HEAT PUMP SYSTEM HAVING A DEFROST MECHANISM FOR LOW AMBIENT AIR TEMPERATURE OPERATION

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Abstract

A heat pump system includes a hot gas bypass defrost mechanism which enables normal heat pump operation at low ambient air temperatures, and may be used for heating swimming pools. The bypass defrost mechanism is activated by sensing a drop in compressor suction line pressure, which occurs at low ambient temperatures when frost forms on an evaporator in the heat pump, which disrupts normal heat pump operation. The defrost mechanism includes a circuit that redirects a portion of hot refrigerant discharged by a compressor directly to the evaporator, thereby bypassing other heat pump components and defrosting the evaporator.
FIG. 1
HEAT PUMP SYSTEM HAVING A DEFROST MECHANISM FOR LOW AMBIENT AIR TEMPERATURE OPERATION

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority of U.S. Provisional Patent Application Ser. No. 60/721,479, filed Sep. 28, 2005, the disclosure of which is incorporated by reference herein in its entirety.

FIELD OF THE INVENTION

[0002] The present invention is directed to heat pump systems. More particularly, the present invention is directed to vapor compression heat pump systems with hot gas bypass defrosting for low ambient air temperature operation.

BACKGROUND OF THE INVENTION

[0003] The evaporator element of a vapor compression heat pump system is subject to a degradation in operating efficiency due to the frosting of the evaporator coils. Frosting occurs when the water vapor, in the ambient air surrounding the chilled evaporator, condenses on the outer surfaces of the evaporator and freezes. One method utilized to defrost the evaporator, is to reverse the heat pump cycle, wherein the evaporator becomes the condenser. Another method utilized to defrost the evaporator, is to direct a portion of the high temperature and pressure refrigerant vapor, herein referred to as hot gas, that is discharged from the compressor, directly through the evaporator, bypassing the condenser.

[0004] The hot gas bypass defrost method is frequently utilized in heat pump systems which do not require a reversal of the cycle in normal operation (i.e., the heating function is not required to become a cooling function), and the hot gas bypass defrost method is often the least complex method for defrosting the evaporator in such heat pump systems. In addition, the hot gas bypass defrost method avoids cooling the heated fluid during the defrosting operation because the functioning of the condenser is never reversed to function as the evaporator.

[0005] The frosting of the evaporator generally increases with decreases in the temperature of the ambient air surrounding the evaporator. Therefore, decreases in ambient air temperatures also decrease the ability of the heat pump systems to operate normally.

[0006] What is needed, but has yet to be provided, is a heat pump system having a hot gas bypass defrost mechanism, which operates normally at low ambient air temperatures. This and other needs/objectives are addressed by the present invention. Additional advantageous features and functionalities of the present invention will be apparent from the disclosure which follows, particularly when reviewed in conjunction with the accompanying drawings.

SUMMARY OF THE INVENTION

[0007] A heat pump is provided which includes a compressor, a condenser, a compressor discharge line connecting the compressor to the condenser, an expansion device, a condenser discharge line connecting the condenser to the expansion device, an evaporator, an expansion device discharge line connecting the expansion device to the evaporator, a suction line connecting the evaporator to the compressor, and a by-pass valve having an inlet, which is in fluid communication with the compressor discharge line, and an outlet, which is in fluid communication with the expansion valve discharge line. Controlling means are provided for controlling the by-pass valve so as to adjust the by-pass valve between an open position and a closed position in response to pressure in the suction line, so as to defrost the evaporator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of the present invention, reference is made to the following detailed description of various exemplary embodiments considered in conjunction with the accompanying drawings, in which:

[0009] FIG. 1 is a schematic diagram of a heat pump, illustrating a hot gas bypass defrost circuit equipped with a capacity control discharge valve mechanism;

[0010] FIG. 2 is an elevational view of the capacity control discharge valve mechanism shown schematically in FIG. 1;

[0011] FIG. 3 is a schematic diagram of the heat pump shown in FIG. 1, illustrating a hot gas bypass defrost circuit equipped with a solenoid valve mechanism;

[0012] FIG. 4 is an electrical schematic of the solenoid valve mechanism shown in FIG. 3;

[0013] FIG. 5 is a perspective view of an exterior design for the heat pump illustrated in FIGS. 1-4;

[0014] FIG. 6 is a front elevational view of the heat pump shown in FIG. 5;

[0015] FIG. 7 is a side elevational view of the heat pump shown in FIG. 5; and

[0016] FIG. 8 is an exploded perspective view of the heat pump illustrated in FIGS. 5-7.

DETAILED DESCRIPTION OF THE INVENTION

[0017] Tests conducted on a heat pump adapted to heat swimming pool water have demonstrated that the heat pump, operating at low ambient temperatures in the range of from about 40 degrees to about 50 degrees Fahrenheit (° F.), usually encounters frosting of the entire evaporator, which produces a reduction in the compressor suction pressure, thereby causing the heat pump compressor low-pressure switch to cease operation of the compressor. Tests have also demonstrated that, in order for the heat pump to continue to operate at low ambient air temperatures, the compressor suction pressure is required to be maintained at, or above, about 50 pounds per square inch (psi) and compressor suction temperature is required to be maintained above about 32° F.
A first exemplary embodiment of the present invention is illustrated in FIGS. 1-2. Referring now to FIG. 1, a heat pump system 10 includes a refrigerant circuit 12 and a defrost circuit 14. The refrigerant circuit 12 is constructed and operates in a manner similar to that of a conventional heat pump. The refrigerant (not shown) which flows through the heat pump 10 may be any suitable compressible refrigerant, such as carbon dioxide or a hydrocarbon refrigerant.

The refrigerant circuit 12 includes in serial order and operatively coupled, a compressor 16, a condenser 18, an expansion device 20, and an evaporator 22. The compressor 16, condenser 18, expansion device 20, and evaporator 22 are fluidly interconnected by a compressor discharge line 24, a condenser discharge line 26, an expansion device discharge line 28, and a compressor suction line 30. The expansion device may be a thermostatic expansion valve (TXV) or another suitable expansion device.

When the heat pump 10 is operating, the refrigerant in the refrigerant circuit 12 flows continuously, and in serial order, through the compressor 16, the compressor discharge line 24, the condenser 18, the condenser discharge line 26, the expansion device 20, the expansion device discharge line 28, the evaporator 22, the suction line 30, and again through the compressor 16. More particularly, the low pressure and temperature refrigerant vapor exiting the evaporator 22 is drawn by suction pressure into the compressor 16 where the refrigerant is compressed and discharged from the compressor 16 as hot gas, and then flows through the compressor discharge line 24 and through the condenser 18. As the hot gas flows through the condenser 18, thermal energy is removed from the refrigerant and transferred to a fluid, such as swimming pool water, surrounding the condenser 18, wherein the hot gas is condensed to a liquid. The refrigerant then flows through the condenser discharge line 26 and through the expansion device 20, which reduces the pressure of the liquid refrigerant. The refrigerant then flows through the expansion device discharge line 28 and through the evaporator 22, wherein thermal energy is transferred from the ambient air surrounding the evaporator 22 to the evaporator 22. The liquid refrigerant in the evaporator 22 is then evaporated into a gaseous state. The refrigerant vapor, exiting the evaporator 22, then flows through the compressor suction line 30 and is again drawn by suction pressure into compressor 16, where the cycle is repeated.

Because thermal energy is transferred from the ambient air surrounding the evaporator 22, water vapor in the ambient air condenses on the chilled outer surface of the evaporator 22, forming frost. When sufficient quantities of frost are formed on the outer surface of the evaporator 22, the heat transfer functioning of the evaporator 22 becomes impaired. The defrost circuit 14 is employed to defrost the evaporator 22 and restore the normal heat transfer functioning of the evaporator 22. The defrost circuit 14 directs a portion of the hot gas, which is discharged from the compressor 16, directly into the evaporator 22, thereby bypassing the condenser 18 and the expansion device 20. The defrost circuit 14 includes a capacity control discharge valve 32, which will be described in greater detail below.

Referring to FIGS. 1-2, in general, but FIG. 2, in particular, the capacity control discharge valve 32 has an inlet 34, an outlet 36, and an equalization tube connection 38. The valve 32 may be any suitable capacity control discharge valve such as Valve Model No. ASDRE-2-0/80 manufactured by the Spartan Valve Company (Washington, Mo.). An inlet line 40 is in fluid communication with the discharge valve inlet 34 and the compressor discharge line 24, for conveying hot gas to the valve 32. An outlet line 42 is in fluid communication with the valve outlet 36 and the expansion device discharge line 28, for conveying hot gas from the valve 32 to the expansion device discharge line 28. An equalization tube 44 is in fluid communication with the suction line 30 and the connection 38, for communicating the suction pressure to the valve 32.

In operation, when the evaporator 22 becomes frosted, the suction pressure at the compressor suction line 30 is reduced, it being understood that the pressure at the connection 38 is substantially the same as the pressure in the suction line 30. When the valve 32, which is normally closed, senses the suction line pressure at the connection 38 to be lower than a selected pressure value (e.g., 60 psi in this embodiment), the valve 32 is opened proportionately, such proportionate opening being greater for lower sensed pressures at the connection 38. More particularly, when the discharge valve 32 is opened, a portion of the hot gas flows from the discharge line 24, in serial order, through the inlet line 40, the discharge valve 32, the outlet line 42, and the evaporator 22, thereby bypassing the condenser 18 and the expansion device 20. The opening of the valve 32 thereby defrosts the evaporator 22, and simultaneously raises the suction pressure, thus enabling the evaporator 22, the compressor 16, and the heat pump 10 to operate at low ambient air temperatures in a normal manner. During the aforesaid operation of the valve 32, a portion of the hot gas continues to flow through the condenser 18, thereby continuing to transfer thermal energy to the fluid (such as swimming pool water) surrounding the condenser 18, thus continuing to heat such fluid.

Referring to the Graph 1 and Table 1 below, laboratory tests have demonstrated that the heat pump 10 operates normally at ambient air temperatures as low as 40° F.
Graph 1: Bypass Defrosting Test Results

- Room went 85°F - Mammal
- Defrost mechanism activated
- Room went to 40°F with defrost mechanism activated
- Defrost mechanism shut-off
- Room went to 35°F with defrost mechanism activated
- Room went to 50°F without defrost mechanism
- Suction temperature rose above frozen point
- Suction temperature sank below
- Defrost mechanism activated
- Ticks & litres

Graph showing temperature and pressure changes over time.
TABLE 1

TEST RESULT OBSERVATIONS:
Graph 1 shows the testing results of the defrost mechanism, wherein a manual shut off valve was installed to activate and deactivate the discharge valve mechanism of the heat pump:
Graph 1: From left to right:

---Room temperature went from 80°F to 50°F without defrost mechanism, suction temperature sank below frozen point

---Defrost mechanism was activated, suction temperature rose above frozen point

---Room temperature went down to 45°F and defrost mechanism was turned off. Suction temperature went down to about 26°F

---Room temperature maintained at 45°F and the defrost mechanism was activated. Suction temperature rose above frozen point

---Room temperature went down to 40°F with defrosting mechanism activated. Suction temperature maintained around the frozen point

---Defrost was turned off, suction temperature took a dive

---Room went down to 35°F and defrost mechanism was activated, suction temperature maintained at about 27 to 28°F

From the test results, the unit can operate at 40°F ambient without frost issues. The unit will begin to frost once the ambient temperature is below 40°F depending on the humidity conditions. As we can see that the suction pressure still maintained about 50 psi even the room went to 40°F and about 48 psi when the room went to 35°F. So the unit would continue to operate with ambient in 30k, but the low-pressure switch will shut down the unit once severe frost covered large part of the coil.

Another exemplary embodiment of the present invention is illustrated in FIGS. 3-4. Elements illustrated in FIGS. 3-4 which correspond to the elements described above with reference to FIGS. 1-2 have been designated by corresponding reference numerals increased by one hundred, while new elements are designated by odd-numbered reference numerals in the one hundreds. The embodiment of the present invention shown in FIGS. 3-4 operates and is constructed in a manner consistent with the embodiment of FIGS. 1-2, unless it is stated otherwise.

Referring to FIG. 3, a heat pump system 110 includes a refrigerant circuit 112 and a defrost circuit 114. The defrost circuit 114, which operates in conjunction with a high pressure switch 115 disposed in a compressor suction line 130, includes a solenoid valve 117, which is disposed between an inlet line 140 and an outlet line 142.

FIG. 4 illustrates a transformer 119 for powering the valve 117. Wires 121 (shown as solid lines) electrically interconnect the valve 117, the switch 115, and the transformer 119.

In operation, the switch 115 senses the suction pressure at the compressor suction line 130. More particularly, the switch 115 is set up to open at a selected suction line pressure value (e.g., 60 psi in this embodiment). When the suction line 130 pressure is higher than 60 psi, the switch 115 is open, the transformer 119 is not activated, and the valve 117 is not energized. When the valve 117 is not energized, the valve 117 is closed to the flow of hot gas therethrough. When the switch 115 senses the suction line 130 pressure to be lower than 60 psi, the switch 115 is closed, the transformer 119 is activated, and the valve 117 is energized. When the valve 117 is energized, the valve 117 is opened to the flow of hot gas therethrough. As described above, the bypass flow of hot gas defrosts the evaporator 122 while simultaneously raising the pressure in the suction line 130, thereby enabling the heat pump 110 to operate at low ambient air temperatures in a normal manner.

Elements of the present invention are illustrated in FIGS. 5-8. Elements illustrated in FIGS. 5-8 which correspond to the elements described above with reference to FIGS. 1-2 have been designated by corresponding reference numerals increased by two hundred, while new elements are designated by odd-numbered reference numerals in the two hundreds. The embodiment of the present invention shown in FIGS. 5-8 operates and is constructed in a manner consistent with the embodiment of FIGS. 1-2, unless it is stated otherwise.

Referring to FIGS. 5-7, there is shown a heat pump 210 having an exterior design 211. Referring to FIG. 8, there are shown disassembled elements of the heat pump 210, including a compressor 216, a condenser 218, an expansion device 220, and an evaporator 222. Referring still to FIG. 8, there are shown disassembled elements of the heat pump 210, including a fan top assembly 223, an evaporator support 225, an evaporator guard 227, a base pan assembly 229, a side panel 231, a control box assembly 233, and a cover assembly 235.

It will be understood that the embodiments of the present invention described herein are merely exemplary and that a person skilled in the art may make many variations and modifications without departing from the spirit and scope of the invention. All such variations and modifications, including those discussed above, are intended to be included within the scope of the invention as defined in the appended claims.

I claim:

1. In a heat pump including a compressor; a condenser; a compressor discharge line connecting said compressor to said condenser; an expansion device; a condenser discharge line connecting said condenser to said expansion device; an evaporator; an expansion device discharge line connecting said expansion device to said evaporator; a suction line connecting said evaporator to said compressor;

and a by-pass valve having an inlet, which is in fluid communication with said compressor discharge line, and an outlet, which is in fluid communication with said expansion device discharge line, the improvement comprising:

controlling means for controlling said by-pass valve so as to adjust said by-pass valve between an open position and a closed position in response to pressure in said suction line.

2. The heat pump of claim 1, wherein said by-pass valve is a capacity control discharge valve.

3. The heat pump of claim 2, wherein said controlling means includes an equalization tube extending between said capacity control discharge valve and said suction line.

4. The heat pump of claim 3, wherein said valve moves into its said open position in response to the suction line pressure dropping below a selected value associated with frost formation on said evaporator, whereby refrigerant flowing from said compressor discharge line to said evaporator causes the evaporator to defrost.

5. The heat pump of claim 4, wherein said selected suction line pressure value is 60 psi.

6. The heat pump of claim 1, wherein said by-pass valve is a solenoid valve.

7. The heat pump of claim 6, wherein said controlling means includes a pressure switch adapted to sense pressure
in said suction line, said pressure switch being electrically connected to said solenoid valve.

8. The heat pump of claim 7, wherein said solenoid valve moves into its said open position in response to the suction line pressure dropping below a selected value associated with frost formation on said evaporator, whereby refrigerant flowing from said compressor discharge line to said evaporator causes said evaporator to defrost.

9. The heat pump of claim 8, wherein said selected suction line pressure value is 60 psi.

10. In a heat pump including a refrigerant circuit having a compressor; a condenser; a compressor discharge line connecting said compressor to said condenser; an expansion device; a condenser discharge line connecting said condenser to said expansion device; an evaporator; an expansion device discharge line connecting said expansion device to said evaporator; and a suction line connecting said evaporator to said compressor; the improvement comprising:

a defrost circuit including a valve having an inlet and an outlet; an inlet line in fluid communication with said compressor discharge line and said inlet; an outlet line in fluid communication with said outlet and said expansion device discharge line; and controlling means for controlling said valve so as to adjust said valve between an open position and a closed position in response to pressure in said suction line, wherein said valve moves into its said open position in response to the pressure in said suction line dropping below a selected value, whereby refrigerant flowing from said compressor discharge line to said evaporator causes the evaporator to defrost.

11. The heat pump system of claim 10, wherein said valve is a capacity control discharge valve.

12. The heat pump system of claim 11, wherein said controlling means includes an equalization tube in fluid communication with said suction line and said valve, said equalization tube being adapted to communicate the pressure in said suction line to said valve.

13. The heat pump system of claim 10, wherein said valve is a solenoid valve.

14. The heat pump system of claim 13, wherein said controlling means includes a transformer electrically connected to said solenoid valve, and a switch disposed in said suction line and electrically connected to said transformer.

15. A method for defrosting an evaporator of a heat pump which also includes a compressor; a condenser; a compressor discharge line connecting the compressor to the condenser; an expansion device; a condenser discharge line connecting the condenser to the expansion device; an expansion device discharge line connecting the expansion device to the evaporator; a suction line connecting the evaporator to the compressor; and a by-pass valve having an inlet, which is in fluid communication with the compressor discharge line, and an outlet, which is in fluid communication with the expansion device discharge line, the method comprising the steps of:

selecting a pressure value associated with the formation of frost on the evaporator;

monitoring the pressure in the suction line;

opening the by-pass valve when the pressure in the suction line drops below the selected value, thereby allowing a flow of refrigerant from the compressor, through the by-pass valve and into the evaporator, wherein the refrigerant is of a temperature sufficient to defrost the evaporator;

continuing to monitor the pressure in the suction line; and

closing the by-pass valve when the pressure in the suction line returns to the selected value.