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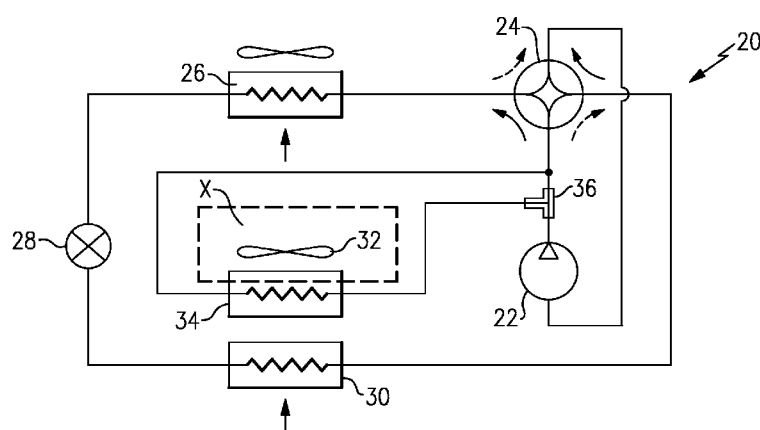
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(54) Title: HEAT PUMP WITH MICROCHANNEL HEAT EXCHANGERS AS BOTH OUTDOOR AND REHEAT HEAT EXCHANGERS

**FIG.1**

(57) Abstract: A heat pump refrigerant system has a compressor for delivering a compressed refrigerant to a reversing refrigerant flow control device. The reversing refrigerant flow control device selectively delivers refrigerant to an outdoor heat exchanger in a cooling mode of operation, and to an indoor heat exchanger in a heating mode of operation. Refrigerant from an outdoor heat exchanger passes through an expansion device to an indoor heat exchanger in a cooling mode, and from the indoor heat exchanger through an expansion device and to the outdoor heat exchanger in a heating mode. A reheat circuit includes a reheat heat exchanger positioned to be in the path of air delivered over the indoor heat exchanger and into an environment to be conditioned. The reheat heat exchanger and outdoor heat exchanger both are provided by microchannel heat exchangers. The reheat circuit is utilized to minimize or prevent refrigerant charge migration while operating at a wide spectrum of environmental conditions or switching between modes of operation.

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HEAT PUMP WITH MICROCHANNEL HEAT EXCHANGERS AS BOTH OUTDOOR AND REHEAT HEAT EXCHANGERS

BACKGROUND OF THE INVENTION

[0001] One type of refrigerant system is a heat pump. A heat pump can be utilized to heat air being delivered into an environment to be conditioned, or to cool and typically dehumidify the air delivered into the indoor environment. In a basic heat pump, a compressor compresses a refrigerant and delivers it downstream through a refrigerant flow reversing device, typically a four-way reversing valve. The refrigerant flow reversing device initially routes the refrigerant to an outdoor heat exchanger, if the heat pump is operating in a cooling mode, or to an indoor heat exchanger, if the heat pump is operating in a heating mode. From the outdoor heat exchanger, the refrigerant passes through an expansion device, and then to the indoor heat exchanger, in the cooling mode of operation. In the heating mode of operation, the refrigerant passes from the indoor heat exchanger to the expansion device and then to the outdoor heat exchanger. In either case, the refrigerant is routed through the refrigerant flow reversing device back into the compressor. The heat pump may utilize a single bi-directional expansion device or two separate expansion devices.

[0002] In recent years, much interest and design effort has been focused on the efficient operation of the heat exchangers (indoor and outdoor) in heat pumps. Higher effectiveness of the refrigerant system heat exchangers directly translates into the augmented system efficiency and reduced life-time cost. One relatively recent advancement in heat exchanger technology is the development and application of parallel flow, or so-called microchannel or minichannel, heat exchangers (these two terms will be used interchangeably throughout the text), as the indoor and outdoor heat exchangers.

[0003] These parallel flow heat exchangers are provided with a plurality of parallel heat transfer tubes, typically of a non-round shape, among which refrigerant is distributed and flown in a parallel manner. The heat exchange tubes typically incorporate multiple channels and are orientated generally substantially perpendicular to a refrigerant flow direction in the inlet, intermediate and outlet manifolds that are in flow communication with the heat transfer tubes. Heat transfer enhancing fins are typically disposed in between and rigidly attached to the heat exchange tubes. The primary reasons for the employment of the parallel flow heat exchangers, which usually have aluminum furnace-brazed construction,

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are related to their superior performance, high degree of compactness, structural rigidity and enhanced resistance to corrosion.

[0004] Microchannel heat exchangers have been proposed in the past for the outdoor heat exchanger application. One challenge with utilizing microchannel heat exchangers as the outdoor heat exchanger is also an advantage. Microchannel heat exchangers have a small internal volume and therefore store less refrigerant charge. Although this is an advantage, it may become a disadvantage on occasion. As an example, the excessive charge which may migrate from other refrigerant system components at continuously changing environmental conditions and modes of operation and is typically stored in an outdoor heat exchanger having large internal volume, such as a round tube and plate fin heat exchanger, will not be able to accumulate in a microchannel heat exchanger having much smaller internal volume. The smaller internal volume of microchannel heat exchangers makes them extremely sensitive to overcharge situations. This could cause refrigerant charge imbalance, degrade refrigerant system performance and cause nuisance shutdowns.

[0005] Another component in known refrigerant systems is a reheat cycle, typically utilizing primary refrigerant circulating throughout the system. In such a reheat cycle, at least a portion of high pressure and relatively high temperature refrigerant is tapped and passed through a reheat heat exchanger. The reheat heat exchanger is positioned to be in the path of air flowing over an indoor heat exchanger and being directed into an environment to be conditioned. The reheat heat exchanger is positioned downstream of the indoor heat exchanger, with respect to the airflow. The reheat cycle is utilized to provide a dehumidification function, while keeping temperature essentially the same, and enhance refrigerant system dehumidification capability. Typically, the air is cooled at the main indoor heat exchanger, which serves as an evaporator in a cooling mode of operation. By cooling the air at the evaporator below the temperature desired for the environment to be conditioned, additional moisture amount can be removed from the air stream. That air then passes over the reheat heat exchanger where it is heated back toward the target temperature.

[0006] Heat pump refrigerant systems have started to implement microchannel heat exchangers, but they experience significant challenges from refrigerant charge migration. When the environmental conditions change, the mode of operation may be altered

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as well (i.e., switching between cooling, heating, reheat). Also, in addition to changes in the environmental conditions and modes of operation, the charge migration problem can occur if the system is unloaded to satisfy thermal load demand in the conditioned space.

[0007] Heat pumps equipped with a reheat circuit may also utilize this circuit to increase the effective size of the indoor heat exchanger (the condenser) and overall system efficiency/capacity, in a heating mode of operation. This may aggravate the charge migration problem mentioned above. Similar charge migration conditions may be observed when the refrigerant system switches from one reheat mode of operation to another or has an adjustable reheat circuit capability. This is particularly true if a single reheat circuit covers both part-load and full-load operation.

[0008] Reheat heat exchangers have not utilized microchannel heat exchanger design and construction.

SUMMARY OF THE INVENTION

[0009] A heat pump has a compressor for delivering a compressed refrigerant to a reversing refrigerant flow control device. The reversing refrigerant flow control device selectively delivers refrigerant to an outdoor heat exchanger in a cooling mode, and to an indoor heat exchanger in a heating mode. Refrigerant from an outdoor heat exchanger passes through an expansion device to an indoor heat exchanger in a cooling mode, and from the indoor heat exchanger through an expansion device and to the outdoor heat exchanger in a heating mode. A reheat circuit includes a reheat heat exchanger positioned to be in the path of air delivered over the indoor heat exchanger and into an environment to be conditioned. The reheat heat exchanger and outdoor heat exchanger both are provided by microchannel heat exchangers.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0010]** Figure 1 is a schematic view of a first embodiment.
- [0011]** Figure 2 is a schematic view of a second embodiment.
- [0012]** Figure 3 is a schematic view of a third embodiment.
- [0013]** Figure 4A shows an exemplary microchannel heat exchanger.

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[0014] Figure 4B is a cross-section through a portion of the Figure 4A heat exchanger.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] Figure 1 shows a heat pump refrigerant system 20 wherein a compressor 22 compresses a refrigerant and delivers it through a reversing refrigerant flow control device such as a four-way reversing valve 24. The four-way reversing valve 24 routes the compressed refrigerant to an outdoor heat exchanger 26 when the heat pump refrigerant system 20 is in a cooling mode of operation. Downstream of the outdoor heat exchanger 26, the refrigerant passes through an expansion device 28, and then through an indoor heat exchanger 30. As known, if the heat pump 20 is operated in a heating mode, the four-way reversing valve 24 is controlled to route the refrigerant first to the indoor heat exchanger 30, the expansion device 28, and then to the outdoor heat exchanger 26. In both modes of operation, the refrigerant is returned to the four-way reversing valve 24 and routed back to the compressor 22. The expansion device 28 can be a single bi-directional expansion device or a pair of unidirectional expansion devices.

[0016] As shown, a three-way refrigerant flow control device such as a three-way valve 36 selectively routes at least a portion of refrigerant from a location downstream of the compressor 22 through a reheat heat exchanger 34 of a reheat refrigerant circuit and returns this refrigerant to the main refrigerant circuit. As also known, the three-way valve 36 can be replaced by a pair of conventional solenoid valves. An air-moving device such as a fan 32 moves air over the indoor heat exchanger 30, and the reheat heat exchanger 34, and into an environment to be conditioned X.

[0017] The operation of a reheat cycle is known in the art. In the present application, both heat exchangers 26 and 34 use a microchannel heat exchanger design and construction. The indoor heat exchanger 30 may also be a microchannel heat exchanger, or could be any other heat exchanger type, such as for instance round tube and plate fin heat exchanger.

[0018] In the cooling mode of operation, the outdoor microchannel heat exchanger 26 serves as a condenser, and the indoor heat exchanger 30 serves as an evaporator. The condenser 26 contains a high pressure refrigerant mixture of liquid and vapor

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and the evaporator 30 contains a low pressure refrigerant mixture of liquid and vapor. In the heating mode of operation, the outdoor microchannel heat exchanger 26 becomes an evaporator containing a low pressure refrigerant mixture, and the indoor heat exchanger 30 becomes a condenser containing a high pressure refrigerant mixture. In other words, the heat exchangers 26 and 30 switch their functionality when the mode of operation of the refrigerant system 20 is switched from heating to cooling and visa versa. When the heat pump 20 having conventional heat exchangers operates in the heating mode, it generally operates at lower pressures and requires less refrigerant charge. In many cases, the refrigerant charge excess or imbalance is contained in a suction side accumulator or in a discharge side receiver (not shown).

[0019] The microchannel outdoor heat exchanger 26 has a relatively small internal volume, and its overall charge amount does not vary appreciably with mode of operation and/or environmental conditions. This is not true for the indoor heat exchanger 30, which has significant internal volume and requires noticeable refrigerant charge change to operate at a different pressure and perform different functionality. Therefore, a small refrigerant charge change in the outdoor microchannel heat exchanger 26 cannot accommodate the refrigerant charge amount change for the indoor heat exchanger 30 required for the proper charge balance and operation of the heat pump refrigerant system 20. For instance, a significantly higher refrigerant charge amount required in the indoor heat exchanger 30 cannot be compensated by the lower charge amount in the outdoor microchannel heat exchanger 26, while switching from cooling to heating mode of operation. The reheat heat exchanger 34 typically contains a high pressure refrigerant liquid in the cooling mode of operation. This extra refrigerant charge amount can be utilized to regain refrigerant charge balance while switching between cooling and heating modes of operation. If the reheat heat exchanger 34 becomes a part of an active refrigerant cycle, by at least partially opening the three-way valve 36 to direct at least a portion of refrigerant into the reheat heat exchanger 34, in the heating mode of operation, it will contain high pressure refrigerant vapor, and the remaining refrigerant charge will be pushed into the condenser 30 to compensate for the lack of refrigerant charge there. At the same time, since a combined condenser, which includes both heat exchangers 30 and 34, allows for discharge pressure reduction and further refrigerant charge balance. If the reheat heat exchanger 34 is of a

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microchannel type, this extra charge amount will not be drastic and will not cause operational malfunction of the heat pump refrigerant system 20.

[0020] In this case, the refrigerant side accumulator or receiver may not be required at all, but in any case, the refrigerant charge imbalance that typically becomes much more pronounced for the refrigerant systems with microchannel condensers, will be significantly reduced or completely eliminated. Additional benefits obtained from the reheat heat exchanger 34 becoming a part of an active refrigerant circuit in the heating mode of operation include improved efficiency and capacity of the heat pump refrigerant system 20. Switching between other modes of operation may yield similar results. Further, if the three-way valve 36 has capability to control refrigerant flow through the reheat heat exchanger 34, for instance through modulation or pulsation, the precise amount of the required refrigerant charge compensation can be controlled.

[0021] As shown in Figure 2, in an alternate heat pump refrigerant system 40, the outdoor heat exchanger 26 is provided with a refrigerant flow control device such as a valve 46, and an outdoor heat exchanger bypass line 44. At least a portion of refrigerant can be routed around the outdoor heat exchanger 26, and through a refrigerant flow control device such as a valve 47 that is positioned on the bypass line 44. As in the Figure 1 embodiment, the reheat circuit has a three-way refrigerant flow control device such as a three-way valve 48 positioned between the expansion device 28 and the outdoor heat exchanger 26 that selectively blocks or routes at least a portion of refrigerant through a reheat heat exchanger 50 of the reheat refrigerant circuit. Again, in this embodiment, both heat exchangers 30 and 50 are provided by microchannel heat exchangers.

[0022] Here again, in the cooling mode of operation, the outdoor microchannel heat exchanger 26 serves as a condenser, and the indoor heat exchanger 30 serves as an evaporator. The condenser 26 contains a high pressure refrigerant mixture of liquid and vapor and the evaporator 30 contains a low pressure refrigerant mixture of liquid and vapor. In the heating mode of operation, the outdoor microchannel heat exchanger 26 becomes an evaporator containing a low pressure refrigerant mixture, and the indoor heat exchanger 30 becomes a condenser containing a high pressure refrigerant mixture. Again, the small refrigerant charge change in the outdoor microchannel heat exchanger 26 cannot accommodate the refrigerant charge amount change in the indoor heat exchanger 30 required

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for the proper charge balance and operation of the heat pump refrigerant system 20. The reheat heat exchanger 34 typically contains a high pressure liquid refrigerant in the cooling mode of operation. This extra refrigerant charge amount can be utilized to regain refrigerant charge balance while switching between cooling and heating modes of operation. If the reheat heat exchanger 34 is in communication with active refrigerant circuit, in the heating mode of operation, it will contain low pressure refrigerant, and the remaining refrigerant charge will be pushed into the condenser 30 to compensate for the lack of refrigerant charge there. Since the reheat heat exchanger 34 is microchannel, this extra charge amount will not be drastic and will not cause operational malfunction of the heat pump refrigerant system 20. Additional benefits obtained from the reheat heat exchanger 34 becoming a part of an active refrigerant circuit in the heating mode of operation may include performance and control enhancement of the heat pump refrigerant system 20. Switching between other modes of operation may yield similar results.

[0023] In addition, valves 46, 47 and 48 can be of an adjustable type to control refrigerant flow around the heat exchangers 26 and 50. This can be used to further compensate for the distinct internal volumes of the heat exchangers 26 and 30 and further control refrigerant charge amount migration at a wide spectrum of environmental conditions and modes of operation. The valve 46 is optional, and the valves 47 and 48 can be controlled independently to selectively bypass at least a portion of refrigerant around the heat exchangers 26 and 50. Further, modulation or pulsation techniques can be utilized to control valves 46, 47 and 48.

[0024] Figure 3 shows an embodiment 70 of multiple circuit heat pump refrigerant system. Although two independent refrigerant circuits are depicted, any number of refrigerant circuits can be utilized, along with any number of refrigerant circuits equipped with the reheat function. For instance, in Figure 3, both heat pump refrigerant circuits 200 and 201 route the refrigerant through an outdoor heat exchanger 72 and an indoor heat exchanger 74. A refrigerant flow control device such as a three-way valve 78 selectively taps at least a portion of refrigerant through a reheat heat exchanger 80 of a single reheat circuit associated with the refrigerant circuit 200. An air-moving device such as a fan 82 moves air over the indoor heat exchanger 74 and the reheat heat exchanger 80 and into the environment X to be conditioned. Also, a bypass line 44 and refrigerant flow control devices such as

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valves 46 and 47 allow bypass of at least a portion of refrigerant around the outdoor heat exchanger 72 within the refrigerant circuit 200.

[0025] Again, a microchannel heat exchanger is used for both the outdoor heat exchanger 72 and the reheat heat exchanger 80. Similarly, the refrigerant charge migration issues mentioned above are reduced or entirely eliminated. At changeover to a heating mode of operation, the reheat circuit communication with the main refrigerant circuit allows for the refrigerant charge rebalance and proper operation of the heat pump refrigerant system 70 at part-load and full-load conditions. Also, the smaller internal volume reheat heat exchanger is less likely to store higher than desirable amount of refrigerant. Thus, the utilization of microchannel heat exchangers for the outdoor heat exchanger and the reheat heat exchanger provides benefits over the prior art.

[0026] The basic operation of the refrigerant system 70 is similar to the heat pump refrigerant systems discussed above. The outdoor heat exchanger 72 will be a condenser during a cooling mode of operation and an evaporator during a heating mode of operation. The reverse is true of the indoor heat exchanger 74. At part-load conditions, one of the two refrigerant circuits may be operated while the other refrigerant circuit may be shut down to adjust the capacity provided by the multi-circuit heat pump refrigerant system 70, in order to satisfy thermal load demands in the conditioned space X. Therefore, the adjustable control of the refrigerant flow control devices 78, 46 and 47 may assist in precise refrigerant charge migration control at part-load and full-load operation, and in a heating mode of operation in particular, in addition to a variety of environmental conditions and modes of operation.

[0027] Figure 4A shows one exemplary four-pass microchannel heat exchanger for the invention. An inlet refrigerant line 146 delivers refrigerant into an inlet chamber of a manifold 147. From the inlet chamber of the manifold 147, the refrigerant flows into a first tube bank 148, into a first chamber of an intermediate manifold 133, into a second tube bank 150, and into an intermediate chamber of the manifold 147. From the intermediate chamber of the manifold 147, the refrigerant then flows across the third tube bank 152 into the second chamber of the intermediate manifold 133. As can be appreciated, divider plates 143 in the manifolds 147 and 133 control the reverse flow of the refrigerant. From the second chamber of the intermediate manifold 133, the refrigerant flows into a forth tube bank 154 towards an outlet chamber of the manifold 147 and into an outlet refrigerant line 150. Obviously, other

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microchannel heat exchanger pass arrangements are acceptable and within the scope of the invention. Each tube bank 148, 150, 152, and 154, although depicted as a single heat exchange tube for simplicity, typically contains multiple heat exchange tubes.

[0028] The Figure 4B is cross-sectional view of the exemplary heat exchange tube of the tube banks 148, 150, 152, and 154 shown in Figure 4A. The heat exchange tubes in the tube banks 148, 150, 152, and 154 may be similar in design. They all typically consist of a plurality of parallel refrigerant channels 100 separated by walls 101. The channels 100 allow for enhanced heat transfer characteristics and provide improved structural rigidity. The cross-section of the channels 100 may take different shapes, and although illustrated as a rectangular in Figure 4B, may be, for instance, of triangular, trapezoidal, oval or circular configurations.

[0029] The channels 100 may have a hydraulic diameter less than 5 mm, and even more narrowly less than 3 mm. Notably, the term “hydraulic diameter” does not imply that the refrigerant channels 100 are circular.

[0030] It should be pointed out that many different reheat circuit schematics and configurations could be used in this invention. Two depicted reheat circuit configurations should be considered as exemplary, since other reheat circuit designs can be employed and are within the scope of the invention.

[0031] The relatively small volume of the microchannel outdoor heat exchanger may result in charge imbalance issues, compared to the relatively large volume of the indoor heat exchanger, particularly during change-over between heating and cooling modes of operation. Engaging the internal volume of the reheat heat exchanger in the active refrigerant circuit at certain environmental conditions and modes of operation will help compensate for this imbalance, but since the reheat heat exchanger is also of a relatively small internal volume, this compensation will not raise additional issues. In one embodiment, a valve to control the flow of refrigerant to the reheat heat exchanger is opened when the heat pump is switched to be in a heating mode of operation.

[0032] Although an embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.

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CLAIMS

What is claimed is:

1. A heat pump refrigerant system comprising:
a compressor for delivering a compressed refrigerant to a reversing refrigerant flow control device, said reversing refrigerant flow control device selectively delivering the refrigerant to an outdoor heat exchanger in a cooling mode, and to an indoor heat exchanger in a heating mode, refrigerant from said outdoor heat exchanger passing through an expansion device and to said indoor heat exchanger in a cooling mode, and from said indoor heat exchanger through an expansion device and to said outdoor heat exchanger in a heating mode;
a reheat circuit including a reheat heat exchanger positioned to be in the path of air delivered over said indoor heat exchanger and into an environment to be conditioned; and
said reheat heat exchanger and said outdoor heat exchanger both being provided by microchannel heat exchangers.
2. The heat pump refrigerant system as set forth in claim 1, wherein said reheat circuit is utilized to minimize or prevent refrigerant charge migration.
3. The heat pump refrigerant system as set forth in claim 1, wherein said reheat circuit taps refrigerant from a location intermediate said outdoor heat exchanger and said expansion device.
4. The heat pump refrigerant system as set forth in claim 1, wherein said reheat circuit taps refrigerant from a location intermediate said compressor and said outdoor heat exchanger.
5. The heat pump refrigerant system as set forth in claim 1, wherein said reheat circuit includes a refrigerant flow control device controlled with at least one of modulation and pulsation techniques to vary the amount of refrigerant that is tapped into the reheat circuit.

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6. The heat pump refrigerant system as set forth in claim 1, wherein said heat pump refrigerant system is a multi-circuit refrigerant system with a plurality of said compressors delivering refrigerant through a plurality of said reversing refrigerant flow control devices.
7. The heat pump refrigerant system as set forth in claim 6, wherein the amount of refrigerant tapped into the reheat circuit is selectively controlled at part-load and full-load conditions to minimize or prevent refrigerant charge migration.
8. The heat pump refrigerant system as set forth in claim 1, wherein said microchannel heat exchangers include a plurality of tube banks that route the refrigerant in parallel paths and in opposed directions.
9. The heat pump refrigerant system as set forth in claim 1, wherein each of said microchannel heat exchangers include tubes with a plurality of separate refrigerant channels which extend parallel to each other and have a hydraulic diameter of less than 5 mm, and preferably less than 3 mm.
10. The heat pump refrigerant system as set forth in claim 1, wherein a bypass is provided around said outdoor heat exchanger to selectively bypass at least a portion of refrigerant around said outdoor heat exchanger.
11. The heat pump refrigerant system as set forth in claim 1, wherein said indoor heat exchanger is also a microchannel heat exchanger.
12. A method of operating a heat pump refrigerant system comprising the steps of:
 - (a) delivering a compressed refrigerant to a reversing refrigerant flow control device, said reversing refrigerant flow control device selectively delivering the refrigerant to an outdoor heat exchanger in a cooling mode, and to an indoor heat exchanger in a heating mode, refrigerant from said outdoor heat exchanger passing through an expansion device and to said indoor heat exchanger in a cooling mode, and from said indoor heat exchanger through an expansion device and to said outdoor heat exchanger in a heating mode;

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(b) a reheat circuit including a reheat heat exchanger positioned to be in the path of air delivered over said indoor heat exchanger and into an environment to be conditioned;

(c) said reheat heat exchanger and said outdoor heat exchanger both being provided by microchannel heat exchangers;

(d) communicating refrigerant to said reheat heat exchanger when the heat pump is a heating mode.

13. The method of operating a heat pump refrigerant system as set forth in claim 12, wherein said reheat circuit is utilized to minimize or prevent refrigerant charge migration.

14. The method as set forth in claim 12, including the step of bypassing refrigerant around said outdoor heat exchanger when the heating mode is actuated.

15. The method as set forth in claim 12, wherein said heat pump refrigerant system is a multi-circuit system and the amount of refrigerant tapped into the reheat circuit is selectively controlled at part-load and full-load conditions to minimize or prevent refrigerant charge migration.

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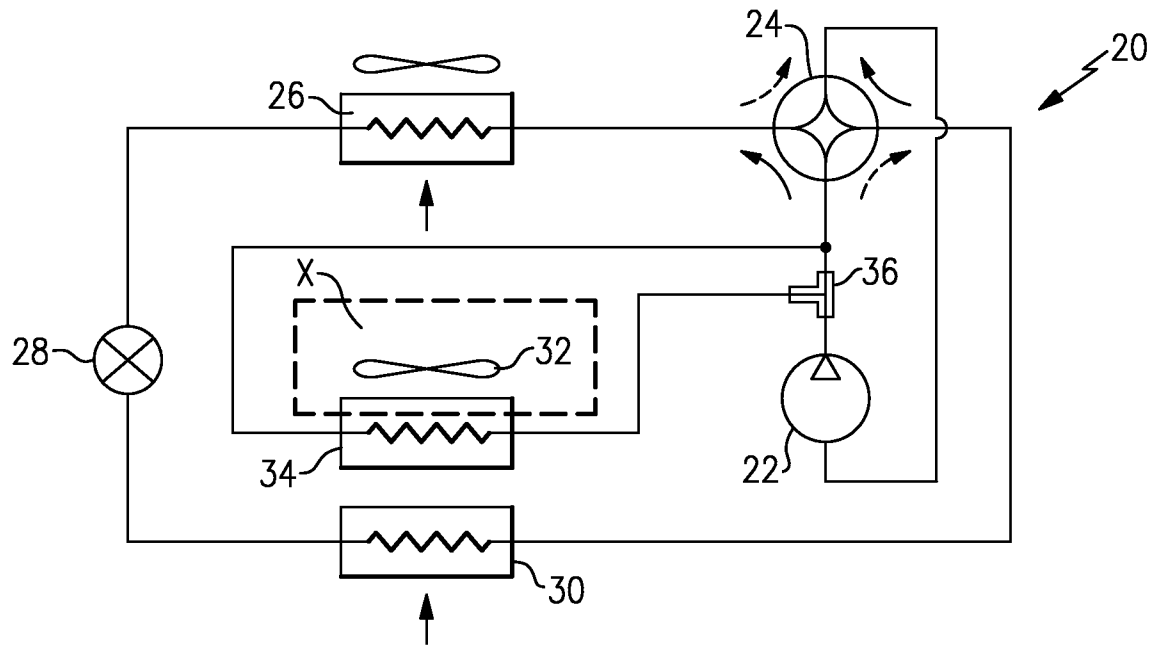


FIG. 1

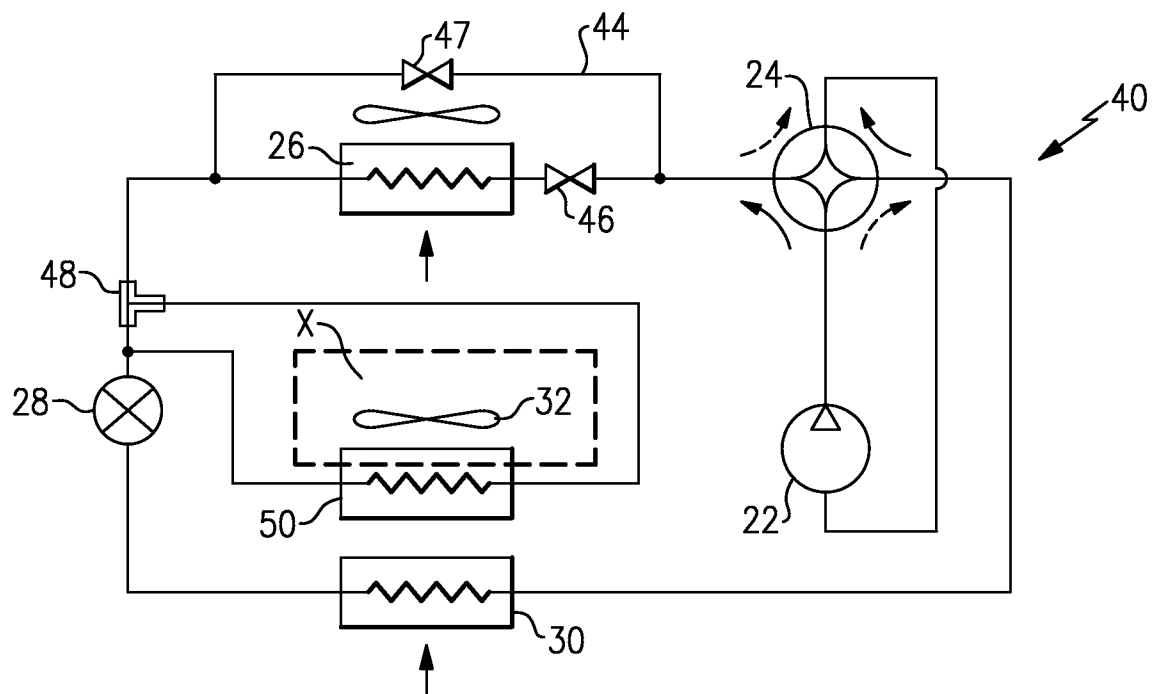


FIG. 2

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