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HEAT PUMP

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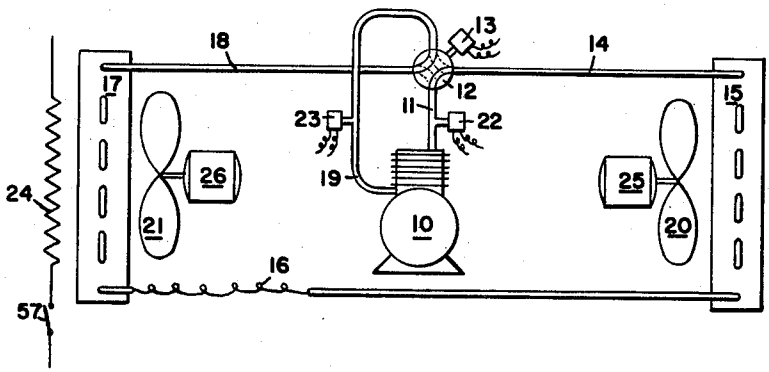


FIG. 1

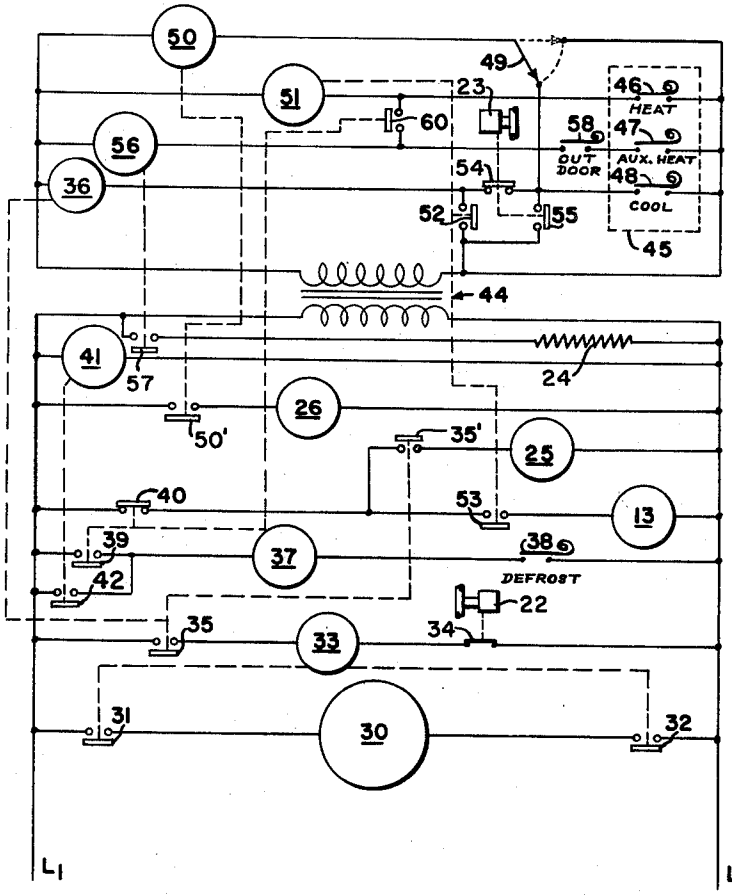


FIG. 2

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HEAT PUMP

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This invention relates broadly to air conditioning apparatus and more particularly to air conditioning apparatus employing a reverse cycle refrigeration system. Apparatus of this type are generally known as heat pumps and are operable to supply either cool or warm air to an enclosure being served by the air conditioning apparatus.

In heat pumps of the air-to-air type, heat is extracted from one source of air and rejected to another. During cooling operation, heat extracted from a source of air flowing over the indoor coil is rejected to a stream of air flowing over the outdoor heat transfer coil. When the heat pump is employed to supply heated air to an enclosure, heat extracted from the source of air flowing over the outdoor heat transfer coil is rejected to a stream of air flowing over the indoor heat transfer coil.

Under some circumstances it has been found that during cooling operation the indoor heat transfer coil which functions as an evaporator tends to frost. The frost accumulation on the indoor coil may build up sufficiently to materially impair the efficiency of the refrigeration system. Too, the air flow over the indoor coil may be reduced and possibly blocked entirely under most unfavorable conditions. It is therefore desirable to provide control means to prevent such undesirable frost accumulation. The use of a low pressure cutout in the manner proposed would minimize the problem of frosting or freeze-up of the indoor coil or evaporator during cooling operation.

The solution of one problem may create other problems. Thus the low pressure cutout must be carefully applied to a heat pump. During heating operation the indoor coil functions as a condenser and the outdoor coil functions as an evaporator. At low outdoor ambient temperatures, the suction temperature and corresponding suction pressure would be reduced. The low pressure cutout might open causing the compressor to be deenergized thus terminating the supply of heat at a time when it is required.

Also at relatively low outdoor ambient temperatures the outdoor coil often becomes coated with an insulating layer of frost which impedes the efficiency of the refrigerating system by reducing the heat transfer characteristics of this coil. As frost forms on the outdoor coil, the suction pressure would be reduced and the low pressure cutout would open as above noted causing the compressor to stop.

Means are commonly provided for removing the coating of frost from the outdoor heat exchange coil of the heat pump during heating operation. One conventional method of doing this is to reverse the refrigerant flow so that the air conditioning apparatus temporarily reverts to cooling cycle operation. The operation of the fan for passing air over the outdoor coil is terminated to speed up the defrost cycle. It is desired that the fan for passing air over the indoor coil be maintained operative for the same purpose. However, inasmuch as the indoor coil now functions as an evaporator, cold air will be discharged into the area to be treated.

It has been proposed that an electric resistance heater, which is commonly built into the air conditioning apparatus for supplementing heating capacity of the refrigerating equipment itself, be employed to temper the air being blown into the area to be conditioned during the

defrost cycle. The desired characteristics during both heating and cooling by the air conditioning apparatus having a refrigeration system operable under the reverse cycle principle have been attained by this invention.

By the present invention a heat pump has been provided with means for preventing excessive frost accumulation on the indoor coil during cooling operation without adversely affecting the operation of the air conditioning apparatus during heating operation. Further, by the present invention there has been provided a novel method for operating a heat pump.

An object of this invention is to provide a heat pump wherein the disadvantages and deficiencies of prior construction are obviated.

Another object of this invention is to provide an improved heat pump operating under the reverse cycle principle.

Still another object of this invention is to provide a heat pump having means responsive to a predetermined condition of the refrigeration system for preventing excessive frost accumulation on the indoor coil during cooling operation, such means being constructed and arranged so as not to interfere with efficient functioning of the heat pump during heating operation.

Yet another object of this invention is to provide a heat pump having means responsive to a predetermined suction pressure for preventing excessive frost accumulation on the indoor coil during cooling operation.

Another object of this invention is to provide a heat pump having means for preventing excessive frost accumulation on the indoor coil during cooling operation without adversely affecting heating operation, means for maintaining the indoor fan operative during heating and defrosting operations, and means for tempering the air being discharged into the area to be treated during defrost operation.

This invention relates to a heat pump having a refrigeration system comprising a compressor, reversing means, an outdoor coil, refrigerant metering means, and an indoor coil, a motor for driving said compressor, and means responsive to a predetermined condition of the refrigeration system for preventing excessive frost accumulation on the indoor coil during cooling operation without adversely affecting the refrigeration system during heating operation.

This invention also relates to a method for operating a heat pump of the type comprising a compressor, reversing means, an outdor coil, refrigerant metering means and an indoor coil interconnected to form a reverse cycle refrigeration system comprising the steps of condensing refrigerant in the outdoor coil while evaporating refrigerant in the indoor coil to cool the air to be conditioned, regulating compressor operation by a control responsive to a predetermined suction pressure to prevent frost accumulation on the indoor coil during cooling operation, and condensing refrigerant in the indoor coil while evaporating refrigerant in the outdoor coil to heat the air to be conditioned.

Other objects and features of the invention will be apparent upon the consideration of the ensuing specification and drawings in which:

FIGURE 1 is a diagrammatic view of a heat pump forming the subject of this invention; and

FIGURE 2 is a wiring schematic of an electric circuit for use with the heat pump of FIGURE 1.

Referring more particularly to FIGURE 1 there is shown for the purpose of illustrating this invention an air-to-air heat pump employing a refrigeration system operable under the reverse cycle principle. In apparatus of this type a first heat transfer coil is disposed within the area to be conditioned by the heat pump and a second coil is located outside the area, usually in the ambient.

Compressor 10 discharges relatively hot gaseous refrigerant through discharge line 11 to the reversing means 12, preferably, a four-way reversing valve, which is employed for the purpose of reversing refrigerant flow through a portion of the system in order to obtain the desired heating and cooling effects. From reversing means 12, controlled by the operation of the solenoid 13 in a manner later to be described, the hot gaseous refrigerant flows during cooling cycle operation through line 14 to outdoor heat exchange coil 15 wherein condensation of the gaseous refrigerant occurs as ambient air is passed over the surface of outdoor coil 15 by fan 20.

The condensed liquid refrigerant flows from coil 15 through suitable expansion means 16, which may be a capillary tube, as shown, or expansion valve means as are well known to those skilled in the art, to indoor heat exchange coil 17, serving as an evaporator during the cooling cycle. The expansion means provides the requisite pressure drop between the heat exchange coils in the refrigeration system.

In indoor heat exchange coil 17, refrigerant is vaporized as heat is extracted from the stream of air delivered over the indoor coil by fan 21. Vaporous refrigerant so formed flows through line 18 to reversing valve 12 from whence the refrigerant flows through suction line 19 back to compressor 10 to complete the refrigerant flow cycle.

Each of the fans 20 and 21 may be driven by suitable drive mechanism, for example, electric motors 25 and 26 respectively.

To heat the area to be treated the reversing valve 12 is actuated to place line 18 in communication with discharge line 11. Under these circumstances heat from the hot gaseous refrigerant flowing into coil 17 is rejected to the air within the area to be treated. The rejection of heat from the refrigerant converts the gaseous refrigerant to liquid refrigerant which flows through expansion means 16 to outdoor coil 15, which now functions as an evaporator. The vaporous refrigerant created in outdoor coil 15 as a result of heat transfer between the refrigerant and the ambient air flows through reversing valve 12 into suction line 19 back to compressor 10.

A suitable high pressure cutout control 22 may be connected to discharge line 11 by conventional connecting means. A low pressure cutout control 23 may be T'd into suction line 19. Each control actuates a switch in the electrical circuit as will be later described.

As above noted the refrigeration system may be incapable of providing sufficient heat to the area to be treated during heating operation, especially when the heat pump is used in geographical areas which are subject to low outdoor ambient temperatures. An auxiliary heater 24 which consists of a suitable high resistance wire through which current is adapted to be selectively passed may be used to provide supplementary heat. Thus the air, heated to a certain degree by being induced through heat exchange coil 17 by fan 21, is further heated by being passed over resistance wire 24 which is energized upon closing of switch 57.

The electrical control circuitry for the heat pump is shown in FIGURE 2. A suitable source of alternating current (not shown) is adapted to supply current via leads L1 and L2. It will be understood of course that the system can operate on three-phase current, if it is suitably modified.

The motor 30 for actuating compressor 10 is energized when the contacts 31 and 32 are closed. Contactor coil 33 for closing contacts 31 and 32 is in series with cooling relay contact 35 across lines L1 and L2. A normally closed high pressure cutout switch 34 is also in series with the contact coil 33 and the cooling relay contact 35. The switch 34 is adapted to be opened when a predetermined high head pressure is sensed in discharge line 11 by high pressure cutout control 22.

Also disposed in the primary circuit across the leads

L1 and L2 are defrost relay 37 and defrost thermostat 38. The defrost thermostat may be responsive to the temperature on the surface of the outdoor coil. One defrost relay contact 39 is placed in series with defrost relay 37 and defrost thermostat 38. A second defrost relay contact 40 is positioned in series with reversing valve relay contact 53 and reversing valve solenoid 13 across the leads L1 and L2.

Defrost timer motor 41, which operates continuously during operation of the refrigeration system of the air conditioning apparatus, is disposed across the leads L1 and L2. A cam-actuated defrost timer contact 42 is provided in the primary circuit in parallel with defrost relay contact 39. The defrost timer contact 42 may be closed for a brief interval during each cycle of operation of the defrost timer motor 41.

A second cooling relay contact 35' is in series with outdoor fan motor 25. The outdoor fan motor 25 and cooling relay contact 35' are disposed in parallel with reversing valve relay contact 53 and reversing valve solenoid 13 in the primary control circuit and are also in series with defrost relay contact 40.

The indoor fan motor 26 may be energized upon the closing of the indoor fan relay contact 50'.

The secondary control circuit may be connected with the primary control circuit by means of transformer 44. Included in the secondary control circuit is a room thermostat 45 comprising a two-stage heating thermostat and a single-stage cooling thermostat. First stage heating thermostat 46 is in series across the secondary control circuit with reversing valve relay 51. The second stage heating thermostat 47 is in series across the secondary control circuit with outdoor thermostat 58 and resistance heater relay 56. Upon energization of relay 56, contact 57 is closed, energizing heater 24.

Normally open defrost relay contact 60 is disposed in parallel across thermostats 46 and 47 and is adapted to be closed during defrost operation to energize the resistance heater 24.

Also provided in the secondary control circuit are fan switch 49 movable from an automatic position shown in solid line to a continuous operating position illustrated in dotted line and indoor fan relay 50 in series therewith.

Cooling relay 36 is in series across the secondary circuit with normally closed low pressure cutout switch 54 and cooling thermostat 48. Normally opened low pressure cutout switch 55 and normally opened reversing valve relay contact 52 complete the illustrated secondary control circuit.

Operation

During cooling operation, the cooling thermostat 48 of the room thermostat 45 will close in response to a predetermined demand for cooling. Assuming that the switch arm 49 is in the solid line position shown permitting automatic operation of the fan, the indoor fan relay 50 will be energized, closing indoor fan relay contact 50' in the primary control circuit and energizing the indoor fan motor 26.

Simultaneous with the energization of indoor fan motor 26, cooling relay 36 will be energized closing contacts 35' and 35. A first circuit is completed via lead L1, normally closed defrost relay contact 40, cooling relay contact 35', outdoor fan motor 25 and lead L2 energizing the outdoor fan motor. A second circuit is completed via lead L1, cooling relay contact 35, contactor coil 33, high pressure switch 34 and lead L2. Upon energization of coil 33 contacts 31 and 32 are closed, thus energizing compressor motor 30.

During cooling operation, compressor 10 forwards high pressure vaporous refrigerant through reversing means 12 and line 14 to outdoor coil 15. Heat is extracted from the refrigerant by the air stream passing over coil 15, condensing the refrigerant. Condensed refrigerant passes through metering means 16 to indoor coil 17, where the refrigerant is vaporized. The vaporized refrigerant re-

turns to compressor **10** through line **18**, reversing means **12** and suction line **19**.

As the indoor coil frosts during certain operating conditions, the suction pressure will be reduced. Upon attainment of a predetermined low suction pressure the low pressure cutout control **23** will open switch **54** and close switch **55**. It will be noted in the secondary control circuit that the cooling relay **36** is deenergized thus opening contacts **35'** and **35**. This results in the opening of the outdoor fan motor circuit and the compressor motor circuit, whereby outdoor fan motor **25** and compressor motor **30** are deenergized. The compressor will remain inoperative until the frost is melted from the indoor coil and control **23** causes switch **54** to close. Thus during cooling operation, the evaporator is provided with freeze-up protection.

Considering now heating operation, assume that room thermostat **45** senses a demand for heating. The first heating stage **46** of the room thermostat **45** will close energizing reversing valve relay **51**. Reversing valve relay contacts **52** and **53** will be closed. The closing of contact **52** energizes a circuit including reversing valve relay contact **52** and cooling relay **36**. Compressor motor **30** will be energized as aforementioned when cooling relay contact **35** closes. With the closing of reversing valve relay contact **53** a circuit is completed via lead **L1**, defrost relay contact **40**, reversing valve relay contact **53**, reversing valve solenoid **13** and lead **L2**, thus energizing solenoid **13** and actuating the reversing valve to the heating position to port refrigerant from discharge line **11** into line **18** to indoor heat exchange coil **17**. At the same time a circuit has been completed via lead **L1**, defrost relay contact **40**, compressor relay contact **35'**, outdoor fan motor **25** and lead **L2** to energize outdoor fan motor **25**.

Thus under the heating cycle of operation refrigerant flows from indoor coil **17** through refrigerant metering means **16** to outdoor coil **15**. Heat rejected to the air passing over the indoor heat exchange coil warms the air being supplied to the area to be treated. The hot vaporous refrigerant discharged from compressor **10** is condensed in the indoor coil **17**. The refrigerant vaporized in outdoor coil **15** as a result of heat transfer between the refrigerant and the ambient air flows through reversing valve **12** into suction line **19** back to compressor **10**.

During the heating cycle of operation described, the temperature of the outdoor air may drop so that a heat sink of relatively low temperature is available. The refrigeration system acts to draw a low suction temperature and pressure so that heat may flow from the outdoor air stream to the refrigerant. Very often a coating of frost accumulates on the surface of outdoor coil **15**. The defrost control means depicted in FIGURE 2 are operable to sense the collection of this frost and to temporarily reverse the system to act on cooling cycle operation to remove the frost.

Defrost timer motor **41** operates continuously. Periodically during rotation of the defrost timer motor cam (not shown), defrost timer contact **42** is closed for a brief interval. When the defrost thermostat **38** senses a need for defrost and closes and contact **42** is closed, a circuit is completed via lead **L1**, defrost timer contact **42**, defrost relay **37**, defrost thermostat **38** and lead **L2** to energize defrost relay **37**. Defrost relay contact **39** is closed to provide a holding circuit for defrost relay **37** and defrost relay contact **40** is opened thus deenergizing the outdoor fan motor **25** and breaking the circuit to the reversing valve solenoid **13**.

At the same time, defrost relay contact **60** was closed to permit energization of heater **24** as is more fully considered later.

Under these circumstances reversing valve **12** is moved to the position shown in FIGURE 1 permitting the flow of hot gaseous refrigerant directly to outdoor coil **15** which has a frost accumulation thereon.

After removal of the undesirable frost accumulation from the outdoor coil the defrost thermostat **38** will open deenergizing defrost relay **37**. It will be noted that during defrost operation defrost relay contact **40** was open and the outdoor fan motor **25** was deenergized. However it is desirable that the indoor fan be maintained active to provide a loaded evaporator. This is desirable in order to maintain the head pressure and have a relatively large body of hot gaseous refrigerant discharged from the compressor. The indoor fan is maintained in operation in the following manner. As ice builds up on the outdoor coil during defrost operation the suction pressure will drop causing contact **54** to open. When this happens contact **55** will close. Indoor fan relay **50** will therefore be energized via a circuit including low pressure contact **55**, fan switch **49** and indoor fan relay **50**. With the energization of indoor fan relay **50**, indoor fan relay contact **50'** closes and the indoor fan motor **26** in the primary control circuit is energized.

Returning now to a consideration of heating operation, let us assume that the refrigeration system itself cannot supply the demand for heat and that there is a requirement for additional heat. The second heating stage **47** of indoor thermostat **45** will close at a predetermined temperature. In series with auxiliary heater relay **56** and heating thermostat **47** is an outdoor thermostat **58**. Thus it will be evident that auxiliary heater **24** will not be energized to supply supplementary heat until such time as the outdoor thermostat closes at a predetermined temperature lower than that at which thermostat **47** closes. When the outdoor temperature drops to such predetermined level, outdoor thermostat **58** will close, placing auxiliary heater relay **56** under control of thermostat **47**. Upon energization of resistance heater relay **56** contact **57** will close to energize resistance heater **24** and provide supplementary heat.

As has been noted above during defrost operation the system temporarily reverts to the cooling cycle of operation. Thus the indoor coil functions as an evaporator. To shorten the defrost time it is desirable that the fan **21** be maintained in operation, however the cold air being blown over indoor coil **17** results in discomfort to the occupants of the room being conditioned.

By the present heat pump system the air being discharged into the room being conditioned is tempered. This is accomplished by maintaining auxiliary heater relay **56** energized during defrost operation. It will be noted that during defrost operation defrost relay contact **60** was closed so that a circuit was completed via thermostat **46**, contact **60** and auxiliary heater relay **56**. With the energization of auxiliary heater relay **56**, switch **57** is closed and resistance heater **24** is energized.

Thus by the present invention air conditioning apparatus operable under the reverse cycle principle has been provided with means responsive to a predetermined condition of the refrigeration system for preventing excessive frost accumulation on the indoor coil during cooling operation without adversely affecting the functioning of the refrigeration system during heating operation.

By maintaining the indoor fan on during defrost operation ice and frost removal from the outdoor coil is expedited and the time that the indoor coil must function as an evaporator is minimized. The air passed over the evaporator is cooled, however, there is little discomfort to the occupants in the area being conditioned for the air is heated by heater **24**.

While I have descrived a preferred embodiment of the invention, it will be understood that the invention is not limited thereto, since it may be otherwise embodied within the scope of the following claims.

I claim:

1. In a reverse cycle refrigeration system operable to selectively cool and heat an enclosure, the combination of a refrigeration system comprising: compression means, reversing means, an outdoor coil; refrigerant metering

means, and an indoor coil connected in refrigerant flow relationship, fan means for passing air over said indoor coil, cooling control means operable in response to a first predetermined enclosure condition to energize said compression means and fan means to cool, said cooling control means including a first circuit for energizing said compression means, means operable in response to a predetermined system condition indicative of a frosted indoor coil to interrupt said first circuit to de-energize said compression means to defrost the indoor coil, heating control means operable in response to a second predetermined enclosure condition to energize said reversing means, said compression means, and said fan means to heat, means operable to de-energize said reversing means to defrost the outdoor coil, and means for rendering said indoor coil defrost means ineffective during heating cycle operation including a second circuit for energizing said compression means having first and second switch contacts, means for closing said first switch contact in response to actuation of said heating control means, and means for closing said second switch contact in response to actuation of said indoor coil defrost means.

2. Apparatus according to claim 1 in which said system includes a resistance heater for supplying supplementary heat, control means for energizing said resistance heater in response to predetermined indoor and outdoor conditions to heat the enclosure, said outdoor coil defrosting means including means operable to bypass said resistance heater control means to energize said resistance heater.

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