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(54) REVERSE CYCLE HEAT PUMP

(71) We, BORG-WARNER CORPORATION, a Corporation organized and existing under the laws of the State of Delaware, United States of America, of 200 South Michigan Avenue, Chicago, State of Illinois 60604, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

Reverse cycle heat pumps contain a suction line heat exchanger which is operative only during the heating cycle to re-evaporate excessive liquid refrigerant carried by the lubricant as it flows to the compressor suction inlet.

In U.S. Patent 3,077,086, an oil distillation apparatus is provided for a reverse cycle heat pump. A mixture of refrigerant and oil is bled off from the discharge side of the low side refrigerant pump, said mixture being pumped through an oil still which is heated by compressor discharge gas. Since discharge gas, rather than high pressure refrigerant liquid, is used to provide heat for distillation, and the heat exchanger is utilized on both the heating and cooling cycles, the present invention is easily distinguished therefrom.

In U.S. Patent 3,246,482 a heat exchanger is located between the liquid refrigerant line and the suction line; but this is operative both during the heating and cooling cycles of operation. Many similar patents are related to designs which are purposely charged with sufficient refrigerant to maintain a liquid level in the accumulator during both the heating and cooling cycles of operation. Consequently, these require heat exchange for both cycles of operation in order to evaporate liquid returning in the suction line from the accumulator.

This invention relates generally to reverse cycle heat pumps and more particularly to heat pumps which are provided with heat exchange means to effect heat transfer from the hot liquid leaving the coil operating as a condenser to the suction gas leaving the coil operator as an evaporator. This heat transfer can take place with substantially no thermodynamic loss and the refrigerant piping is such that the heat exchanger is automatically bypassed when the system is converted from heating to cooling operation. In capillary type, reverse cycle heat pumps, it was quite common in the prior art to overcharge the system so that during the heating cycle a substantial quantity of refrigerant was maintained in a suction line accumulator. This is true because the charge required for cooling operation is much greater than that which is required for heating. It was also common to provide a bleed hole in the accumulator suction tube to assure that oil would be returned to the compressor. However, the liquid refrigerant mixed with the oil results in both refrigerant and oil being returned to the compressor. Unless it is evaporated, the liquid refrigerant will flow to the compressor oil sump where it will dilute the oil, causing poor lubrication and reduced compressor service life. The present invention provides for heat exchange relation between the high pressure liquid leaving the indoor coil and the suction gas. Thus the liquid at a high pressure is subcooled while any liquid in the suction gas is evaporated at no thermodynamic loss. For cooling operation, the accumulator operates with no refrigerant liquid at normal conditions. If heat were used, the compressor would become overheated at high load conditions.

According to the invention there is provided in a heat pump system including a compressor: a fluid reversal means; an indoor coil; an outdoor coil; first and second expansion means; means for conducting refrigerant in a first closed circuit path from said compressor through said reversal means to said outdoor coil and then through said first refrigerant expansion means to said indoor coil and back to said compressor; said reversal means being adapted to be repositioned to allow refrigerant from said compressor to flow in a second closed circuit path to said indoor coil through said second refrigerant expansion means to said outdoor coil and then back to said compressor, a heat exchanger for bringing fluid returning to said compressor into

heat exchange contact with high pressure liquid from said indoor coil during flow in said second closed circuit path, and means for directing high pressure liquid from the outdoor coil directly to the indoor coil through the first refrigerant expansion means without passing through the heat exchanger.

The invention will be further described, by way of example, with reference to the accompanying drawings, wherein:

FIGURE 1 is a schematic diagram of a reverse cycle heat pump constructed in accordance with the present invention;

FIGURE 2 is a modification of the heat pump system shown in FIGURE 1; and

FIGURE 3 is still another modification of the heat pump system shown in FIGURE 1.

Referring now to FIGURE 1, a heat pump system is shown which includes a compressor 10, a reversing valve 12, an outdoor coil 14, a check valve 16, a capillary 18, an indoor coil 20, a suction line accumulator 22 and a heat exchanger 24. The arrows with solid line stems on FIGURE 1 show the direction of refrigerant flow for cooling operations which may be further described as follows: refrigerant compressed in compressor 10 flows through hot gas line 26 to four way reversing valve 12 which in its solid line position causes flow from line 26 to hot gas line 28, connected to outdoor coil 14. The refrigerant condenses in coil 14 and flows through hot liquid line 30, check valve 16 and capillary 18 to low pressure liquid line 32. Refrigerant flow continues through indoor coil 20, now functioning as the evaporator, then through coil gas line 34, the other (solid-line) passage in reversing valve 12, line 36, suction line accumulator 22 and line 40 to heat exchanger 24.

The heat exchanger 24, which may be of any conventional type, e.g. shell and tube, or tube soldered to tube, has no fluid flowing on one side so that during the cooling cycle there is no significant heat transfer of any sort as the refrigerant flows therethrough and via line 44 to the suction side of compressor 10.

During the heating cycle, valve 12 is moved to its dotted line position and refrigerant flow is indicated by the arrows having the dashed line stems. From compressor 10, refrigerant flows through line 26, through valve 12 and line 34 to the indoor coil 20 which is operating as a condenser. Flow continues through lines 32 and 46 to heat exchanger 24, where it is brought into heat exchange relation witht cooled gas (and liquid refrigerant/lubricating oil) flowing back to the compressor through lines 40 and 44. The subcooled liquid from the heat exchanger then flows through line 48, which contains check valve 50 and capillary 52, to line 30. Due to the pressure drop in passing through the capillary 52 the fluid in the line 30 cannot pass through the check valve 16 which is subject to a high static pressure from the fluid in the line 32 on the high pressure outlet side of the compressor, but is directed to outdoor coil 14, operating as the evaporator, and then passes through the line 28, valve 12, line 36, suction line accumulator 22 and line 40 to the other side of heat exchanger 24. The liquid refrigerant entrained in the stream is evaporated by the heat from the hot liquid stream (being subcooled) and the mixture of refrigerant gas and lubricating oil is directed to the suction side of compressor 12 through line 44.

The system just described is best utilized as a unit in which all components are in a self contained assembly. Typical of such installations would be window or through-the-wall units. If the system is split—that is the compressor and outdoor coil are in one package, and the evaporator in another, some modifications must be made in the FIGURE 1 system. The main difference is in the liquid and gas lines to (and from) the inside coil.

An installation is shown in FIGURE 2 in which the indoor and outdoor coils are each part of separate packages or subassemblies which are connected together on site. In FIGURE 2 where the elements are the same and correspond to the unit of FIGURE 1, the same reference numerals are employed.

The system is quite similar to the packaged unit system of FIGURE 1 except that line 34 has a connecting section 34*a* and line 32 has a connecting section 32*a*, their respective connecting sections being joined on site to complete the respective lines 34 and 32. For cooling operation refrigerant flows from compressor 10 through reversing valve 12 and line 28. From coil 14 condensed refrigerant flows through check valve 50, line 32, including section 32*a* and capillary 52 to indoor coil 20. Refrigerant vapor then flows through line 34, including connecting section 34*a*, to reversing valve 12, line 36, suction accumulator 22, heat exchanger 24, and line 44 back to the suction side of the compressor.

During the heating cycle, refrigerant from compressor 10 is delivered through hot gas line 26 and reversing valve 12 (through the passages as shown in the dotted line position), and then through line 34 (34*a*) to indoor coil 20. From the indoor coil 20 refrigerant flows through line 32, check valve 54 (which offers less flow resistance then capillary 52), connecting section 32*a*, and then through line 46 to heat exchanger 24. From the heat exchanger, the subcooled refrigerant flows through line 48 through capillary 56 and line 30 to the outdoor coil 14.

Refrigerant vapor then flows through line 28, reversing valve 12, line 36, to suction line accummulator 22. The suction gas returns to compressor 10 through line 40, heat exchanger 24, and line 44.

FIGURE 3 discloses still another modification of the invention. Again, the same reference numerals are applied where the elements are common to FIGURE 1 and in generally the same relationship. For the cooling cycle, refrigerant from compressor 10 passes through hot gas line 26, reversing valve 12, and line 28 to outdoor coil 14. The condensed refrigerant then flows through line 30, check valve 16, and line 60 through a filter-dryer element 62 disposed therein. From there the refrigerant flows through capillary 70, line 72, to the indoor coil 20 by a line 32. The return to compressor suction is the same as in the previous embodiments, that is, through line 34, reversing valve 12, suction line accumulator 22, line 40, heat exchanger 24, and suction gas line 44.

During heating operation, hot gas from compressor 10 flows through hot gas line 26 and reversing valve 12 (through passages as shown in the dotted line position) and line 34 to indoor coil 20. From the indoor coil, the condensed refrigerant flows through line 32, check valve 74, line 60 (including filter-dryer 62), line 46 to heat exchanger 24. From the heat exchanger, the subcooled liquid is passed through capillary 76, line 30 to outdoor coil 14. Vapor returns to the suction side of the compressor through line 28, reversing valve 12, suction line accumulator 22, line 40, heat exchanger 24, and suction gas line 44. As before flow through the check valve 16 from the line 30 is prevented due to the higher pressure of the fluid in the line between the check valves 16 and 74.

WHAT WE CLAIM IS:—

1. In a heat pump system including a compressor; a fluid reversal means; an indoor coil; an outdoor coil; first and second expansion means; means for conducting refrigerant in a first closed circuit path from said compressor through said reversal means to said outdoor coil and then through said first refrigerant expansion means to said indoor coil and back to said compressor; said reversal means being adapted to be repositioned to allow refrigerant from said compressor to flow in a second closed circuit path to said indoor coil through said second refrigerant expansion means to said outdoor coil and then back to said compressor, a heat exchanger for bringing fluid returning to said compressor into heat exchange contact with high pressure liquid from said indoor coil during flow in said second closed circuit path, and means for directing high pressure liquid from the outdoor coil directly to the indoor coil through the first refrigerant expansion means without passing through the heat exchanger.

2. Apparatus as defined in claim 1 including in the second closed circuit path a first conduit for conducting hot condensed refrigerant from the indoor coil through the heat exchanger in heat exchange relation with low pressure refrigerant vapor having returned from the outdoor coil to the compressor; and in the first closed circuit path a second conduit adapted to conduct hot condensed refrigerant from the outdoor coil directly to the first expansion means.

3. Apparatus as claimed in Claim 2, including a suction line accumulator upstream from the heat exchanger and the compressor.

4. A heat pump comprising: a refrigerant compressor; a reversing valve; an outdoor coil; a heat exchanger including means defining first and second independent fluid paths adapted to transfer heat therebetween; an indoor coil; a first refrigerant line connecting the discharge from said compressor to said reversing valve; a second refrigerant line connecting said reversing valve to said outdoor coil; a third refrigerant line connecting said outdoor coil to said indoor coil, said third refrigerant line having a first section thereof including a first capillary and a first check valve permitting flow through said first section only in the direction toward said indoor coil; a fourth refrigerant line connecting said indoor coil with said reversing valve; a fifth refrigerant line connecting said reversing valve to said first fluid path in said heat exchanger; a sixth refrigerant line connecting said first fluid path to the suction side of said compressor whereby, upon operation of the system in the cooling cycle, refrigerant passes from compressor discharge, in series, through said first refrigerant line, said reversing valve, said second refrigerant line, said outdoor coil, said refrigerant line, said first check valve, said first capillary, said indoor coil, said fourth refrigerant line, said reversing valve, said fifth refrigerant line, said heat exchanger, and said sixth refrigerant line; a seventh refrigerant line connecting a second section of said third refrigerant line with said heat exchanger, through said second fluid path, for effecting heat transfer to refrigerant flowing through said first fluid path; an eighth refrigerant line connecting said second fluid path said outdoor coil, said line including a second check valve and a second capillary whereby, upon operation of the system in the heating cycle, refrigerant passes from compressor discharge, in series, through said first refrigerant line, said reversing valve, said in-

Refrigerant vapor then flows through line 28, reversing valve 12, line 36, to suction line accummulator 22. The suction gas returns to compressor 10 through line 40, heat exchanger 24, and line 44.

FIGURE 3 discloses still another modification of the invention. Again, the same reference numerals are applied where the elements are common to FIGURE 1 and in generally the same relationship. For the cooling cycle, refrigerant from compressor 10 passes through hot gas line 26, reversing valve 12, and line 28 to outdoor coil 14. The condensed refrigerant then flows through line 30, check valve 16, and line 60 through a filter-dryer element 62 disposed therein. From there the refrigerant flows through capillary 70, line 72, to the indoor coil 20 by a line 32. The return to compressor suction is the same as in the previous embodiments, that is, through line 34, reversing valve 12, suction line accumulator 22, line 40, heat exchanger 24, and suction gas line 44.

During heating operation, hot gas from compressor 10 flows through hot gas line 26 and reversing valve 12 (through passages as shown in the dotted line position) and line 34 to indoor coil 20. From the indoor coil, the condensed refrigerant flows through line 32, check valve 74, line 60 (including filter-dryer 62), line 46 to heat exchanger 24. From the heat exchanger, the subcooled liquid is passed through capillary 76, line 30 to outdoor coil 14. Vapor returns to the suction side of the compressor through line 28, reversing valve 12, suction line accumulator 22, line 40, heat exchanger 24, and suction gas line 44. As before flow through the check valve 16 from the line 30 is prevented due to the higher pressure of the fluid in the line between the check valves 16 and 74.

WHAT WE CLAIM IS:—

1. In a heat pump system including a compressor; a fluid reversal means; an indoor coil; an outdoor coil; first and second expansion means; means for conducting refrigerant in a first closed circuit path from said compressor through said reversal means to said outdoor coil and then through said first refrigerant expansion means to said indoor coil and back to said compressor; said reversal means being adapted to be repositioned to allow refrigerant from said compressor to flow in a second closed circuit path to said indoor coil through said second refrigerant expansion means to said outdoor coil and then back to said compressor, a heat exchanger for bringing fluid returning to said compressor into heat exchange contact with high pressure liquid from said indoor coil during flow in said second closed circuit path, and means for directing high pressure liquid from the outdoor coil directly to the indoor coil through the first refrigerant expansion means without passing through the heat exchanger.

2. Apparatus as defined in claim 1 including in the second closed circuit path a first conduit for conducting hot condensed refrigerant from the indoor coil through the heat exchanger in heat exchange relation with low pressure refrigerant vapor having returned from the outdoor coil to the compressor; and in the first closed circuit path a second conduit adapted to conduct hot condensed refrigerant from the outdoor coil directly to the first expansion means.

3. Apparatus as claimed in Claim 2, including a suction line accumulator upstream from the heat exchanger and the compressor.

4. A heat pump comprising: a refrigerant compressor; a reversing valve; an outdoor coil; a heat exchanger including means defining first and second independent fluid paths adapted to transfer heat therebetween; an indoor coil; a first refrigerant line connecting the discharge from said compressor to said reversing valve; a second refrigerant line connecting said reversing valve to said outdoor coil; a third refrigerant line connecting said outdoor coil to said indoor coil, said third refrigerant line having a first section thereof including a first capillary and a first check valve permitting flow through said first section only in the direction toward said indoor coil; a fourth refrigerant line connecting said indoor coil with said reversing valve; a fifth refrigerant line connecting said reversing valve to said first fluid path in said heat exchanger; a sixth refrigerant line connecting said first fluid path to the suction side of said compressor whereby, upon operation of the system in the cooling cycle, refrigerant passes from compressor discharge, in series, through said first refrigerant line, said reversing valve, said second refrigerant line, said outdoor coil, said refrigerant line, said first check valve, said first capillary, said indoor coil, said fourth refrigerant line, said reversing valve, said fifth refrigerant line, said heat exchanger, and said sixth refrigerant line; a seventh refrigerant line connecting a second section of said third refrigerant line with said heat exchanger, through said second fluid path, for effecting heat transfer to refrigerant flowing through said first fluid path; an eighth refrigerant line connecting said second fluid path said outdoor coil, said line including a second check valve and a second capillary whereby, upon operation of the system in the heating cycle, refrigerant passes from compressor discharge, in series, through said first refrigerant line, said reversing valve, said in-

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door coil, said second section of said third frigerant line, said reversing valve, said in- said second fluid path, said eighth refriger- ant line, including said second check valve and said second capillary, said outdoor coil, said second refrigerant line, said reversing valve, said fifth refrigerant line, said first fluid path, and said sixth refrigerant line to compressor suction.

5. A heat pump system constructed and arranged to operate substantially as herein- before described with reference to and as shown in FIGURE 1, FIGURE 2 or FIG- URE 3 of the accompanying drawings.

J. A. KEMP & CO.,
Chartered Patent Agents,
14 South Square,
Gray's Inn,
London WC1R 5EU.

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