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P. R. DE ARMOTT ET AL

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HEAT PUMP CAPACITY CONTROL

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FIG. 1

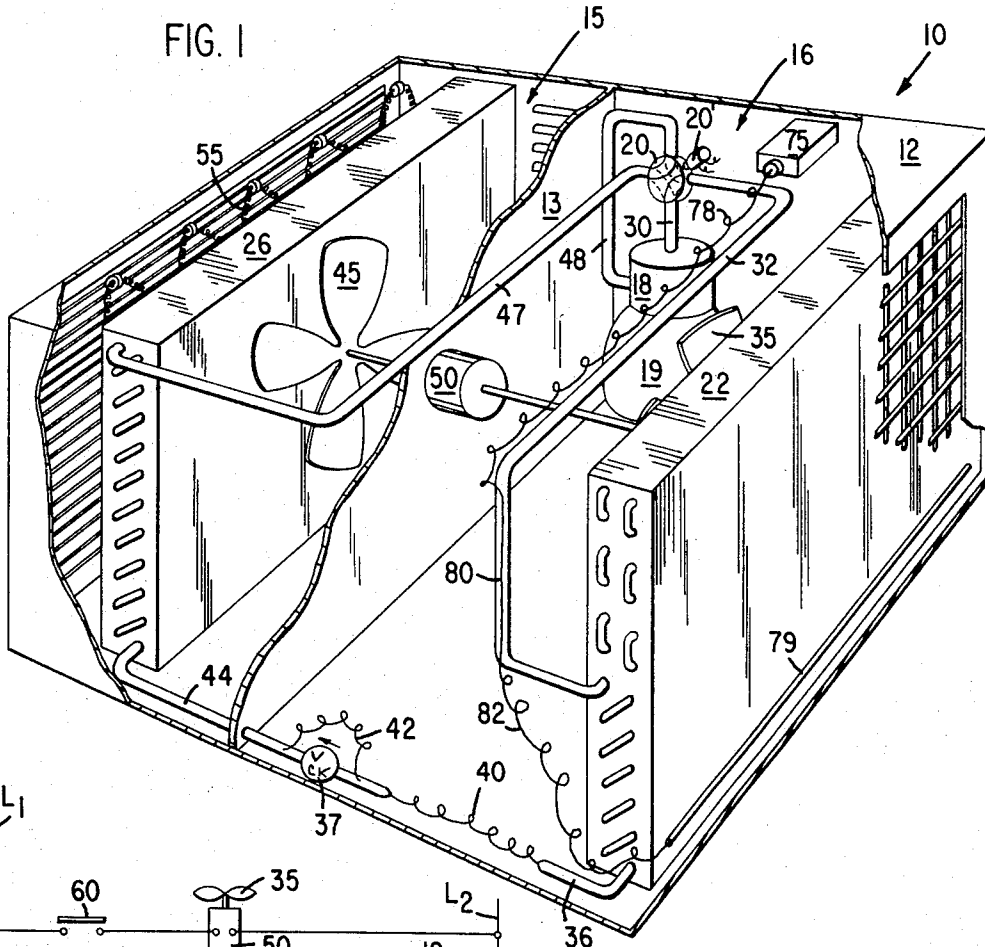
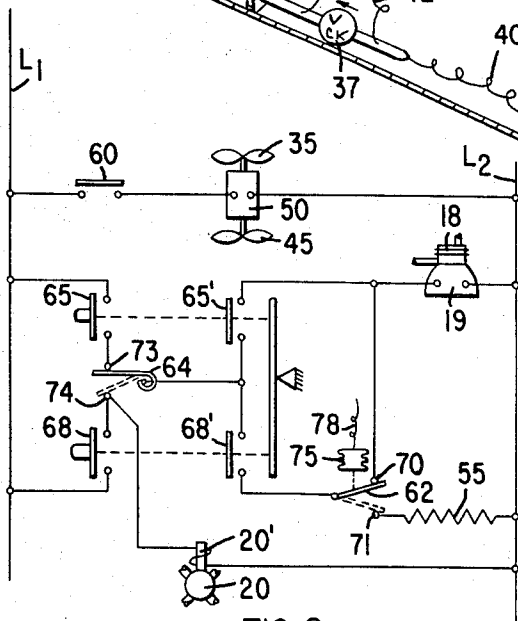
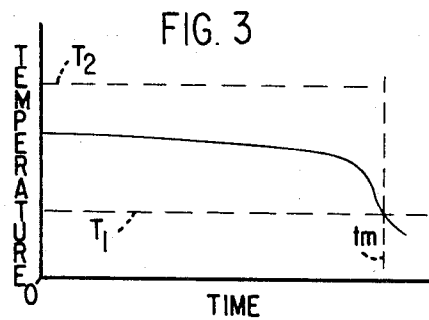


FIG. 2



INVENTORS.
PATRICK R. DE ARMOTT.
WILLIAM A. MOAKLEY, JR.
BY

Frederick L. Mc Mullen

ATTORNEY.

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HEAT PUMP CAPACITY CONTROL

Patrick R. De Armott, North Syracuse, and William A. Moakley, Jr., Baldwinsville, N.Y., assignors to Carrier Corporation, Syracuse, N.Y., a corporation of Delaware
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ABSTRACT OF THE DISCLOSURE

Reverse cycle refrigeration system having control means to insure maximum utilization of refrigeration system as a heat source with a corresponding minimum use of an auxiliary heat source, the control means including a first part responsive to temperature of refrigerant leaving the evaporator to initiate defrost of the outdoor coil while actuating the auxiliary heat source, a second part responsive to the presence of the ice on the control to continue defrosting until the evaporator is free of ice while maintaining the auxiliary heat source in operation, and a third part responsive to ambient to terminate system heating cycle operation while actuating the auxiliary heat source.

This invention relate refrigeration systems and, more particularly, to a capacity control for a reverse cycle refrigeration system.

In refrigeration systems of the reverse cycle type, commonly known as heat pumps, the system outdoor heat exchange coil, which during heating cycle operation functions as an evaporator, may accumulate frost and/or ice, particularly at low outdoor temperatures. The accumulation of ice reduces the heat transfer capability of the outdoor coil with concurrent reduction in system heating capacity. An auxiliary source of heat, commonly electric, is provided to offset the loss of system heating capacity. The cost however of electric heat is substantially greater than system heat. Accordingly it is more economical to use the system to heat, even though outdoor temperatures may be well below the temperature at which frost and ice can form of the outdoor coil, than to terminate system operation and use electric heat.

When using the system to heat at low outdoor temperatures, it is necessary to protect the system components against damage arising from excess accumulations of ice on the outdoor coil. Primarily, the ice may damage the outdoor fan. Further, icing can reduce outdoor coil effectiveness to a point where liquid refrigerant floods through the outdoor coil into the compressor. To extract maximum heat from the system at low outdoor temperatures while guarding the system components from damage due to icing of the outdoor coil, a control mechanism is desired which is not only capable of initiating defrost of the outdoor coil when needed, but is capable of preventing system operation altogether when outdoor temperature conditions are such that rapid icing of the outdoor coil would normally be anticipated if the system were operated on the heating cycle.

It is a principal object of the present invention to provide a new and improved capacity control for reverse cycle refrigeration systems.

It is a further object of the present invention to provide a reverse cycle refrigeration system incorporating a control effective to realize maximum use of the system as the source of heat with corresponding minimum use of the auxiliary heat source.

It is an object of the present invention to provide a control mechanism for reverse cycle refrigeration systems adapted to defrost the system outdoor coil following a predetermined buildup of ice on the outdoor coil; the

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control terminating outdoor coil defrost in response to the removal of substantially all of the ice from the outdoor coil.

It is an object of the present invention to provide a capacity control for reverse cycle refrigeration systems effective to prevent system heating cycle operation in certain environmental temperature conditions conducive to the rapid build-up of ice on the outdoor coil.

This invention relates to a reverse cycle refrigeration system comprising, in combination, a compressor having suction and discharge sides; an outdoor coil; a line serially connecting the compressor discharge side with the outdoor coil; expansion means; and an indoor coil serially arranged between the expansion means and the compressor suction side whereby a closed refrigeration circuit is formed, the system being effective upon energization of the system to cool; a reversing valve effective when actuated to connect the discharge side of the compressor with the indoor coil and the suction side of the compressor with the line leading to the outdoor coil so that the system heats upon energization of the compressor; an auxiliary heat source; and control means adapted to insure maximum utilization of the refrigeration system as a heat source with corresponding minimum use of the auxiliary heat source, the control means including a first control part responsive to temperature conditions of the refrigerant adjacent the leaving end of the outdoor coil effective at a predetermined refrigerant temperature condition to initiate defrost of the outdoor coil while actuating the auxiliary heat source; a second control part responsive to the presence of ice on the outdoor coil effective to continue defrosting of the outdoor coil until the outdoor coil is substantially completely freed of ice while maintaining the auxiliary heat source actuated, the control means second part being adapted to conclude defrosting of the outdoor coil while rendering the auxiliary heat source inoperable when the outdoor coil is freed of ice; and a third control part responsive to outdoor temperature conditions adapted at an outdoor temperature indicative of a drastic reduction in system heating capacity and concurrent increase in the propensity of ice to form on the outdoor coil to terminate system heating cycle operation while actuating the auxiliary heat source.

Other objects will be apparent from the ensuing description and drawings in which:

FIGURE 1 is a perspective view of a heat pump apparatus incorporating the capacity control of the present application;

FIGURE 2 is a wiring diagram for the apparatus shown in FIGURE 1; and

FIGURE 3 is a graph illustrating the change in temperature of refrigerant leaving the outdoor heat exchange coil of the apparatus of FIGURE 1 as ice forms on the outdoor coil during heating cycle operation.

Referring to FIGURE 1 of the drawings, there is shown an air conditioning apparatus 10 of the type adapted to cool or heat, commonly known as a heat pump. Heat pump 10 has an outer shell or casing 12 which may be mounted in the window or other opening of a room. Casing 12 is divided by partition 13 into indoor and outdoor compartments 15, 16 respectively. Casing 12 encloses the several component parts of the reverse cycle refrigeration system which include refrigerant compressor 18, reversing valve 20, outdoor heat exchange coil 22, outdoor fan 35 and capillaries 40, 42 arranged in outdoor compartment 16, and indoor fan 45, indoor heat exchange coil 26, and auxiliary heat source 55 arranged in indoor compartment 15. Fans 35, 45 are driven by fan motor 50. Alternately, fans 35, 45 may be provided with individual motors.

Referring to the control circuit of FIGURE 2, fan

motor 50 is series connected with selector switch 60 across leads L_1 , L_2 . Leads L_1 , L_2 designate a suitable source of electrical energy (not shown). A three-phase source of electrical energy may be employed upon modification of the circuit in a manner known to those skilled in the art.

Drive motor 19 of compressor 18 is series connected with cooling selector switches 65, 65' and indoor thermostatic switch 64 across leads L_1 and L_2 . Heating selector switches 68, 68', indoor thermostatic switch 64 and capacity control switch 62 are series connected with compressor drive motor 19 across leads L_1 and L_2 . The auxiliary heat source, resistor 55, is connected in parallel with motor 19 through control switch 62. Reversing valve solenoid 20' is series connected with heating selector switch 68 across leads L_1 , L_2 .

Control switch 62 and indoor thermostatic switch 64 are two pole type switches, where the switch arm thereof normally closes one of the switch poles or contacts at all times.

To cool, selector switches 60, 65, 65' are closed. Closure of switch 60 completes an energizing circuit to fan motor 50 to maintain fans 34, 45 in continuous operation. On closure of contact 73 by indoor thermostatic switch 64 in response to a predetermined demand for cooling, an energizing circuit is completed through switches 65, 64, 65' to energize compressor drive motor 19.

Gaseous refrigerant discharged by compressor 18 flows through discharge line 30 to reversing valve 20 which routes the refrigerant through line 32 to outdoor coil 22. There the gaseous refrigerant is condensed by air passed over the surface of coil 22 by fan 35. Condensed refrigerant from outdoor coil 22 flows through line 36, capillary 40 and check valve 37 to line 44 and indoor coil 26. Check valve 37 permits refrigerant to bypass capillary 42 during cooling cycle operation.

Refrigerant in indoor coil 26 is vaporized in extracting heat from the stream of air being conditioned which is passed over indoor coil 26 by fan 45. The cooled conditioned air is exhausted into the area conditioned while vaporized refrigerant returns through line 47, reversing valve 20 and suction line 48 to compressor 18 to complete the cycle.

To heat, selector switches 60, 68, 68' are closed, switch 60 completing the energizing circuit to fan motor 50 as described above. Closure of switch 68 completes a circuit to reversing valve solenoid 20' which moves valve 20 to the dotted line position of the drawing. On a predetermined demand for heat, indoor thermostatic switch 64 closes contact 74 to complete, through switches 68, 64, 68', 62, an energizing circuit to the compressor drive motor 19.

Vaporous refrigerant from compressor 18 is routed by reversing valve 20 through line 47 to indoor coil 26 where heat from the refrigerant flowing through coil 26 is rejected to the stream of air which is passed over indoor coil 26 by fan 45. Condensed refrigerant from coil 26 flows through line 44, capillaries 42, 40 and line 36 to outdoor coil 22 where heat extracted from the air passed over coil 22 by fan 35 vaporizes the refrigerant. Vaporous refrigerant from outdoor coil 22 returns through line 32, reversing valve 20, and suction line 48 to compressor 18 to complete the cycle.

During heating cycle operation ice may form on outdoor coil 22 which reduces the effectiveness of coil 22 and hence the heating ability of heat pump 10. To restore the effectiveness of coil 22, coil 22 is defrosted.

Capacity control switch 62 includes a bellows type actuator 75 and a capillary sensing element 78 charged with a temperature sensitive fluid selected to control from the coldest point along capillary 78. One part 79 of capillary 78 extends across the width of outdoor coil 22 and is spaced closely adjacent coil 22 near the bottom thereof so that water formed on coil 22 during defrost thereof and flowing downwardly along the face of the coil washes across capillary part 79. Preferably, part 79 if the capil-

lary is insulated to reduce thermal response and prevent short cycling of the compressor from transient conditions. A second part 80 of capillary 78 is arranged in heat exchange relation with refrigerant line 32. Alternately, capillary part 80 may be disposed in heat exchange relation with coil 22. A third part 82 of capillary 78 is disposed in outdoor compartment 16 of heat pump 10 for sensing outdoor temperature conditions.

Referring to FIGURE 3 of the drawings, the relationship between temperatures of the refrigerant leaving outdoor coil 22 versus time is graphically shown for an outdoor temperature condition low enough to cause ice to form on coil 22. As ice accumulates on outdoor coil 22 during heating cycle operation, the temperature of the refrigerant leaving coil 22 gradually decreases. As coil 22 becomes encrusted with ice, refrigerant temperatures fall suddenly as at time *tm* of FIGURE 3 indicating an almost total loss in system heating capacity.

The defrost control of the present invention, which includes part 80 of capillary 78 in heat exchange relation with refrigerant line 32, is arranged to respond to a temperature T_1 reflecting the sudden fall in temperature of refrigerant leaving outdoor coil 22. It is understood that during heating cycle operation temperatures of the refrigerant in line 32 are lower than temperatures adjacent outdoor coil 22 as sensed by capillary section 79. Accordingly, when the temperature of the refrigerant leaving coil 22 in line 32 reaches T_1 , switch 62 is moved to open contact 70 and interrupt the energizing circuit to compressor drive motor 19, while closing contact 71 to complete an energizing circuit to resistance heater 55. The cessation in flow of refrigerant through outdoor coil 22 and refrigerant line 32 permits temperatures of coil 22 to approach the prevailing outdoor temperature. Assuming outdoor temperatures to be above freezing, ice on coil 22 melts.

Water from the melting ice flows downwardly along the face of outdoor coil 22 and over part 79 of capillary 78 chilling the temperature sensitive medium therein. Although temperature of the refrigerant in line 32 rises following initiation of the defrost cycle, the defrost control, which controls from the coldest point along capillary 78, sustains the defrost cycle as long as chilled water from the melting ice contacts capillary part 79. Through this arrangement, complete removal of ice from coil 22 prior to the reinitiation of the system heating cycle is assured. During the defrost cycle, auxiliary heater 55 serves as the source of heat for the area being conditioned.

When temperatures along capillary 78 rise above a preset cut-in temperature T_2 of the defrost control, switch 62 is moved to open contact 71 and close contact 70 to complete the energizing circuit to compressor drive motor 19 whereby the system heating cycle operation is resumed. Opening of contact 71 deenergizes resistance heater 55.

As noted, temperature T_1 is selected to correspond to the drastic reduction in refrigeration system heating capacity caused by icing of outdoor coil 22. Where outdoor temperatures fall to T_1 , a similar reduction in heating capacity will be experienced even though icing of the outdoor coil may not have occurred. Capillary part 82 responds to outdoor temperature conditions and, at an outdoor temperature T_1 , switch 62 is moved to open contact 70 and close contact 71 to deenergize the compressor drive motor 19 and terminate system heating cycle operation while energizing auxiliary heater 55. At outdoor temperature T_2 , switch 62 is moved to open contact 71 and close contact 70 to resume system heating cycle operation.

Temperature T_2 is selected both to assure effective melting of ice on coil 22 as well as to prevent short cycling of the compressor caused by rapid re-icing of outdoor coil 22.

While we have described a preferred embodiment of our invention, it will be understood that our invention is

not limited thereto, but may be otherwise embodied within the scope of the following claims.

We claim:

1. In a reverse cycle refrigeration system the combination of a compressor having suction and discharge sides; an outdoor coil; a line serially connecting said compressor discharge side with said outdoor coil; expansion means; and an indoor coil serially arranged between said expansion means and said compressor suction side whereby a closed refrigeration circuit is formed, said system being effective upon energization of said system to cool; a reversing valve effective when actuated to connect the discharge side of said compressor with said indoor coil and the suction side of said compressor with the line leading to said outdoor coil so that said system heats upon energization of said compressor; an auxiliary heat source; control means adapted to insure maximum utilization of said refrigeration system as a heat source with a corresponding minimum use of said auxiliary heat source, said control means including a first control part responsive to temperature conditions of the refrigerant adjacent the leaving end of said outdoor coil effective at a predetermined refrigerant temperature condition to initiate defrost of said outdoor coil while actuating said auxiliary heat source; a second control part responsive to the presence of ice on said outdoor coil, effective to continue defrosting of said outdoor coil until said outdoor coil is substantially completely freed of ice while maintaining said auxiliary heat source actuated, said control means second part being adapted to conclude defrosting of said outdoor coil while rendering said auxiliary heat source inoperable when said outdoor coil is freed of ice; and a third control part responsive to outdoor temperature conditions adapted at an outdoor temperature indicative of a drastic reduction in system heating capacity and concurrent increase in the propensity for ice to form on the outdoor coil to terminate system heating cycle operation while actuating said auxiliary heat source.

2. A reverse cycle refrigeration system according to claim 1 including a first circuit for energizing said compressor and a second circuit for energizing said auxiliary heat source, said first control part being adapted to interrupt said compressor energizing circuit to render said compressor inoperative while completing said auxiliary heat source circuit to energize said auxiliary heat source at said predetermined refrigerant temperature condition.

3. In a reverse cycle refrigeration system the combination of a compressor having suction and discharge sides; an outdoor coil; a line serially connecting said compressor discharge side with said outdoor coil; expansion means; and an indoor coil serially arranged between said expansion means and said compressor suction side whereby a closed refrigeration circuit is formed, said system being effective upon energization of said system to cool;

a reversing valve effective when actuated to connect the discharge side of said compressor with said indoor coil and the suction side of said compressor with the line leading to said outdoor coil so that said system heats upon energization of said compressor; an auxiliary heat source; control means adapted to insure maximum utilization of said refrigeration system as a heat source with a corresponding minimum use of said auxiliary heat source, said control means including a first control part responsive to temperature conditions of the refrigerant adjacent the leaving end of said outdoor coil effective at a predetermined refrigerant temperature condition to initiate defrost of said outdoor coil while actuating said auxiliary heat source; a second control part responsive to the presence of ice on said outdoor coil, effective to continue defrosting of said outdoor coil until said outdoor coil is substantially completely freed of ice while maintaining said auxiliary heat source actuated, said control means second part being adapted to conclude defrosting of said outdoor coil while rendering said auxiliary heat source inoperable when said outdoor coil is freed of ice; and a third control part responsive to outdoor temperature conditions adapted at an outdoor temperature indicative of a drastic reduction in system heating capacity and concurrent increase in the propensity for ice to form on the outdoor coil to terminate system heating cycle operation while actuating said auxiliary heat source, a first circuit for energizing said compressor and a second circuit for energizing said auxiliary heat source, said first control part being adapted to interrupt said compressor energizing circuit to render said compressor inoperative while completing said auxiliary heat source circuit to energize said auxiliary heat source at said predetermined refrigerant temperature condition, said control means including a pressure actuator and an elongated capillary, said capillary and actuator forming a closed system having a suitable temperature responsive fluid charge, said first control part comprising a first portion of said capillary length disposed in heat exchange relation with said refrigerant line, said second control part comprising a second portion of said capillary spacedly disposed across the surface of said outdoor coil adjacent the lower edge thereof, and said third control part comprising a third portion of said capillary length arranged in the ambient.

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MEYER PERLIN, *Primary Examiner*.