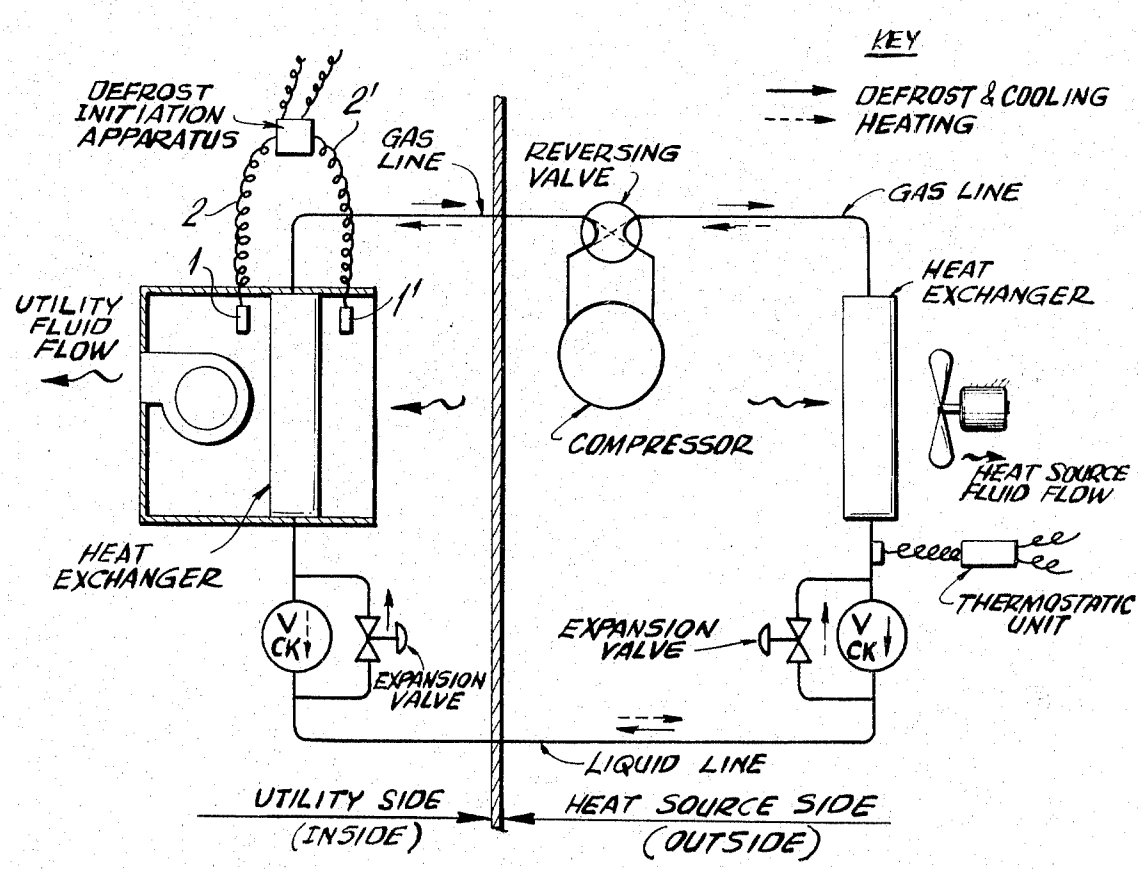

KEY
DEFROST & COOLING
HEATING
DEFROST INITIATION APPARATUS
2'
GAS LINE
REVERSING VALVE
GAS LINE
2
1
1'
HEAT EXCHANGER
UTILITY FLUID FLOW
COMPRESSOR
HEAT SOURCE FLUID FLOW
HEAT EXCHANGER
THERMOSTATIC UNIT
V CK
EXPANSION VALVE
EXPANSION VALVE
V CK
LIQUID LINE
UTILITY SIDE (INSIDE)
HEAT SOURCE SIDE (OUTSIDE)

FIG.10

DEFROSTING METHOD AND APPARATUS

FIELD OF THE INVENTION

This invention relates to defrosting methods and apparatus and, more particularly, to a novel and improved method and apparatus for defrosting a heat exchanger, on the heat source side of refrigeration apparatus, responsive to measurement of the temperature difference between the inlet fluid and the outlet fluid of a second heat exchanger on the utilization side of the refrigeration apparatus.

BACKGROUND OF THE INVENTION

In refrigeration apparatus of the conventional heat pump type including a heat exchanger on the heat source side on which frost is deposited, the defrosting time has been determined on the basis of changes in state, such as windage loss, etc., due to the frosting thereof or, alternatively, defrosting has been carried out periodically by means of timers. Thus, defrosting can be carried out by means of a timer or based on detection of air pressure loss in an outdoor coil, on utilization of the temperature difference between the outdoors and that of the refrigerant, or on detection of a decrease in the rate of air flow through the outdoor unit. As a consequence, changes in state of an indoor heat exchanger, on the utilization side of the refrigeration apparatus, and which accurately indicate a decrease in the efficiency of heat exchange, have not been detected. The detection time has been determined indirectly with reference to a decreased degree in the heat exchange efficiency, from the operating conditions. Known methods have the defects of being influenced by outdoor weather conditions and by interior temperatures.

Thus, a heat exchanger on the heat source side of a refrigeration apparatus, and placed outdoors, is coated with frost or ice in dependence upon the operating conditions. As seen from the graph of FIG. **1**, when the frost accumulation exceeds a certain limit, the heat exchangeability begins to decrease and the heat extraction due to the outdoor heat exchanger begins to decrease and gradually approach, in ability, the input of a compressor. In such a case, the accomplishment coefficient, which is the ratio of heat exchangeability to unit input, approaches **1**, so that the heat pump is of little effect. Thus, it is necessary to melt away the frost prior to serious reduction of the efficiency due to the frost accumulation.

This condition is shown in FIG. **2**. In the condition shown in FIG. **2**, an extremely frequent defrosting results in an increase of the area of the hatched regions shown in FIG. **2**, or an increase in the heat exchange by defrosting, which is unfavorable. As a result, it is necessary to detect the time for defrosting initiation as a function of the least loss over the time period of operation. Based on experience, this is the time when the ratio of the temperature difference between A and B, shown in FIG. **2**, attains a value of 0.8 to 0.9. ARI Standard 240, in the United States of America, requires the ratio to be above 0.9 at the time of defrosting, and the ratio of the defrosting period to the overall period of operation to be less than 20 percent.

SUMMARY OF THE INVENTION

The present invention is directed to providing a defrosting method and apparatus by which there is detected a defrosting initiation time at which the loss of heat transfer capability, due to deposition of frost and defrosting during an operating period of refrigeration apparatus, is minimized. Briefly, in accordance with the invention, the maximum temperature difference across a heat exchanger on the utilization side of the refrigeration apparatus is determined, and the time at which the ratio of the temperature difference across this heat exchanger to the maximum temperature difference thereacross is decreased to a certain value is detected. The method of the invention may be practiced with mechanical, electrical and electronic apparatus. Furthermore, the method and apparatus of the invention are applicable equally to mechanical refrigeration apparatus, electrical refrigeration apparatus, and other types of refrigeration apparatus.

An object of the invention is to provide an improved method of defrosting the heat exchanger on the heat source side of refrigeration apparatus.

Another object of the invention is to provide improved defrosting apparatus for defrosting the heat exchanger on the heat source side of refrigeration apparatus.

A further object of the invention is to provide such a method and apparatus in which defrosting of the heat exchanger, on the heat source side of a refrigeration apparatus, is initiated responsive to the temperature difference across a second heat exchanger, on the utilization side of the refrigeration apparatus, decreasing to a predetermined value.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIGS. **1** and **2** are graphical illustrations of the changes in heat exchangeability, as influenced by frost accumulation, in a heat exchanger on the heat source side of refrigeration apparatus, with FIG. **1** illustrating the case in which the frost is not melted and FIG. **2** illustrating the case where defrosting is effected periodically;

FIG. **3** is a somewhat schematic perspective view of apparatus embodying the invention;

FIG. **3A** is an enlarged sectional view of a portion of FIG. **3**;

FIG. **4** is a diagrammatic illustration of the main elements of the machine shown in FIG. **3**;

FIG. **5** is a graphic illustration of the operation of the element shown in FIG. **4**;

FIGS. **6**, **7** and **8** are schematic wiring diagrams of three different embodiments of electric control means in accordance with the invention;

FIG. **9** is a schematic diagram of apparatus embodying the invention and utilizing adjustable resistors, in correspondence with FIG. **8**; and

FIG. **10** is a schematic diagram of refrigeration apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **3**, a temperature-sensitive cylinder **1**, arranged at the outlet of a heat exchanger on the utilization side of a refrigeration apparatus, is connected by capillary tubing **2** to a bellows **4** one end of which

is fixed against movement by a fixture 3. The movable end of bellows 4 carries a pin 5 on which is secured to a disk 6 which transmits displacement of pin 5 to a pin 7 on one end of a lever 8. A similar temperature-sensitive cylinder 1' is arranged at the inlet of the heat exchanger on the utilization side of the apparatus, and connected by capillary tubing 2' to a bellows 4' having one end fixed by a fixture 3' and whose movable end carries a pin 5' secured to a disk 6' engaging pin 7 in opposition to disk 6. Thus, the pin 7 is subjected to the difference between the temperatures measured by cylinders 1 and 1', or the temperature differs between the outlet and inlet sides of the heat exchanger on the utilization side of the refrigeration apparatus.

Lever 8 is pivotal about a pin 10 mounted on a fixture 9, and has arms 8', 8'' and 20''. Arm 8' adjustably receives a screw 16, provided with a lock nut 17, for operating a switch 13 through the medium of a switch operator 15. Arm 8'' adjustably receives a screw 18, provided with a lock nut 17', for engagement with a second lever 12 which is also pivoted on pin 10. Arm 20' adjustably receives a screw 19, provided with a lock nut 17'', for operating a switch 22 through a switch operator 23. Lever 8 also has arms or projections 20 and 20' to which respective springs 11 and 11' are connected, at one end, the opposite ends of these springs being connected to fixed points.

As stated, lever 12 turns about pin 10, or coaxially with lever 8. Lever 12 mounts switch 13, and has a pointed tip 12' cooperable with a finely serrated member 25 positioned in the housing 26 and biased toward point 12' by a spring 27. Switch 13 has conductors 14 and 14' connected thereto, and switch 22 has conductors 24 and 24' connected thereto.

When there is no difference in the air temperature between the inlet and the outlet of the heat exchanger on the utilization side, the pressures in temperature-sensitive cylinders 1 and 1' are identical and lever 8 occupies a preselected position, such as the position D—D, for example, shown in FIG. 4. When a heat exchange operation is initiated, the pressure in temperature-sensitive cylinder 1 increases and a force, corresponding to the pressure difference between the temperature-sensitive cylinders 1, 1', is applied to pin 7. As a result, lever 8 swings counterclockwise about pin 10 to an extent determined by the springs 11, 11'. Screw 18 causes lever 12 to turn through the same angle against the resistance of the serrations of member 25 engaging lever tipped end 12'.

At the maximum temperature difference, which is shown at B in FIG. 2, lever 12 is fixed against movement relative to member 25 by engagement of tip 12' with the serrations, since there is no longer any force exerted on lever 12 by screw 18 due to there being no further motion of lever 8. Thus, the maximum temperature difference is determined and stored by lever 12. The bias wich which member 25 is engaged with lever tip 12' is so determined as to resist the force, in the working direction, required to operate the operator 15 of switch 13. As best seen in FIG. 3A, one pitch E of the finely divided serrations of member 25 is considered to be the maximum error, and is so determined so as not to interfere with the operation, in dependence on the length of lever 12 and the pitch magnitude.

Upon a decrease in the temperature difference from the maximum value, lever 8 turns clockwise in the direction of a decreased temperature difference, moving away from lever 12. After a predetermined clockwise movement of lever 8, screw 16 on arm 8' engages and depresses operator 15 of switch 13 mounted on lever 12, which latter remains stationary. Thereupon, switch 13 is operated so as to either establish a connection between conductors 14 and 14', or to break such a connection, to provide a defrosting initiation signal. When defrosting has set in, operator 15 is continuously pushed, switch 13 remaining operated, and lever 12 being pushed downwardly over a serration of member 25, due to the rapid drop of the air temperature at the outlet of the heat exchanger on the utilization side, since a switching valve for cooling and heating of the refrigeration apparatus, and which has not been shown, has a cooling position. On the other hand, when the frost on the heat exchanger on the heat source side of the refrigeration apparatus is melted away, the latter is generally returned to its initial heat exchange operation by suitable means, such as the temperaure of the heat exchanger on the heat source side, or outdoors, pressure, reflection of light, or a change in electrical resistance, in a known manner. Under these conditions, lever 8 again turns in a counterclockwise direction responsive to an increase in the temperature difference between the inlet and outlet sides of the heat exchanger on the utilization side, operation of switch 13 is discontinued, and screw 18 moves lever 12 against the resistance of member 25. Thus, the described cycle is repeated.

If the heating operation does not start in spite of melting away of the frost, for any reason, the outlet temperature of the heat exchanger on the utilization side drops extremely. To prevent this, screw 19 is so positioned as to operate the operator 23 of switch 22 and, responsive to operation of switch 22, a signal for a forced heat exchange operation can be developed between the conductors 24 and 24'.

An outline of the operation during a normal defrosting cycle is illustrated in FIG. 4. In this case, when the temperature difference is zero, lever 8 is on the line D—D. At a maximum temperature difference, the line connecting the axis of pin 10 with the operating point of operator 15, and the line connecting the tip of screw 16 with the axis of pin 10, make an angle α with each other. The angle between the line connecting the center of screw 16 with the axis of pin 10 and the line D—D is θ. The angle θ is proportional to the temperature difference determined in dependence on various operating conditions. The point F is the intersection of a line drawn parallel to the line D—D, through the center of screw 16, with the line connecting the center of operator 15 and the axis of pin 10. The ratio of the temperature difference at this time, where a signal for initiating defrosting is provided, to the maximum temperature difference, which is the ratio A/B of FIG. 2, is A/B in FIG. 4, and is indicated graphically in FIG. 5. At this time, θ, α, and A/B have the relation shown in FIG. 5. Of course, an adjustment may be effected so that there is no change in the ratio A/B, by changing the angle θ.

FIG. 6 is a schematic diagram of the electric circuit of the apparatus without the switch 22. An operating potential is applied across the terminals 61, 62 and the reference character 63 indicates a switch forming part of the indoor thermostat and which is closed when the refrigerating apparatus has stopped operating. The switch 64 is the connection between the conductors 14, 14' of FIG. 3, and the switch 65 provides the signal for

termination of defrosting. The operating winding for a switching valve in the refrigerant circuit is indicated at **66**, and the winding controlling the outdoor fan motor is indicated at **67**.

When the refrigerating apparatus stops operating under the control of the indoor thermostat, the temperature difference at the utilization side becomes near zero. At this time, switch **63** of the thermostat operates in a manner so as not to provide a defrosting start signal. Assuming that the switch **65** is a thermostat operated switch, defrosting is not effected until the temperature of the outdoor coil drops to a certain extent, depending upon the preselection of its working point. For terminating defrosting, the thermostat is so selected that the temperature of the outdoor coil may indicate a condition under which the ice or frost has been completely melted. When all the switches **63, 64** and **65** operate, the control windings **66** and **67** are deenergized, and defrosting is initiated. The switch **65** of the defrosting termination thermostat provides a defrosting termination signal when it is closed, and the heating operation is restarted.

The circuit diagram of FIG. **7** is used with the switch **22.** Referring to FIG. **7**, an operating potential is applied at the terminals **71, 72,** and the switch **73** constitutes a switch of the indoor thermostat with the siwtch **74** being the connection between the conductors **14, 14'** of FIG. **3.** A switch **75** is provided to generate a defrosting termination signal. A relay **78** has a normally closed contact **78'** and a normally open contact **78''**, with contact **78''** controlling the energizing circuit of relay or operating windings **76** and **77.** Switch **79** represents the connection between conductors **24, 24'** of switch **22,** and **80'** represents holding contacts of relay **80** which also has normally open contacts **80''**.

If switch **79** is closed with switch **74** remaining open while lever **8** pushes lever **12,** that is, defrosting has been terminated as switch **75** remains closed, the temperature of the refrigerant drops, switch **79** is closed, and thus switch **80''** is closed to start the forced heating operation.

As mentioned above, in accordance with the invention, defrosting is initiated when the temperature difference between the fluid at the inlet and the fluid at the outlet of a utilization side heat exchanger is reduced a slight amount to a previously set ratio to the maximum temperature difference. As a result, it is easily possible to detect a decrease in heat exchange ability required for substantive utilization, and to minimize the loss of heat absorption due to accumulation of frost, over the entire period of heating, and to defrosting, by selecting the time at which defrosting actually is required by virtue of the system conditions.

An electrical arrangement utilizing adjustable slide type resistances is shown schematically in FIG. **8.** In this arrangement, the adjustable contacts of the resistances are secured to the levers **8** and **12.** The operating potential is applied across the terminals **81, 82,** with switch **83** being part of the indoor thermostat, switch **84'** controlling initiation of deicing and being operated by relay winding **84,** and switch **85** providing the signal for termination of defrosting. The switching valve operating winding and the operating or control winding for the outdoor fan motor are illustrated at **86** and **87,** respectively, and operate in the same manner as previously described. Adjustable resistance **88** is adjusted by lever **8,** and adjustable resistance **89** is adjusted by lever **12.** Together with resistances **88** and **89,** fixed resistances **91** and **92** form a bridge circuit.

With respect to adjustable resistances **88** and **89,** the positions of lever **8** and lever **12** are so determined that the resistance value of resistor **89** may correspond to the desired value of the previously set ratio to the resistance value of resistor **88,** at a maximum temperature difference. The position of the maximum temperature difference is mechanically memorized by lever **12,** and then the resistance value is determined. With the decrease in the temperature difference, the resistance of resistor **88** begins to decrease from the value corresponding to the maximum temperature difference. When the value becomes equal to the resistance value previously set on resistor **89,** the voltage applied to relay winding **84** becomes zero, and relay contact **84'** is closed. It will be understood that relay winding **84** may have an amplifier associated therewith. As in the case of FIG. **7,** a forced heating circuit may also be included in the control circuit shown in FIG. **8.**

FIG. **9** illustrates the mechanical components corresponding to FIG. **8.** It will be noted that taps on levers **8** and **12** are cooperable with the resistances **88** and **89,** respectively, to adjust the effective values of these resistances.

FIG. **10,** as stated, is a schematic diagram of refrigeration apparatus embodying the invention and illustrating the first heat exchanger with forced heating as well as illustrating the second heat exchanger. It is believed that the other elements are sufficiently apparent from FIG. **10** that further description would seem unnecessary.

Although not illustrated in the drawing, it is possible to combine a circuit, memorizing a maximum temperature difference, with a circuit setting the ratio, comparing this with the temperature difference in a practical situation, and amplifying and actuating a relay in an electronic manner. The present invention can be applied to heat pump air-conditioners with an air heat source, an to refrigeration apparatus. It is also applicable to arrangements in which the utilization side of the refrigerant is a liquid, such as water.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it will be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A method of defrosting a first heat exchanger on the heat source side of refrigerating apparatus, having a second heat exchanger on the utilization side, and a fluid flow circuit interconnecting the two heat exchangers, comprising the steps of determining the maximum temperature difference between the inlet fluid temperature and the outlet fluid temperature of the second heat exchanger; during operation of the refrigerating apparatus, detecting the difference between such inlet and outlet fluid temperatures of the second heat exchanger; and, when the ratio of the detected temperature difference to the maximum temperature difference decreases below a preset value, due to icing of the first heat exchanger, initiating defrosting of the first heat exchanger.

2. A method of defrosting, as claimed in claim **1,** including continuing the defrosting until the ratio of the detected temperature difference to the maximum tem-

perature difference re-attains the preset value; and then terminating the defrosting.

3. A method of defrosting, as claimed in claim 2, including the step of, when the ratio of the detected temperature difference to the maximum temperature difference decreases below such preset value to another and lower preset value, initiating forced heating of the first heat exchanger.

4. Apparatus for controlling defrosting of a first heat exchanger, on the heat source side of refrigerating apparatus, having a second heat exchanger, on the utilization side, and a fluid flow circuit interconnecting said two heat exchangers, comprising, in combination, respective temperature sensing means detecting the temperature of the fluid entering said second heat exchanger and detecting the temperature of the fluid leaving said second heat exchanger; first means operable by said temperature sensing means to determine and store the maximum temperature difference between the inlet fluid temperature and the outlet fluid temperature of said second heat exchanger; second means operable by said temperature sensing means, during operation of the refrigerating apparatus, in accordance with the difference between the inlet and outlet fluid temperatures of said second heat exchanger; and third means operable conjointly by said first and second means, when the ratio of the detected temperature difference to the maximum temperature difference decreases below a preset value, due to icing of said first heat exchanger, to iniitiate a defrosting cycle of said first heat exchanger.

5. Apparatus, as claimed in claim 4, in which said first and second means conjointly operate said third means to terminate defrosting responsive to the ratio of the detected temperature difference to the maximum temperature difference re-attaining said preset value.

6. Apparatus, as claimed in claim 4, including fourth means operable by said second means when the ratio of the detected temperature difference to the maximum temperature difference attains a predetermined value which is below said preset value, to initiate forced heating of said first heat exchanger.

7. Apparatus for controlling defrosting of a first heat exchanger, on the heat source side of refrigerating apparatus, having a second heat exchanger, on the utilization side, and a fluid flow circuit interconnecting said two heat exchangers, comprising, in combination, respective temperature sensing means detecting the temperature of the fluid entering said second heat exchanger and detecting the temperature of the fluid leaving said second heat exchanger; first means operable by said temperature sensing means to determine and store the maximum temperature difference between the inlet fluid temperature and the outlet fluid temperature of said second heat exchanger; second means operable by said temperature sensing means, during operation of the refrigerating apparatus, in accordance with the difference between the inlet and outlet fluid temperatures of said second heat exchanger; and third means operable conjointly by said first and second means, when the ratio of the detected temperature difference to the maximum temperature difference decreases below a preset value, due to icing of said first heat exchanger, to initiate a defrosting cycle of said first heat exchanger; said second means comprising a first lever pivoted intermediate its ends and subjected to both said temperature sensing means operating on an end of said lever in opposition to each other; said first means comprising a second lever in opposition to each other; said first means comprising a second lever pivoted coaxially with said first lever and movable by said first lever in a direction corresponding to the maximum temperature difference between the inlet fluid temperature and the outlet fluid temperature of said second heat exchanger; said second lever having a pointed free end; and a spring biased finely serrated member engageable with the pointed end of said second lever and operable to retain said second lever at a position corresponding to the maximum temperature difference between the inlet fluid temperature and the outlet fluid temperature of said second heat exchanger; said first lever being movable away from said second lever by said temperature sensing means responsive to a decreaese in the temperature difference between the inlet fluid temperature and the outlet fluid temperature of said second heat exchanger.

8. Apparatus, as claimed in claim 7, including a first adjustable resistor operable by said first lever; a second adjustable resistor operable by said second lever; and a source of potential; said third means comprising a bridge circuit connected to said source of potential and including said first and second adjustable resistors and a pair of fixed resistors, said bridge further including a relay connected between a pair of junctions thereof.

9. Apparatus, as claimed in claim 7, in which said third means comprises a switch carried by one of said levers and having an operator, and an adjustable abutment carried by the other of said levers and engageable with said operator to operate said switch responsive to a predetermined displacement of said first lever in a direction away from said second lever; said switch, when operated, initiating a defrosting cycle of said first heat exchanger.

10. Apparatus, as claimed in claim 9, including a second switch having a second operator; and a second abutment on said first lever; said second abutment engaging said operator to operate said second switch responsive to the ratio of the detected temperature difference to the maximum temperature difference decreasing to a second predetermined value below said preset value; said second switch, when operating, initiating forced heating of said first heat exchanger.

* * * * *