

June 20, 1961

W. L. McGRATH

2,988,897

DEFROST CONTROL FOR REFRIGERATION SYSTEMS

Filed Feb. 1, 1957

2 Sheets-Sheet 1

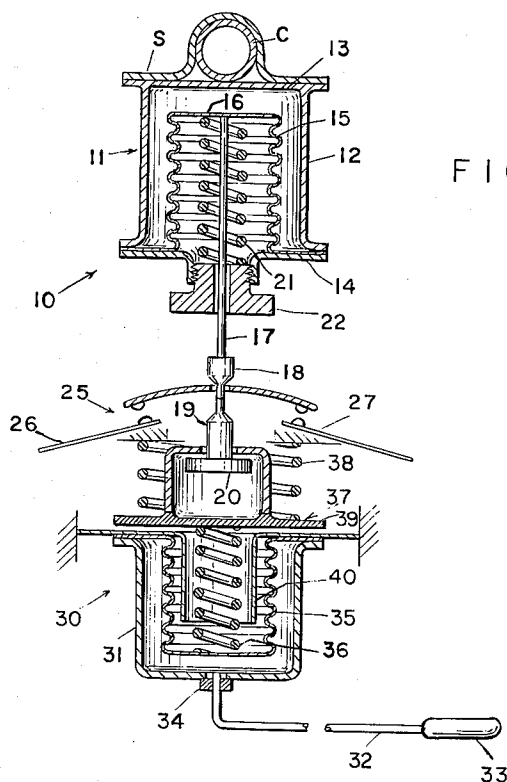


FIG. 1

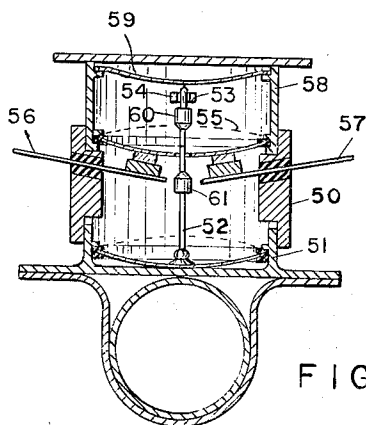
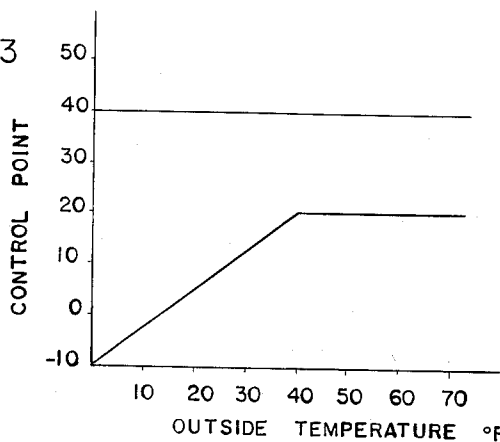


FIG. 2

FIG. 3



INVENTOR.
WILLIAM L. McGRATH.

BY *Herman Seid*

ATTORNEY.

June 20, 1961

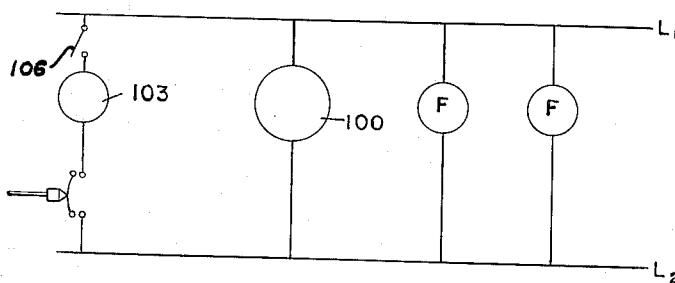
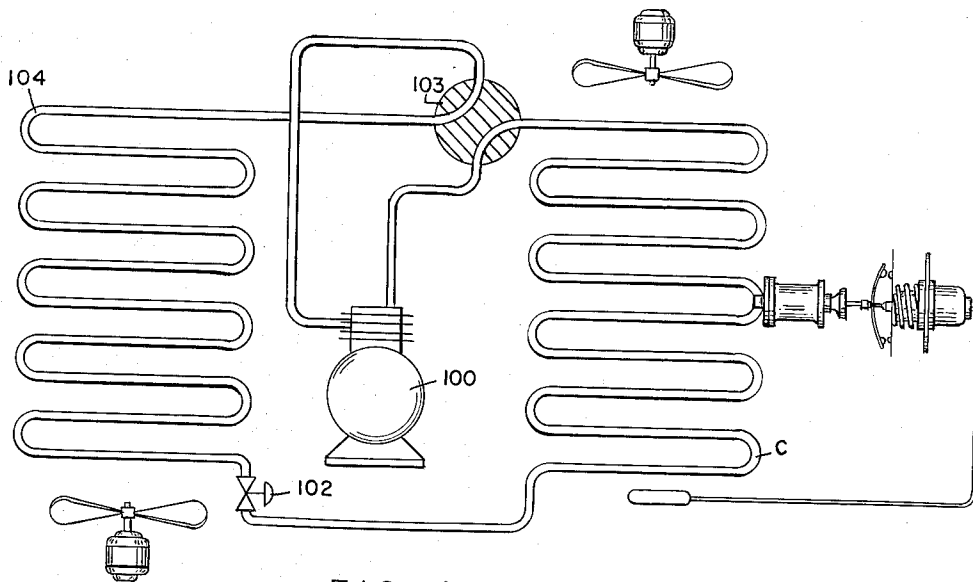
W. L. McGRATH

2,988,897

DEFROST CONTROL FOR REFRIGERATION SYSTEMS

Filed Feb. 1, 1957

2 Sheets-Sheet 2



INVENTOR.
WILLIAM L. McGRATH.
BY *Herman Seid*
ATTORNEY.

1

2,988,897

DEFROST CONTROL FOR REFRIGERATION SYSTEMS

William L. McGrath, Syracuse, N.Y., assignor to Carrier Corporation, Syracuse, N.Y., a corporation of Delaware

Filed Feb. 1, 1957, Ser. No. 637,786
4 Claims. (Cl. 62—156)

This invention relates to condition responsive control devices, more particularly to a control specifically adapted to regulate the defrost cycle of a refrigeration system, when said system is employed in ambient surroundings of greatly varying temperature.

A number of instances arise wherein it is desired to regulate the operation of a mechanism in response to thermal or pressure conditions. Thus, with refrigeration systems, in addition to the need for regulating the operation of the system to attain desired temperature conditions, there specifically arises a problem in conjunction with the defrosting of the evaporator coils of the system. The conventional compression refrigeration cycle circulates a refrigerant through a closed system in which the refrigerant in a gaseous state is first compressed, then fed through a condenser coil where the gaseous refrigerant is liquefied, and in the process gives off heat. Thereafter, the liquid refrigerant is passed through some expansion member where it is converted to a gas and then further expanded in an evaporator coil, absorbing heat in the process. From the evaporator coil the gaseous refrigerant is returned to the compressor for recirculation through the system. The surface of the evaporator coil tends to accumulate frost thereon due to the fact that the surface temperature drops below 32° Fahrenheit, causing any moisture condensed out of the air flowing over the coil to freeze on the surface of the evaporator coil. The build up of frost or ice on the evaporator coil, acts as an insulator decreasing the rate of heat transfer through the coil and substantially minimizing the efficiency of the refrigeration cycle and may eventually render it ineffective. As is apparent, it is thus desirable to provide some means for preventing frost accumulation.

Defrosting of the evaporator coil may be accomplished in a variety of ways, as by stopping of the refrigeration cycle, and either blowing warm air over the evaporator coil, or discharging the relatively warm condenser gas into the evaporator coil. Problems are engendered in providing a control which will initiate any of the available defrosting operations at the proper time.

Where the refrigeration system is employed as a heat pump, that is by positioning of the evaporator coil to permit the outside air to pass thereover, at the same time removing heat from this outside air, and then circulating the heated refrigerant through to an inside positioned condenser where the heat is given off, the problem of obtaining a suitable control for initiating a defrost cycle becomes even more pronounced due to the variations in ambient temperature under which the refrigeration system is employed.

Conventional control devices are not very satisfactory for controlling many systems, particularly heat pumps, which are subject to a wide variation of ambient conditions, since they generally function to initiate the defrost cycle at a fixed suction temperature.

Simple thermostats or pressure switches have been used which cut out or initiate the defrost cycle on a drop to a predetermined evaporator suction temperature and then cut back in when the defrost cycle is completed as the result of reaching a suction temperature in excess of 32°. Other defrosting methods include devices which respond to the static pressure drop in the air stream, or respond to the velocity of the air passing through the coil. These

2

types are difficult to keep in adjustment since they are exposed to cold temperatures (which may never rise above 32° F.), and the temperature or pressure responsive devices are not adequate because of the wide range of evaporator coil temperatures normally encountered even in the absence of frosting.

Where heat pumps are located in temperate climate zones, the evaporator coil is exposed to ambient temperatures ranging from -20° F. to 100° F. A conventional control set to initiate the defrost cycle at any fixed temperature is obviously inadequate since defrosting may not be necessary at the control temperature. Thus, with ambient temperatures below freezing there may possibly be deleterious frosting of the evaporator coil only upon a drop in temperature of the evaporator coil to a point substantially below that of the ambient surroundings, whereas at ambient temperatures slightly above freezing, a much higher evaporator temperature indicates defrosting is necessary.

It is with the above problems in mind that the present means have been evolved, means which permit initiation of a process in response to a given temperature differential between two points and termination of the process in response to one of such temperature measurements. Where regulation is desired of the defrosting operation of a heat pump, the controlling temperatures are those of the outside air and the evaporator coil, or between the saturated refrigerant pressure corresponding to the outside air and the evaporator pressure which is equivalent. In such case defrosting is initiated as a result of a temperature difference between the outside air and evaporator coil, and is terminated as a function of the suction temperature alone. Above a given outside temperature, defrosting is dependent solely on evaporator suction.

It is thus a primary object of this invention to provide an improved temperature or pressure responsive control device.

A further object of this invention is to provide an improved control device for use with refrigeration systems.

Another object of this invention is to provide a control for initiating and terminating the defrost of the evaporator coils of a refrigeration system.

It is also a specific object of this invention to provide improved control means for regulating the defrost cycle of the evaporator coils of heat pumps as a function of the temperature, of the outside air, and of the refrigerant temperature.

Another object of this invention is to provide a simple temperature or pressure responsive control for refrigeration systems which will initiate the defrost cycle upon an increase in temperature differential between the air, and the temperature in the evaporator coil, and will terminate this cycle as a function of refrigerant temperature only.

A still further object is to provide a defrost control which above a given evaporator temperature will not initiate a defrost cycle.

These and other objects of this invention which will become apparent from the following specification and claims are achieved by provision of a novel control device which actuates an electric switch or other control device which is hereshown as most optimally arranged for regulating defrosting operations. The switch controls either the operation of circulating fans, compressors, or valves depending on the mode of defrosting employed. The novel control comprises a switch which is arranged to initiate the defrosting cycle when a given amount of relative movement occurs between two temperature responsive members. One of these members responds to the temperature in the evaporator coil, and the position of the other is dependent on the temperature

in the ambient air passing over said evaporator. Reverse movement of the switch to cut out the defrost operation is accomplished solely as a function of the evaporator coil temperature responsive member. Thus the control functions to regulate a given circuit for initiating a defrost operation in response to a temperature differential between the ambient air and the evaporator coil. Above a given temperature the member responsive to ambient temperatures is made ineffective, and defrosting is subject only to evaporator coil temperature.

The specific constructional features of this invention, and their mode of operation will be made most manifest and particularly pointed out in conjunction with the accompanying drawings, wherein

FIGURE 1 represents a schematic cross-sectional view of a preferred control device embodying the herein disclosed inventive concept;

FIGURE 2 is a cross-sectional view of an alternative embodiment of this invention;

FIGURE 3 is a graph in which the evaporator suction temperature at which defrosting is initiated is plotted against the outside temperature, indicating a suggested arrangement for adjustment of the control when used in conjunction with defrosting a heat pump;

FIGURE 4 is a schematic view of a refrigeration system complete with the control forming the invention; and

FIGURE 5 is a partial schematic view of the electrical circuit employed with the system shown in FIGURE 4.

Referring now more particularly to the drawings, like numerals in the various figures will be taken to designate like parts.

As best seen in FIGURE 1, the thermally responsive control unit 10 here provided comprises a primary bellows unit 11. The bellows unit 11 has a relatively rigid exterior cylindrical wall 12 which is sealed off at its topmost portion, as viewed in the drawings by heat transmitting cover plate 13 and at its lowermost portion by bellows supporting closure 14. Closure 14 is formed with a central aperture, and is secured to a bellows sleeve 15 interposed coaxially within cylindrical wall 12. As seen in the drawing, the top portion 16 of the bellows sleeve is sealed off so that the interior part of the bellows unit is formed with a sealed annular chamber (between wall 12 and sleeve 15) within which a given readily expansible fluid is provided. The fluid employed is any one of a variety of known expansible fluids, preferably of a volatile type responsive to temperature changes. A rod 17 is secured to the upper bellows wall 16, as viewed in the drawing. A spring 21 is mounted about rod 17 so as to bear against the upper wall of the bellows and against a lower adjusting nut 22 forcing the bellows to a distended position. This adjusting nut 22 is formed with a threaded exterior surface engaging an inner tapped surface in the aperture provided in closure 14 of the assembly.

Push rod 17 is provided with a switch closing hub 18 engaging against a switch 25 to move same to the circuit closing position, as seen in the drawing. A switch opening reversing hub 19 on rod 17 is formed with a flange 20 which may be threadably connected to the hub.

Switch 25 is a conventional snap-acting switch of the over-center type and is arranged so as to be actuated by movement of rod 17. The snap-acting switch is illustrated in its normally open position such that the circuit is broken between terminals 26 and 27 of the circuit of which the switch forms a part.

A secondary bellows unit 30, as seen in the lowermost portion of FIGURE 1, is formed, similar to the bellows unit 11, shown in the uppermost portion of the drawing and previously described. In the secondary bellows unit 30 a relatively rigid exterior cylindrical housing 31 is provided. A conduit 32 leading to a temperature sensitive bulb 33 is coupled to cylindrical housing 31 in any conventional manner, such for example, as by means of

coupling 34, as seen in FIGURE 1. Coaxially mounted within the housing is a bellows sleeve 35 which serves to form a sealed annular chamber within housing 31. As previously discussed, any temperature responsive expansible fluid, preferably of a volatile type, is provided within the housing. Bellows sleeve 35 acts against spring 36, which bears against movable cage 37. As seen in the drawing, cage 37 has an opening admitting hub 19, and retaining flange 20. Cage 37 is of a size such that hub 19 may move freely therein over a given distance for a purpose to be made hereinafter more apparent.

Any forces transmitted by spring 36 to cage 37 are opposed by spring 38, acting on cover 39 of cage 37. A stop in the form of an annular flanged member 40 is provided, recessed within housing 31 so that upper wall of bellows 35 will, upon expansion of the volatile fluid within housing 31, strike against the cylindrical wall of stop member 40.

In the alternative embodiment illustrated in FIGURE 2 the bellows units previously disclosed in the modification illustrated in FIGURE 1, are substituted by bi-metallic elements or thermal discs. The primary thermally responsive unit, here shown in the lowermost portion of the drawing, is arranged so as to be encased within a housing for transmitting the temperatures from the controlled unit to the bi-metallic disc 51. The housing 50 supports the bi-metallic thermal unit 51 and this thermal unit 51 is fastened to a push rod 52, which is arranged for movement within annular guides 53 and 54. An over-center switch 55, similar to switch 25 previously described, is arranged so as to be contacted by switch closing hub 60, and switch opening hub 61 on the push rod 52. Switch 55 is arranged within a circuit containing conductors 56 and 57. The secondary thermally responsive member is retained within housing 58, here shown in the upper portion of the drawing, and within this housing 58 thermal disc 59 is mounted. Thermal disc 59 moves downwardly upon a drop in temperature, whereas thermal disc 51 moves upwardly upon a drop in temperature. Housing 58 limits upward movement of disc 59. As seen in the drawing, thermal disc 59 is not secured to push rod 52, and hence restricts or constrains the motion of said rod, only when there is contact between rod 52 and disc 59.

Operation

The novel control here provided functions to actuate a switch, positioned in any circuit which it is desired to regulate in response to varying thermal conditions. As a general proposition, the control may be employed in conjunction with a variety of circuits, but is contemplated particularly for use in refrigeration installations.

The mode of operation of the control is such that within a given temperature range actuation of the switch is determined by a temperature differential between two points, whereas reversing of the switch is a function of the temperature at only one point. However, when the temperature at one of these points rises above a given level, closing or opening of the switch is determined solely as a function of the temperature at another point.

Optimum use can be made of the novel control, when employed in conjunction with a heat pump for regulating the defrost operation of the refrigeration system. As previously pointed out, where refrigeration units are employed as heat pumps, defrosting of the evaporator coils of the system cannot be set to take place at a fixed temperature.

Empirical tests indicate that for heat pumps, optimum results obtain when the control is set to give a mode of operation as illustrated in FIGURE 3. At ambient temperatures above 40° F., defrosting takes place solely as a function of coil temperatures, in this case 20° F. At outside temperatures below 40° F., defrosting is set to take place at a temperature 20° below the ambient temperature.

5

In the embodiment illustrated in FIGURE 1, the novel control structure is arranged to attain the above described mode of operation by positioning primary bellows unit 11 adjacent the evaporator coils of a refrigeration unit employed as a heat pump. As illustrated in FIGURE 1, cover plate 13 of the control is strapped in some suitable fashion, as for example by means of strap S to a return bend of coil C.

It will be appreciated that coil C may be the outside coil in a heat pump having a motor-compressor unit 100 which, on the cooling cycle, feeds hot gaseous refrigerant to the coil C. The refrigerant is liquefied in coil C and passes through restriction 102 to an inside coil 104 located within an enclosure to be supplied with conditioned air. In the inside coil refrigerant is converted to the gaseous state and flows to the compressor to complete the cycle. In order to employ the heat pump to create a heating effect in the enclosure, a conventional four-way valve 103 for reversing flow of refrigerant through a portion of the system is provided. The valve is operable in response to a solenoid (not shown), the coil of which is coupled in the control circuit in series with switch 25, note FIGURE 5. When the circuit is closed, by closing heating-cooling switch 106, the valve is positioned so that refrigerant from the compressor flows to the inside coil, through the restriction and to the outside coil which functions as an evaporator and which may accumulate frost sufficient to necessitate the defrost action that may be obtained by the unit forming the subject of this invention. Heat extracted from the ambient vaporizes the refrigerant which then passes through valve 103 to the compressor. A suitable mounting bracket, as partially shown in diagrammatic FIGURE 4, is secured to the heat pump casing or any other convenient support so that the connection referred to above may be accomplished. The bracket includes extensions shown diagrammatically for mounting those parts of the thermal control requiring fixed support.

In view of the contact between cover 13, and coil C the surface temperature of coil C will be transmitted through plate 13 to the primary bellows unit 11, thus, affecting the fluid contained within the bellows unit to expand or contract said fluid as a function of evaporator coil temperature.

Bulb 33 is positioned in the ambient air stream passing over the evaporator coils, and the volatile fluid contained within the fluid system comprised by secondary bellows unit 31, conduit 32 and bulb 33 will expand or contract in response to the temperature conditions in this ambient air stream. The amount of expansion or contraction of the fluid in secondary bellows unit 30 will determine the compression of spring 36 which bears against cage 37 in opposition to the forces exerted by spring 38 against flange 39 of the cage 37. It is thus seen that the position of cage 37 is a function of the temperature of the ambient air stream passing through the evaporator coils of the heat pump.

Over-center snap-switch 25 is positioned in the valve circuit of the refrigeration system to be controlled. Switch 25 is actuated by switch closing hub 18, or switch opening reversing hub 19 positioned on push rod 17. As is apparent, the motion of push rod 17 to force hubs 18, and 19 against the switch 25 is dependent on the resultant of the forces exerted by bellows 15, spring 21, bellows 35, spring 36, cage 37 and spring 38. The opening of the switch in the illustrated embodiment causes the four way valve to move to the position for directing gaseous refrigerant to the coil C. This is accomplished by deenergizing the coil controlling the solenoid regulating the valve.

Above a given temperature the fluid in bellows unit 30 has no effect on the position of cage 37, and hence push rod 17 since the bellow sleeve 35 is restrained against stop 40.

With a conventional heat pump installation, in temperate climates at ambient temperatures above 40°, the formation of frost is dependent only on the surface tem-

6

perature of the evaporator coil, and thus stop 40 prevents the ambient temperature registered by bulb 33 from affecting the operation of the switch. At these above 40° F. temperatures, switch operation is purely a function of coil temperature as registered in primary bellows unit 11, and hub 19 will move freely within cage 37.

With outside temperatures below 40° the defrosting operation is made a function of the temperature differential between the evaporator coil surface and that of the ambient air stream. At these lower than 40° temperatures push rod 17 will be constrained in its motion by cage 37 engaging flange 20 of hub 19. The lower the temperature in the outside air stream, the more force needed to move push rod 17, and the lower the temperature necessary in the evaporator coil.

In FIGURE 1, the parts of the control are illustrated as functioning under conditions of an outside ambient temperature below 40° F. The switch is shown as open, thus indicating a defrosting condition. The control is moving to close switch 25.

Secondary bellows unit 30 under the effect of a less than 40° F. temperature adjacent bulb 33 is distended (and not in contact with stop 40) so as to retract cage 37. It will be noted that when hub 19 moves to open switch 25, its motion under these conditions was restricted by cage 37 engaging flange 20. However, when push rod 17 is moved by bellows 16 to force hub 18 against switch 25 to close same to terminate the defrost operation, cage 37 has no effect on the motion of rod 17. Hub 19 moves freely in cage 37. Thus, termination of the defrosting operation is purely a function of coil temperature; whereas, initiation of the defrosting operation was dependent on the temperature differential between the coil and ambient air stream.

Obviously, the spring pressures determining the push rod position may be adjusted to provide switch actuation at any desired temperature differential. The described arrangement is set to function as seen in FIGURE 3 to provide for a uniform cut out of the defrosting operation when the surface temperature of the coil reaches 40°. The defrosting operation is initiated at a 20° coil temperature when the outside temperature is at 40° or above, and at a correspondingly lower temperature as the outside air temperature drops.

The control structure illustrated in FIGURE 2 may similarly be employed to regulate the defrost cycle of any refrigeration system by securing the control to a return bend or other portion of evaporator coil C. Strap S is employed to secure contact between plate 50 and the coil thus permitting heat transfer between the coil C and thermal disc 51. Cover plate 58 is exposed to the ambient air stream thus permitting the temperature of the air stream to affect thermal disc 59.

The modification illustrated in FIGURE 2 is shown operating under an ambient temperature condition of less than 40° F. Switch 55 is shown closed, thus indicating a non-defrost condition. The position of thermal disc 59, determined by the ambient temperature of the air stream passing over cover plate 58, is shown as affected by a temperature of less than 40° F. As the ambient temperature drops, the disc will move downwardly to the position shown. In the illustrated position disc 59 contacts push rod 52 affecting the position thereof. Disc 59 is limited to move between plate 58 and guide 54.

Thermal disc 51 adjacent coil C is affected by the temperature of the coil, moving upwardly to the dotted line position as the coil temperature drops. As seen, the forces exerted by the thermal discs 59 and 51 act opposingly on push rod 52, which is secured to disc 51, but free of disc 59.

When the temperature of coil C drops sufficiently to overcome the forces exerted by disc 59 on the rod 52, the rod moves upwardly causing hub 61 to engage switch 55 to break the circuit between conductors 56 and 57, thus initiating the defrost cycle.

When the temperature of coil C rises to 40°, all frost will have been dissipated from coil C, and disc 51 will move downwardly as a result of the temperature increase. Push rod 52 secured to disc 51 will move downwardly with the disc and hub 60 will engage switch 55 in its dotted line position to close the circuit. It will be observed that the circuit closing action of hub 60 is purely a function of the motion of disc 51 in response to temperature conditions at coil C, since the rod 52 is not affixed to disc 59 and thus rod 52 can leave disc 59 and descend downwardly away from it.

At temperatures above 40° F., disc 59 assumes its upward limiting position adjacent plate 58 and does not contact push rod 52. Thus all motion of hubs 60 and 61 is dependent on the position of disc 51 and the coil temperature.

It is thus seen that a simple relatively inexpensive control structure has been provided for regulating the operation of a given mechanism in response to the temperature differential between two points. More specifically, a control structure has been provided particularly suited for control of the defrost operation of a refrigeration system employed as a heat pump, where it is desired to initiate the defrosting of the heat pump as a function of the temperature differential between the ambient air stream and the evaporator coils under given ambient temperature conditions (usually below 40° F.) while at higher ambient temperatures, defrosting is purely a function of evaporator coil temperature. Termination of the defrost cycle is made purely a function of evaporator coil temperature.

The above disclosure has been given by way of illustration and elucidation, and not by way of limitation, and it is desired to protect all embodiments of the herein disclosed inventive concept within the scope of the appended claims.

I claim:

1. A defrost control for a frost accumulating coil in a refrigeration system including means for supplying heat to the coil to cause the defrost action and a circuit regulating operation of the heat supply means, comprising a switch in said circuit; switch actuating means; a first thermal unit, responsive to the temperature of the frost accumulating coil, connected to said switch actuating means, said unit being operable upon a decrease in the temperature of the coil to exert a force on said switch actuating mechanism in a direction to effect movement of the switch to cause the defrost action; a second thermal unit respon-

sive to the temperature of the air flowing over the coil; means operable to resist the action of the first unit to move said actuator in a direction to effect movement of the switch, said means being ineffective to resist reverse movement of the switch actuator under the influence of the first unit as it responds to an increase in the coil temperature, said second thermal unit being operatively associated with said motion resisting means so as to regulate the extent of restraint whereby actuation of the switch to effect defrost occurs in response to a predetermined temperature differential within a given operating temperature range while reverse actuation of the switch may be effective only in response to a coil temperature sufficient to accomplish complete defrost.

2. The invention set forth in claim 1 wherein said switch is of the over-center action type.

3. The invention set forth in claim 1 wherein means are provided for limiting the extent that said second thermal unit may vary the restraining action of said resisting means and thus establish a maximum coil temperature at which defrost action may be accomplished.

4. In an air-to-air heat pump including an outdoor coil subject to frost accumulation at relatively low ambient temperatures, defrost control means comprising means regulating a supply of heat to the coil, a circuit governing the action of said heat supply means, a switch disposed in said circuit, a rod for actuating said switch, means secured to the rod and operable upon a decrease in the temperature of the coil for exerting a force on said rod for the purpose of moving it to engage said switch and effect defrost, means yieldably opposing movement of the rod but not secured to the rod, and means operable in response to the temperature of the air passing over the coil for regulating the extent of effectiveness of the yieldable means opposing the rod movement whereby the force necessary for switch movement to effect defrost is developed in response to a predetermined temperature difference between the air and coil over a given ambient temperature operating range, and the switch movement, under the influence of the rod, for terminating defrost is in response to a coil temperature sufficient to assure complete removal of frost.

References Cited in the file of this patent

UNITED STATES PATENTS

2,216,589	Grooms	Oct. 1, 1940
2,666,298	Jones	Jan. 19, 1954