



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
29.11.2023 Bulletin 2023/48

(21) Application number: **23175483.9**

(22) Date of filing: **25.05.2023**

(51) International Patent Classification (IPC):
F25B 25/00 (2006.01) **F25B 29/00** (2006.01)
F25B 41/20 (2021.01) **F25B 41/40** (2021.01)
F25B 49/02 (2006.01)

(52) Cooperative Patent Classification (CPC):
F25B 29/003; F25B 25/005; F25B 41/20;
F25B 41/40; F25B 49/02; F25B 2313/009;
F25B 2400/0411; F25B 2500/23; F25B 2500/24;
F25B 2600/2501; F25B 2600/2513;
F25B 2600/2521; F25B 2700/191

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **27.05.2022 US 202217826938**

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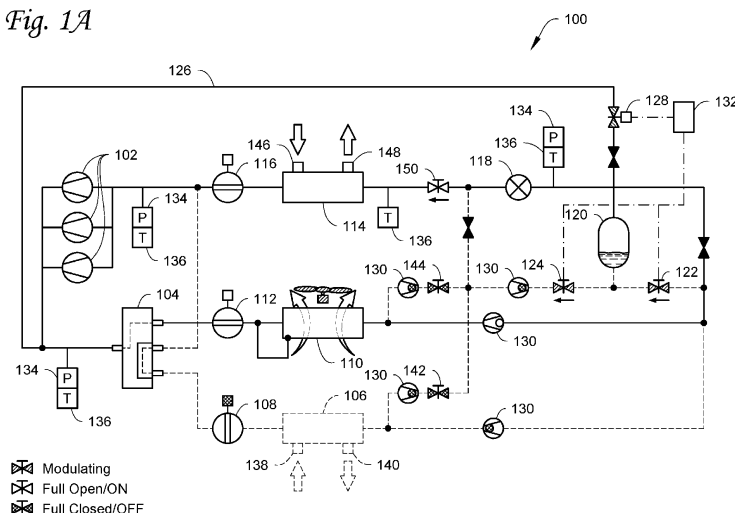
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(54) **HEATING, VENTILATION, AIR CONDITIONING, AND REFRIGERATION (HVACR) SYSTEM AND ASSOCIATED METHOD OF CONTROLLING**

(57) A dynamic receiver is included in parallel to an expander of a heating, ventilation, air conditioning, and refrigeration (HVACR) system. The dynamic receiver allows control of the refrigerant charge of the HVACR system to respond to different operating conditions. The dynamic receiver can be filled or emptied in response to the subcooling observed in the HVACR system com-

pared to desired subcooling for various operating modes. The flow through an expander of the HVACR system can be controlled to account for the mass flow rate through an outlet valve of the dynamic receiver when the dynamic receiver is emptied, preventing or reducing instability or effects on system parameters such as the suction superheat.

Fig. 1A



Description

Field

[0001] This disclosure is directed to a dynamic liquid receiver in a refrigeration circuit and control strategies for dynamic liquid receivers.

Background

[0002] Refrigeration circuits typically include liquid receivers that have fixed filling processes. The refrigerant charge in the receiver is thus maintained at a fixed level. Receiver filling has different effects on efficiency at different loads and at different parts of the operating map. A fixed receiver filling setting has to sacrifice local improvements to efficiency under some operating conditions in order to be set to a value providing adequate efficiency across different parts of the operating map.

Summary

[0003] This disclosure is directed to a dynamic liquid receiver in a refrigeration circuit and control strategies for dynamic liquid receivers.

[0004] By controlling the amount of refrigerant charge in a system dynamically, more efficient operating conditions can be selected for both full-load and part-load conditions and the operating map for the refrigeration system can be increased.

[0005] When working fluid is added to the system by draining from the dynamic receiver into the circulating flow, the change in mass flow can have knock-on effects for operational parameters of the HVACR system such as the suction superheat. Some of these effects can be delayed, not being detected or responded to until 30 seconds or more following the drain of the working fluid. These effects can cause instability and give rise to failures such as activation of low pressure cutouts, low suction superheat timed cutouts, excessive defrosting cycles, activation of high pressure cutouts or the like. By controlling the expander while accounting for drain from the dynamic receiver, the mass flow can be kept more stable, reducing or eliminating these effects and reducing or eliminating the associated failure modes for the HVACR system.

[0006] In an embodiment, a heating, ventilation, air conditioning, and refrigeration (HVACR) system includes a compressor, a first heat exchanger, an expander, a second heat exchanger, and a dynamic receiver in a fluid circuit. The dynamic receiver is in parallel with the expander with respect to the fluid circuit. The HVACR system further includes a fluid line configured to convey discharge from the compressor to the dynamic receiver.

[0007] In an embodiment, the HVACR system further includes a four-way valve.

[0008] In an embodiment, the HVACR system further includes a third heat exchanger. The first heat exchanger

is configured to exchange heat between a working fluid in the fluid circuit and a first process fluid, the second heat exchanger is configured to exchange heat between the working fluid and a second process fluid, and the third heat exchanger is configured to exchange heat with ambient air.

[0009] In an embodiment, the HVACR system further includes a controller configured to operate an inlet valve positioned directly upstream of the dynamic receiver, an outlet valve positioned directly downstream of the dynamic receiver, and a compressor discharge injection valve positioned along the fluid line to regulate a quantity of a working fluid stored in the dynamic receiver. In an embodiment, the controller is configured to determine a target quantity of working fluid to be stored in the dynamic receiver based on a measured liquid line subcooling value and a subcooling threshold value. In an embodiment, the measured liquid line subcooling value is based on a liquid line temperature measurement and a liquid line pressure measurement. In an embodiment, the target quantity of working fluid is further based on a K_p value. In an embodiment, the controller is configured to reduce the quantity of working fluid stored in the dynamic receiver by opening the outlet valve and the compressor discharge injection valve until the target quantity of working fluid is stored in the dynamic receiver. In an embodiment, the controller is configured to increase the quantity of working fluid stored in the dynamic receiver by opening the inlet valve until a target quantity of working fluid is stored in the dynamic receiver. In an embodiment, the subcooling threshold value is based on an operating mode of the HVACR system.

[0010] A method of controlling a heating, ventilation, air conditioning, and refrigeration (HVACR) system according to an embodiment includes determining, using a controller, a target quantity of working fluid to be stored in a dynamic receiver included in the HVACR system, the target quantity based on a subcooling threshold value and a measured subcooling value. The method further includes comparing a quantity of working fluid in the dynamic receiver to the target quantity. When the quantity of working fluid in the dynamic receiver exceeds the target quantity, working fluid is removed from the dynamic receiver by opening an outlet valve directly downstream of the dynamic receiver and opening a compressor discharge injection valve disposed along a fluid line connecting the discharge of a compressor of the HVACR system to the dynamic receiver. When the quantity of working fluid in the dynamic receiver is less than the target quantity, working fluid is added to the dynamic receiver by opening an inlet valve directly upstream of the dynamic receiver with respect to the working fluid flow path in the HVACR system. The dynamic receiver is in parallel with an expander included in the HVACR system.

[0011] In an embodiment, the measured liquid line subcooling value is based on a liquid line temperature measurement and a liquid line pressure measurement. In an embodiment, the target quantity of working fluid is further

based on a K_p value. In an embodiment, the subcooling threshold value is based on an operating mode of the HVACR system.

[0012] In an embodiment, a heating, ventilation, air conditioning, and refrigeration (HVACR) system includes a fluid circuit including a compressor, a first heat exchanger, an expander, and a second heat exchanger. The HVACR system further includes a dynamic receiver, the dynamic receiver in parallel with the expander with respect to the fluid circuit and an outlet valve, configured to control flow from the dynamic receiver to the fluid circuit. The HVACR system further includes a controller configured to determine a mass flow rate through the outlet valve and to control the expander based on the flow rate through the outlet valve.

[0013] In an embodiment, the HVACR system further includes a first pressure sensor configured to measure pressure at the dynamic receiver and a second pressure sensor configured to measure pressure between the expander and the second heat exchanger. In an embodiment, the controller is configured to determine the mass flow rate through the outlet valve based on a differential between a first pressure reading from the first pressure sensor and a second pressure reading from the second pressure sensor.

[0014] In an embodiment, the controller is configured to determine a desired total mass flow rate. The control of the expander based on the flow through the outlet valve includes controlling the expander such that a sum of the mass flow rate through the outlet valve and a mass flow rate through the expander equals the desired total mass flow rate.

[0015] In an embodiment, the HVACR system further includes a four-way valve. In an embodiment, the HVACR system further includes a third heat exchanger, and wherein the first heat exchanger is configured to exchange heat between a working fluid in the fluid circuit and a first process fluid, the second heat exchanger is configured to exchange heat between the working fluid and a second process fluid, and the third heat exchanger is configured to exchange heat with ambient air.

[0016] In an embodiment, a method of controlling a heating, ventilation, air conditioning, and refrigeration (HVACR) system includes determining a mass flow rate through the outlet valve and controlling the outlet valve based on the mass flow rate through the outlet valve. The HVACR system includes a circuit including an expander, a dynamic receiver in parallel with the expander, and an outlet valve configured to control flow from the dynamic receiver to the circuit.

[0017] In an embodiment, the method includes receiving a first pressure measurement from a first pressure sensor configured to measure pressure at the dynamic receiver and receiving a second pressure measurement from a second pressure sensor configured to measure pressure downstream of the expander, and wherein determining the mass flow rate through the outlet valve is based on a differential between the first pressure and the

second pressure.

[0018] In an embodiment, the method further includes determining a desired total mass flow rate. In an embodiment, controlling the outlet valve includes controlling a mass flow rate through the expander such that a sum of the mass flow rate through the outlet valve and the mass flow rate through the expander equals the desired total mass flow rate.

Drawings

[0019]

Figure 1A shows a schematic of a heating, ventilation, air conditioning, and refrigeration (HVACR) system according to an embodiment operating in a cooling mode.

Figure 1B shows the HVACR system of Figure 1A when operating in a heating mode.

Figure 1C shows the HVACR system of Figure 1A when operating in a combined mode providing both heating and cooling.

Figure 2 shows a flowchart of logic for controlling a dynamic receiver according to an embodiment.

Figure 3 shows an HVACR system according to an embodiment operating in a cooling mode.

Figure 4 shows a flowchart of a method for controlling an HVACR system according to an embodiment.

Detailed Description

[0020] This disclosure is directed to a dynamic liquid receiver in a refrigeration circuit and control strategies for dynamic liquid receivers.

[0021] Figure 1A shows a schematic of a heating, ventilation, air conditioning, and refrigeration (HVACR) system according to an embodiment operating in a cooling mode. HVACR system 100 includes one or more compressors 102 and a four-way valve 104. HVACR system 100 further includes a first heat exchanger 106, with a first heat exchanger isolation valve 108 between the four-way valve 104 and the first heat exchanger 106, a second heat exchanger 110, with a second heat exchanger isolation valve 112 between the four-way valve 104 and the second heat exchanger 110, and a third heat exchanger 114, with a third heat exchanger isolation valve 116. The HVACR system 100 further includes an expander 118 and a dynamic receiver 120. Inlet valve 122 is upstream of dynamic receiver 120, and outlet valve 124 is downstream of dynamic receiver 120 with respect to the direction of flow of working fluid through HVACR system 100. A compressor discharge injection line 126 runs from the discharge of the one or more compressors 102 directly to the dynamic receiver 120, with a compressor discharge injection valve 128 disposed along the compressor discharge injection line 126. Check valves 130 are included along various fluid lines to permit only one direction of flow through those particular lines. A controller

132 controls at least the inlet valve 122, outlet valve 124, and compressor discharge injection valve 128. Controller 132 can receive data from one or more pressure sensors 134 and/or temperature sensors 136 measuring the conditions of the working fluid at points in HVACR system 100.

[0022] HVACR system 100 is an HVACR system for providing climate control to at least one conditioned space. In the embodiment shown in Figure 1A, the HVACR system is a four-pipe HVACR system, including separate heating and cooling lines to the appropriate respective heat exchangers so that one or both of heating and cooling can be provided simultaneously.

[0023] One or more compressors 102 are provided. The compressors 102 can be any one or more suitable compressors for compressing a working fluid, such as screw compressors, scroll compressors, or the like. Where multiple compressors 102 are included in HVACR system 100, the compressors can be in parallel with one another. The one or more compressors 102 discharge compressed working fluid into a discharge line conveying the discharge towards four-way valve 104. In an embodiment, the one or more compressors 102 can be one to four compressors.

[0024] Four-way valve 104 is configured to selectively control fluid communication between the discharge of the one or more compressors 102 and one of the second heat exchanger 110 and third heat exchanger 114. Four-way valve 104 is further configured to selectively control communication of the other of the second heat exchanger 110 and third heat exchanger 114 and the suction of the one or more compressors 102. Four-way valve can be any suitable valve or arrangement of valves to provide the selectively controllable fluid communication described above.

[0025] First heat exchanger 106 is a heat exchanger configured to receive a working fluid and exchange heat between the working fluid and a heating process fluid used to provide heating. First heat exchanger 106 can be any suitable type of heat exchanger for providing the heat exchange between the working fluid and the heating process fluid. The heating process fluid can be any suitable process fluid for providing heating, such as water. The heating process fluid can be received from a heating process fluid inlet line 138, and in modes providing heating such as those shown in Figures 1B and 1C, discharged at a relatively higher temperature from the heating process fluid outlet line 140.

[0026] First heat exchanger isolation valve 108 is a valve located between the four-way valve 104 and the first heat exchanger 106. First heat exchanger isolation valve 108 can be any suitable valve having an open position permitting flow therethrough and a closed position prohibiting flow therethrough. First heat exchanger isolation valve 108 can be selectively controlled based on an operating mode of the HVACR system 100, for example, being closed in the cooling mode shown in Figure 1A. It is understood that valves such as first heat ex-

changer isolation valve 108 or any of the other valves described herein may allow small amounts of leakage in the closed position, for example due to wear, manufacturing tolerances or defects, and the like, and that the closed position of the valve is still understood as prohibiting flow even if such leakage may occur.

[0027] In an embodiment, a defrost valve 142 can be located along a fluid line providing communication between expander 118 and the first heat exchanger 106. Defrost valve 142 can be a controllable valve having at least a closed position prohibiting flow therethrough and an open position allowing flow. The defrost valve 142 can be placed into an open position to perform a defrost operation, and closed in other operating modes of the HVACR system 100 such as the cooling only, heating only, and heating and cooling modes shown in Figures 1A-1C, respectively.

[0028] Second heat exchanger 110 is a heat exchanger configured to receive a working fluid and exchange heat between the working fluid and a heat exchange medium other than the heating process fluid or the cooling process fluid heated or cooled, respectively, by HVACR system 100. The heat exchange medium can be, for example, an ambient environment. Second heat exchanger 110 can be any suitable type of heat exchanger for providing the heat exchanger between the working fluid and ambient environment. In an embodiment, ambient environment can accept heat rejected at the second heat exchanger 110 in a cooling mode such as that shown in Figure 1A, with second heat exchanger 110 serving as a condenser to condense the discharge from the one or more compressors 102. In an embodiment, the working fluid can absorb heat from the ambient environment at second heat exchanger 110, for example in the heating mode shown in Figure 1B, where the second heat exchanger 110 serves as an evaporator for working fluid received from expander 118.

[0029] Second heat exchanger isolation valve 112 is located between the four-way valve 104 and the second heat exchanger 110. Second heat exchanger isolation valve 112 can be any suitable valve having an open position permitting flow therethrough and a closed position prohibiting flow therethrough. Second heat exchanger isolation valve 112 can be selectively controlled based on an operating mode of the HVACR system 100, for example, being closed in the heating and cooling mode shown in Figure 1C.

[0030] In an embodiment, a heat pump valve 144 is located along a fluid line providing fluid communication between expander 118 and second heat exchanger 110. Heat pump valve 144 is a controllable valve having at least an open position allowing flow and a closed position prohibiting flow from expander 118 to second heat exchanger 110. Heat pump valve 144 can be in the open position, for example, during a heating operation such as the heating operation of HVACR system 100 shown in Figure 1B. Heat pump valve 144 can be closed in at least some other operating modes, such as the cooling

operating mode shown in Figure 1A and the heating and cooling operating mode shown in Figure 1C.

[0031] Third heat exchanger 114 is a heat exchanger configured to receive a working fluid and exchange heat between the working fluid and a cooling process fluid used to provide cooling. Third heat exchanger 114 can be any suitable type of heat exchanger for providing the heat exchanger between the working fluid and the cooling process fluid. The cooling process fluid can be any suitable process fluid for providing cooling, such as water, combinations of water with ethylene glycol, or the like. The cooling process fluid can be received from a cooling process fluid inlet line 146, and in modes providing cooling such as those shown in Figures 1A and 1C, discharged at a relatively lower temperature from the cooling process fluid outlet line 148. Third heat exchanger 114 operates as an evaporator, evaporating working fluid received from expander 118 by absorbing heat from the cooling process fluid.

[0032] Third heat exchanger isolation valve 116 is a valve located between the four-way valve 104 and/or the suction of the one or more compressors 102 and the third heat exchanger 114. Third heat exchanger isolation valve 116 can be any suitable valve having an open position permitting flow therethrough and a closed position prohibiting flow therethrough. Third heat exchanger isolation valve 116 can be selectively controlled based on an operating mode of the HVACR system 100, for example, being closed in the heating mode shown in Figure 1B and open in the cooling and heating and cooling modes shown in Figures 1A and 1C, respectively.

[0033] Cooling valve 150 is located along the fluid line from expander 118 to third heat exchanger 114. Cooling valve 150 is a controllable valve having at least an open position allowing flow and a closed position prohibiting flow from expander 118 to third heat exchanger 114. Cooling valve 150 can be in the open position, for example, during a cooling operation such as the cooling operation of HVACR system 100 shown in Figure 1A or the heating and cooling operation shown in Figure 1C. Cooling valve 150 can be closed in at least some other operating modes, such as the heating operating mode shown in Figure 1B.

[0034] Expander 118 is configured to expand working fluid received from one of the first heat exchanger 106 or second heat exchanger 110. Expander 118 can be any suitable expander for the working fluid, such as an expansion valve, an expansion plate, an expansion vessel, one or more expansion orifices, or any other known suitable structure for expanding the working fluid.

[0035] Dynamic receiver 120 is a liquid received configured to store working fluid. Dynamic receiver 120 can be any suitable receiver for storing the working fluid, such as but not limited to a reservoir, vessel, container, tank or other suitable volume. Dynamic receiver 120 can store the working fluid as a liquid. Working fluid stored in dynamic receiver 120 is removed from circulation through the remainder of HVACR system 100 while it is stored,

allowing the quantity of working fluid circulating in HVACR system 100 to be controlled by changing the quantity of working fluid stored in dynamic receiver 120. The amount of working fluid in dynamic receiver 120 can be controlled to respond to operating modes and/or operating conditions, for example by controller 132 controlling inlet valve 122, outlet valve 124, and compressor discharge injection valve 128, or controlled according to the method shown in Figure 2 and described below. The dynamic receiver 120 can be sized such that it can accommodate sufficient liquid working fluid to cover a difference in charge between any or all of the operating modes of the HVACR system 100. The sizing of the dynamic receiver 120 may be such that the amount of working fluid that can be stored further accounts for transitions between those operating modes or other operating conditions. For example, in the embodiment shown in Figures 1A-1C, the dynamic receiver 120 can be sized such that it can accommodate up to approximately 60% of the maximum charge of working fluid for the HVACR system 100. In an embodiment, the dynamic receiver 120 can be sized such that it can accommodate up to approximately 40% of the maximum charge of working fluid for the HVACR system 100. The level shown in dynamic receiver 120 in Figure 1A shows one potential approximate quantity of working fluid for the operation mode shown in Figure 1A.

[0036] Inlet valve 122 is upstream of dynamic receiver 120, and outlet valve 124 is downstream of dynamic receiver 120 with respect to the direction of flow of working fluid through HVACR system 100. Inlet valve 122 is a controllable valve having an open position allowing working fluid to pass therethrough and a closed position prohibiting flow therethrough. When in the open position, inlet valve 122 allows working fluid from upstream of the expander 118 to pass to the dynamic receiver 120, where the working fluid can be retained, thereby reducing the charge of working fluid circulating through HVACR system 100. Outlet valve 124 is a controllable valve having an open position allowing working fluid to pass therethrough and a closed position prohibiting flow therethrough. When in the open position, outlet valve 124 allows working fluid to pass from the dynamic receiver 120 into the flow of working fluid downstream of expander 118, rejoining the working fluid being circulated through HVACR system 100.

[0037] Compressor discharge injection line 126 runs from the discharge of the one or more compressors 102 directly to the dynamic receiver 120, with a compressor discharge injection valve 128 disposed along the compressor discharge injection line 126. Compressor discharge injection line 126 provides direct fluid communication between the discharge of the one or more compressors and the dynamic receiver 120, such that compressor discharge can be directed to dynamic receiver 120 without passing through four-way valve 104 or any of the further downstream components of the HVACR system 100 such as first heat exchanger 106, second

heat exchanger 110, and the like. Compressor discharge injection valve 128 is a controllable valve having at least an open position permitting flow therethrough and a closed position prohibiting flow. When compressor discharge injection valve 128 is open, some of the discharge from the one or more compressors 102 can pass into dynamic receiver 120. The discharge from the one or more compressors 102 is the working fluid in the form of a relatively hot gas, which can displace a relatively larger mass of liquid working fluid stored in dynamic receiver 120 to facilitate removal of working fluid from the dynamic receiver 120. Working fluid displaced from the dynamic receiver 120 by compressor discharge can pass through outlet valve 124 to join the flow of working fluid downstream of expander 118.

[0038] Check valves 130 can be positioned along various fluid lines in HVACR system 100 as shown in Figures 1A-1C. Check valves 130 can be passive one-way valves allowing flow through a fluid line in only one direction to facilitate operation in various modes, with their respective responses to the flows present in different operating modes shown in Figures 1A-1C. The check valves 130 can be placed, for example between first heat exchanger 106 and second heat exchanger 110 or third heat exchanger 114, between outlet valve 124 and the remainder of HVACR system 100.

[0039] A controller 132 controls at least the inlet valve 122, outlet valve 124, and compressor discharge injection valve 128 to control the amount of working fluid circulating in HVACR system 100 and the amount of working fluid stored in dynamic receiver 120. Controller 132 can control the amount of working fluid stored in dynamic receiver 120 to achieve a target amount or to be within a defined range for the amount of working fluid stored in dynamic receiver 120. Controller 132 is operatively connected to the inlet valve 122, outlet valve 124, and compressor discharge injection valve 128 such that commands can be sent from controller 132 to those valves. The operative connection can be, for example, a direct wired connection or wireless communications. Controller 132 can be configured to open the inlet valve 122 when working fluid is to be added to the dynamic receiver 120. Controller 132 can be configured to open the compressor discharge injection valve 128 and the outlet valve 124 when working fluid is to be removed from the dynamic receiver 120. Controller 132 can be further configured to close the inlet valve 122 when working fluid is being retained in or removed from dynamic receiver 120. Controller 132 can be further configured to close compressor discharge injection valve 128 and outlet valve 124 when working fluid is retained in or added to dynamic receiver 120.

[0040] Controller 132 can further be configured to determine the target amount or the defined range for the amount of working fluid stored in the dynamic receiver 120. In an embodiment, the target amount or defined range can be determined based on a current operating mode for the HVACR system 100, such as the cooling

mode shown in Figure 1A, the heating mode shown in Figure 1B, or the heating and cooling mode shown in Figure 1C. In an embodiment, the target amount or defined range can be determined based on operating conditions for the HVACR system 100, such as a position on an operating map for the HVACR system 100. In an embodiment, the target amount or defined range can be based on a subcooling value for the HVACR system 100, such as the subcooling value when compared to a subcooling threshold value. The subcooling threshold value can in turn be associated with particular operating modes or operating conditions. In an embodiment, there is a fixed subcooling threshold set for each operating mode. In an embodiment, the subcooling threshold can be adapted to either optimize efficiency, or to allow a larger operating envelope for the HVACR system 100, for example by providing a range or otherwise allowing some measure of deviation from the subcooling threshold. Controller 132 can further be configured to control levels of fluid in dynamic receiver 120 not only in particular operating modes, but during transitions between operating modes, such as transition from heating only to heating and cooling, heating only to cooling only, cooling only to heating only, and the like.

[0041] Pressure sensors 134 and/or temperature sensors 136 can be included to measure the pressure and temperature of the working fluid at one or more locations within HVACR system 100. Pressure sensors 134 can be any suitable pressure sensors for measuring the pressure of the working fluid at a point within HVACR system 100. Temperature sensors 136 can be any suitable temperature sensors for measuring the temperature of the working fluid at a point within HVACR system 100. In an embodiment, pressure sensors 134 and/or temperature sensors 136 can be configured to provide the pressure and/or temperature measurements to controller 132, for example by a wired connection or wireless communications. In an embodiment, at least one pressure sensor 134 and at least one temperature sensor 136 can be included along a liquid line of HVACR system 100 between either first heat exchanger 106 or second heat exchanger 110, depending on which is serving as a condenser in the current operating mode, and the expander 118. In an embodiment, the pressure sensor 134 and the temperature sensor 136 provided along the liquid line can be positioned just upstream from the expander 118 with respect to a direction of flow of the working fluid. In an embodiment, at least one pressure sensor 134 and/or temperature sensor 136 can be provided at the suction of the one or more compressors 102. In an embodiment, at least one pressure sensor 134 and/or temperature sensor 136 can be provided at the discharge of the one or more compressors 102. Pressure sensors 134 and/or temperature sensors 136 can be further provided at other points of interest along the HVACR system 100, for example providing a temperature sensor just upstream of the third heat exchanger 114 with respect to the direction of flow of the working fluid through HVACR system 100.

[0042] In the embodiment shown in Figure 1A, where the HVACR system 100 is functioning as a chiller, the four-way valve 104 directs discharge from the one or more compressors 102 to second heat exchanger 110 and provides a pathway from third heat exchanger 114 back to the suction of the one or more compressors 102. The four-way valve also provides a pathway for fluid communication between the first heat exchanger 106 and the suction of the one or more compressors 102, however in Figure 1A, the pathway is closed from the first heat exchanger 106, due to first heat exchanger isolation valve 108 being in a closed position.

[0043] Figure 1B shows the HVACR system 100 of Figure 1A when it is being operated in a heating mode. In the heating mode shown in Figure 1B, four-way valve 104 is in a position where the discharge of the one or more compressors 102 is directed to the first heat exchanger 106, and where second heat exchanger 110 is in communication with the suction of the one or more compressors 102. The cooling valve 150 and the third heat exchanger isolation valve 116 are in the closed position, preventing flow of the working fluid to third heat exchanger 114. In this embodiment, the working fluid discharged by the one or more compressors 102 passes to first heat exchanger 106, where the working fluid rejects heat, and the heating process fluid accepts that heat. The working fluid then continues to expander 118, and, when inlet valve 122 is open based on a command from controller 132, some of the working fluid can pass to the dynamic receiver 120 through inlet valve 122 prior to reaching expander 118. The working fluid expanded by expander 118 and any working fluid leaving the dynamic receiver 120 by way of outlet valve 124 when outlet valve 124 is opened then pass to second heat exchanger 110 through the heat pump valve 144, which is in the open position. At second heat exchanger 110, the working fluid absorbs heat from ambient air, and then is directed by four-way valve to the suction of the one or more compressors 102. Thus, in the heating mode shown in Figure 1B, the HVACR rejects heat to the heating process fluid at first heat exchanger 106 and absorbs heat from the ambient environment at second heat exchanger 110, functioning as a heat pump to heat the heating process fluid.

[0044] In the heating mode shown in Figure 1B, the amount of working fluid stored in dynamic receiver 120 can be relatively greater than the amount stored in dynamic receiver 120 during the cooling mode shown in Figure 1A, meaning a smaller volume of working fluid is circulating through HVACR system 100. However, it is understood that the quantities of working fluid in dynamic receiver 120 and circulating through the remainder of HVACR system 100 can be determined particularly based on specific operating conditions and other factors as described herein.

[0045] Figure 1C shows the HVACR system 100 of Figure 1A when operating in a combined mode providing both heating and cooling. In the heating and cooling mode

shown in Figure 1C, four-way valve 104 is in a position where the discharge of the one or more compressors 102 is directed to the first heat exchanger 106. Second heat exchanger isolation valve 112 and heat pump valve 144 are in the closed position, preventing flow of the working fluid to second heat exchanger 110. Four-way valve 104 further provides communication between the third heat exchanger 114 and the suction of the one or more compressors 102. In this embodiment, the working fluid discharged by the one or more compressors 102 passes to first heat exchanger 106, where the working fluid rejects heat, and the heating process fluid accepts that heat. The working fluid then continues to expander 118, and, when inlet valve 122 is open based on a command from controller 132, some of the working fluid can pass to the dynamic receiver 120 through inlet valve 122 prior to reaching expander 118. The working fluid expanded by expander 118 and any working fluid leaving the dynamic receiver 120 by way of outlet valve 124 then pass to third heat exchanger 114 through the cooling valve 150, which is in the open position. At third heat exchanger 114, the working fluid absorbs heat from the cooling process fluid, and then passes to the suction of the one or more compressors 102. Thus, in the heating and cooling mode shown in Figure 1C, the HVACR rejects heat to the heating process fluid at first heat exchanger 106 and absorbs heat from the cooling process fluid at third heat exchanger 114, cooling the cooling process fluid while also heating the heating process fluid.

[0046] In the heating and cooling mode shown in Figure 1C, the amount of working fluid stored in dynamic receiver 120 can be relatively greater than the amount stored in dynamic receiver 120 during the cooling mode shown in Figure 1A and relatively less than the amount stored in dynamic receiver 120 during the heating mode shown in Figure 1B, meaning an intermediate volume of working fluid is circulating through HVACR system 100 in this mode. However, it is understood that the quantities of working fluid in dynamic receiver 120 and circulating through the remainder of HVACR system 100 can be determined particularly based on specific operating conditions and other factors as described herein.

[0047] While Figures 1A-1C show an HVACR system including three heat exchangers and piping to select among them to meet different heating and/or cooling needs including simultaneous heating and cooling, it is understood that embodiments can include other HVACR system designs such as air conditioners, ordinary heat pump systems, or the like. An example of an air conditioner or chiller according to an embodiment could include, for example, only the active elements of the HVACR system 100 when in the cooling mode shown in Figure 1A. An example of a heat pump could include, for example, only the active elements of HVACR system 100 when in the heating mode shown in Figure 1C. These embodiments will continue to include the dynamic receiver 120, inlet valve 122, and outlet valve 124 in parallel with an expander such as expander 118, and further in-

clude compressor discharge injection line 126. HVACR systems according to embodiments can include any two heat exchangers, such as two of the first, second, and third heat exchangers 106, 110, and 114, with one of those heat exchangers operating as a condenser and the other as an evaporator. While the HVACR system 100 shown in Figures 1A-1C includes first, second, and third heat exchangers 106, 110, and 114, any one or more can be excluded depending on the particular system, for example in systems that are strictly providing heating or cooling, or that are standard reversible heat pumps.

[0048] In addition to the modes shown in Figures 1A-1C, the various valves including the first, second, and third heat exchanger isolation valves 108, 112, and 116, cooling valve 150, heat pump valve 144, and defrost valve 142, and four-way valve 104 can be positioned in combination with one another to achieve other operation modes for the HVACR system 100, such as purging, defrosting, or recovering lubricant. The check valves 130 respond to the direction of flow provided through control of those other valves to achieve the particular desired operation of the HVACR system 100. Examples of other modes that can be included include defrost modes or any other suitable type of operation for the particular HVACR system 100. The control of dynamic receiver 120 in such modes can be to provide at or near a minimum working fluid charge within HVACR system 100 for the particular operating mode.

[0049] Figure 2 shows a flowchart of logic for controlling a dynamic receiver of a heating, ventilation, air conditioning and refrigeration (HVACR) system according to an embodiment. Method 200 includes obtaining a subcooling threshold value 202, obtaining a measured subcooling value 204, determining a target quantity of working fluid 206, comparing the target quantity of working fluid to an actual quantity of working fluid in the receiver 208, and based on the comparison, performing one of adding working fluid to the receiver 210 or removing working fluid from the receiver 212. Optionally, obtaining the measured subcooling at 204 can include obtaining a liquid line temperature 214 and/or obtaining a liquid line pressure 216.

[0050] A subcooling threshold value is obtained at 202. The subcooling threshold value can be a specific subcooling value or range of subcooling values associated with a particular operating mode, such as the heating, cooling, or heating and cooling modes shown in Figures 1A-1C, or for particular operating conditions such or other operational parameters. The subcooling threshold value can in turn be associated with particular operating modes or operating conditions. In an embodiment, there is a fixed subcooling threshold value set for each operating mode. In an embodiment, the subcooling threshold value can be adapted to either optimize efficiency, or to allow a larger operating envelope for the HVACR system 100, for example by providing a range or otherwise allowing some measure of deviation from the subcooling threshold

value.

[0051] A measured subcooling may be obtained at 204. Optionally, obtaining the measured subcooling at 204 can include obtaining a liquid line temperature 214 and/or obtaining a liquid line pressure 216. In an embodiment, the measured subcooling is a value representative of the subcooling currently occurring in the HVACR system. The measured subcooling can be calculated from a temperature in a liquid line of the HVACR system obtained at 214 and/or a pressure in the liquid line obtained at 216. The measured subcooling can be obtained, for example, as a difference between a saturated liquid temperature and the liquid line temperature. In an embodiment, the saturated liquid temperature can be determined based on the pressure in the liquid line obtained at 216. Optionally, a smoothing function can be used when obtaining the measured subcooling at 204. Obtaining the liquid line temperature 214 can include measuring the temperature in a liquid line conveying working fluid from a heat exchanger serving as a condenser to an expander. The liquid line temperature can be obtained at 214 through measuring the temperature using a temperature sensor provided along the liquid line, for example directly upstream of the expander. Obtaining the liquid line pressure at 216 can include measuring the pressure in the liquid line, for example through a pressure sensor provided along the liquid line, such as one directly upstream of the expander. In an embodiment, the temperature sensor used at 214 and the pressure sensor used at 216 can be located at approximately the same position along the liquid line.

[0052] A target quantity of working fluid is determined at 206. The target quantity of working fluid can be based on a difference between the measured subcooling and the subcooling threshold value. In an embodiment, the target quantity can further be based on a K_p value for the HVACR system, where K_p is a gain adjustment factor. K_p can be used at least in part to match the HVACR system dynamics to control actions, to account for the reactive nature of operating the valves controlling flow into or out of the dynamic receiver. In an embodiment, the target quantity can be based directly on the current operating mode of the HVACR system, such as heating, cooling, heating and cooling, purge, defrost, or other possible operating modes of the HVACR system, which can each have a charge quantity associated with that operating mode.

[0053] The target quantity of working fluid is compared to an actual quantity of working fluid in the receiver at 208. Based on the comparison, the method 200 can proceed to either adding working fluid to the receiver 210 when the actual quantity of working fluid in the receiver is less than the target quantity, or removing working fluid from the receiver 212 when the actual quantity of working fluid in the receiver exceeds the target quantity.

[0054] Working fluid can be added to the receiver at 210. Adding working fluid to the receiver 210 can include opening an inlet valve. Adding working fluid to the receiver

er 210 can further include ensuring that an outlet valve of the receiver and a compressor discharge injection valve are both closed. Some working fluid passing through the fluid circuit of the HVACR system passes through the inlet valve into the receiver, where it can be stored. The fluid line connecting to the receiver to introduce working fluid into the receiver can be upstream of an expander of the HVACR system with respect to a direction of working fluid flow through the HVACR system. Adding working fluid from the receiver 210 can be performed for as long as the amount of working fluid is below a target amount of working fluid determined at 206, based on the comparison performed at 208.

[0055] Working fluid can be removed from the receiver at 212. The working fluid can be removed from the receiver 212 by opening an outlet valve of the receiver and opening a compressor discharge injection valve. Removing working fluid from the receiver 212 can further include ensuring an inlet valve for the receiver is closed. Compressor discharge fluid introduced by the compressor discharge injection valve is a hot gas, and introduction of the compressor discharge fluid can drive out a relatively larger quantity of the stored working fluid in the receiver, which leaves the receiver by way of the outlet valve. The working fluid removed from the receiver is introduced to the HVACR system downstream of an expander of the HVACR system, relative to the direction of flow of working fluid through the HVACR system. The working fluid can continue to be removed from the receiver at 212 so long as the quantity of working fluid remains greater than the target quantity of working fluid, as determined by the comparison at 208.

[0056] Figure 3 shows an HVACR system according to an embodiment operating in a cooling mode. HVACR system 300 includes one or more compressors 302 and a four-way valve 304. HVACR system 300 further includes a first heat exchanger 306, with a first heat exchanger isolation valve 308 between the four-way valve 304 and the first heat exchanger 306, a second heat exchanger 310, with a second heat exchanger isolation valve 312 between the four-way valve 304 and the second heat exchanger 310, and a third heat exchanger 314, with a third heat exchanger isolation valve 316. The HVACR system 300 further includes an expander 318 and a dynamic receiver 320. Inlet valve 322 is upstream of dynamic receiver 320, and outlet valve 324 is downstream of dynamic receiver 320 with respect to the direction of flow of working fluid through HVACR system 300. A compressor discharge injection line 326 runs from the discharge of the one or more compressors 302 directly to the dynamic receiver 320, with a compressor discharge injection valve 328 disposed along the compressor discharge injection line 326. Check valves 330 are included along various fluid lines to permit only one direction of flow through those particular lines. A controller 332 controls at least the expander 318, along with inlet valve 322, outlet valve 324, and compressor discharge injection valve 328. Controller 332 can receive data from

one or more pressure sensors 334 and/or temperature sensors 336 measuring the conditions of the working fluid at points in HVACR system 300.

[0057] HVACR system 300 is an HVACR system for providing climate control to at least one conditioned space. In the embodiment shown in Figure 3, the HVACR system is a four-pipe HVACR system, including separate heating and cooling lines to the appropriate respective heat exchangers so that one or both of heating and cooling can be provided simultaneously.

[0058] One or more compressors 302 are provided. The compressors 302 can be any one or more suitable compressors for compressing a working fluid, such as screw compressors, scroll compressors, or the like. Where multiple compressors 302 are included in HVACR system 300, the compressors can be in parallel with one another. The one or more compressors 302 discharge compressed working fluid into a discharge line conveying the discharge towards four-way valve 304. In an embodiment, the one or more compressors 302 can be one to four compressors.

[0059] Four-way valve 304 is configured to selectively control fluid communication between the discharge of the one or more compressors 302 and one of the second heat exchanger 310 and third heat exchanger 314. Four-way valve 304 is further configured to selectively control communication of the other of the second heat exchanger 310 and third heat exchanger 314 and the suction of the one or more compressors 302. Four-way valve can be any suitable valve or arrangement of valves to provide the selectively controllable fluid communication described above.

[0060] First heat exchanger 306 is a heat exchanger configured to receive a working fluid and exchange heat between the working fluid and a heating process fluid used to provide heating. First heat exchanger 306 can be any suitable type of heat exchanger for providing the heat exchange between the working fluid and the heating process fluid. The heating process fluid can be any suitable process fluid for providing heating, such as water. The heating process fluid can be received from a heating process fluid inlet line 338, and in modes providing heating, discharged at a relatively higher temperature from the heating process fluid outlet line 340. In the cooling mode shown in Figure 3, first heat exchanger is not connected in the circuit and working fluid does not circulate.

[0061] First heat exchanger isolation valve 308 is a valve located between the four-way valve 304 and the first heat exchanger 306. First heat exchanger isolation valve 308 can be any suitable valve having an open position permitting flow therethrough and a closed position prohibiting flow therethrough. First heat exchanger isolation valve 308 can be selectively controlled based on an operating mode of the HVACR system 300, for example, being closed in the cooling mode shown in Figure 3. It is understood that valves such as first heat exchanger isolation valve 308 or any of the other valves described herein may allow small amounts of leakage in the closed

position, for example due to wear, manufacturing tolerances or defects, and the like, and that the closed position of the valve is still understood as prohibiting flow even if such leakage may occur.

[0062] In an embodiment, a defrost valve 342 can be located along a fluid line providing communication between expander 318 and the first heat exchanger 306. Defrost valve 342 can be a controllable valve having at least a closed position prohibiting flow therethrough and an open position allowing flow. The defrost valve 342 can be placed into an open position to perform a defrost operation, and closed in other operating modes of the HVACR system 300.

[0063] Second heat exchanger 310 is a heat exchanger configured to receive a working fluid and exchange heat between the working fluid and a heat exchange medium other than the heating process fluid or the cooling process fluid heated or cooled, respectively, by HVACR system 300. The heat exchange medium can be, for example, an ambient environment. Second heat exchanger 310 can be any suitable type of heat exchanger for providing the heat exchanger between the working fluid and ambient environment. In an embodiment, ambient environment can accept heat rejected at the second heat exchanger 310 in a cooling mode such as that shown in Figure 3, with second heat exchanger 310 serving as a condenser to condense the discharge from the one or more compressors 302. In an embodiment, the working fluid can absorb heat from the ambient environment at second heat exchanger 310, for example in a heating mode where the second heat exchanger 310 serves as an evaporator for working fluid received from expander 318.

[0064] Second heat exchanger isolation valve 312 is located between the four-way valve 304 and the second heat exchanger 310. Second heat exchanger isolation valve 312 can be any suitable valve having an open position permitting flow therethrough and a closed position prohibiting flow therethrough. Second heat exchanger isolation valve 312 can be selectively controlled based on an operating mode of the HVACR system 300, for example, being closed in a combined heating and cooling mode.

[0065] In an embodiment, a heat pump valve 344 is located along a fluid line providing fluid communication between expander 318 and second heat exchanger 310. Heat pump valve 344 is a controllable valve having at least an open position allowing flow and a closed position prohibiting flow from expander 318 to second heat exchanger 310. Heat pump valve 344 can be in the open position, for example, during a heating operation of HVACR system 300. Heat pump valve 344 can be closed in at least some other operating modes, such as the cooling operating mode shown in Figure 3 or a heating and cooling operating mode.

[0066] Third heat exchanger 314 is a heat exchanger configured to receive a working fluid and exchange heat between the working fluid and a cooling process fluid

used to provide cooling. Third heat exchanger 314 can be any suitable type of heat exchanger for providing the heat exchanger between the working fluid and the cooling process fluid. The cooling process fluid can be any suitable process fluid for providing cooling, such as water, combinations of water with ethylene glycol, or the like. The cooling process fluid can be received from a cooling process fluid inlet line 346, and in modes providing cooling such as the cooling mode shown in Figure 3 or a combined heating and cooling mode. The cooling process fluid is discharged at a relatively lower temperature from the cooling process fluid outlet line 348. Third heat exchanger 314 operates as an evaporator, evaporating working fluid received from expander 318 by absorbing heat from the cooling process fluid.

[0067] Third heat exchanger isolation valve 316 is a valve located between the four-way valve 304 and/or the suction of the one or more compressors 302 and the third heat exchanger 314. Third heat exchanger isolation valve 316 can be any suitable valve having an open position permitting flow therethrough and a closed position prohibiting flow therethrough. Third heat exchanger isolation valve 316 can be selectively controlled based on an operating mode of the HVACR system 300, for example, being closed in a heating mode and open in the cooling mode shown in Figure 3 or a combined heating and cooling modes.

[0068] Cooling valve 350 is located along the fluid line from expander 318 to third heat exchanger 314. Cooling valve 350 is a controllable valve having at least an open position allowing flow and a closed position prohibiting flow from expander 318 to third heat exchanger 314. Cooling valve 350 can be in the open position, for example, during a cooling operation such as the cooling operation of HVACR system 300 shown in Figure 3 or a combined heating and cooling operation. Cooling valve 350 can be closed in at least some other operating modes, such as a heating operating mode.

[0069] Expander 318 is configured to expand working fluid received from one of the first heat exchanger 306 or second heat exchanger 310. Expander 318 can be any suitable expander for the working fluid, such as an expansion valve, an expansion plate, an expansion vessel, one or more expansion orifices, or any other known suitable structure for expanding the working fluid. In the embodiment shown in Figure 3, expander 318 is a controllable expander configured such that a mass flow through expander 318 can be controlled. Expander 318 can be connected to controller 332 such that expander 318 is controlled based on commands received from controller 332. For example, expander 318 can be an electronically controllable expansion valve.

[0070] Dynamic receiver 320 is a liquid receiver configured to store working fluid. Dynamic receiver 320 can be any suitable receiver for storing the working fluid, such as but not limited to a reservoir, vessel, container, tank or other suitable volume. Dynamic receiver 320 can store the working fluid as a liquid. Working fluid stored in dy-

dynamic receiver 320 is removed from circulation through the remainder of HVACR system 300 while it is stored, allowing the quantity of working fluid circulating in HVACR system 300 to be controlled by changing the quantity of working fluid stored in dynamic receiver 320. The amount of working fluid in dynamic receiver 320 can be controlled to respond to operating modes and/or operating conditions, for example by controller 332 controlling inlet valve 322, outlet valve 324, and compressor discharge injection valve 328, or controlled according to the method shown in Figure 2 and described above. The dynamic receiver 320 can be sized such that it can accommodate sufficient liquid working fluid to cover a difference in charge between any or all of the operating modes of the HVACR system 300. The sizing of the dynamic receiver 320 may be such that the amount of working fluid that can be stored further accounts for transitions between those operating modes or other operating conditions. For example, in the embodiment shown in Figure 3, the dynamic receiver 320 can be sized such that it can accommodate up to approximately 60% of the maximum charge of working fluid for the HVACR system 300. In an embodiment, the dynamic receiver 320 can be sized such that it can accommodate up to approximately 40% of the maximum charge of working fluid for the HVACR system 300. The level shown in dynamic receiver 320 in Figure 3 shows one potential approximate quantity of working fluid for the operation mode shown in Figure 3.

[0071] Inlet valve 322 is upstream of dynamic receiver 320, and outlet valve 324 is downstream of dynamic receiver 320 with respect to the direction of flow of working fluid through HVACR system 300. Inlet valve 322 is a controllable valve having an open position allowing working fluid to pass therethrough and a closed position prohibiting flow therethrough. When in the open position, inlet valve 322 allows working fluid from upstream of the expander 318 to pass to the dynamic receiver 320, where the working fluid can be retained, thereby reducing the charge of working fluid circulating through HVACR system 300. Outlet valve 324 is a controllable valve having an open position allowing working fluid to pass therethrough and a closed position prohibiting flow therethrough. When in the open position, outlet valve 324 allows working fluid to pass from the dynamic receiver 320 into the flow of working fluid downstream of expander 318, rejoining the working fluid being circulated through HVACR system 300.

[0072] Compressor discharge injection line 326 runs from the discharge of the one or more compressors 302 directly to the dynamic receiver 320, with a compressor discharge injection valve 328 disposed along the compressor discharge injection line 326. Compressor discharge injection line 326 provides direct fluid communication between the discharge of the one or more compressors and the dynamic receiver 320, such that compressor discharge can be directed to dynamic receiver 320 without passing through four-way valve 304 or any of the further downstream components of the HVACR

system 300 such as first heat exchanger 306, second heat exchanger 310, and the like. Compressor discharge injection valve 328 is a controllable valve having at least an open position permitting flow therethrough and a closed position prohibiting flow. When compressor discharge injection valve 328 is open, some of the discharge from the one or more compressors 302 can pass into dynamic receiver 320. The discharge from the one or more compressors 302 is the working fluid in the form of a relatively hot gas, which can displace a relatively larger mass of liquid working fluid stored in dynamic receiver 320 to facilitate removal of working fluid from the dynamic receiver 320. Working fluid displaced from the dynamic receiver 320 by compressor discharge can pass through outlet valve 324 to join the flow of working fluid downstream of expander 318.

[0073] Check valves 330 can be positioned along various fluid lines in HVACR system 300 as shown in Figure 3. Check valves 330 can be passive one-way valves allowing flow through a fluid line in only one direction to facilitate operation in various modes, responding respectively to the flows present in different operating modes. The check valves 330 can be placed, for example between first heat exchanger 306 and second heat exchanger 310 or third heat exchanger 314, between outlet valve 324 and the remainder of HVACR system 300.

[0074] Controller 332 is configured to control the expander 318. Controller 332 controls expander 318 such that a desired mass flow rate of working fluid is provided to the heat exchanger downstream of expander 318. The controller 332 can be configured to determine the mass flow rate through the outlet valve 324, for example based on an operational setting of the outlet valve 324 and a pressure differential across outlet valve 324. The pressure differential can be determined based on readings from pressure sensors 334, such as a pressure sensor 334 configured to measure pressure upstream of the expander and a pressure sensor 334 configured to measure pressure at the dynamic receiver 320. In an embodiment, the controller 332 can determine and control the mass flow rate through the expander 318 based on a pressure differential across the expander 318 and the operational state of the expander 318. The mass flow rate provided to the heat exchanger downstream of expander 318 can include both the mass flow rate through expander 318 and also any mass flow rate through outlet valve 324 when outlet valve 324 is opened to return fluid to the circuit of HVACR system 300 from the dynamic receiver 320. In an embodiment, controller 332 is configured to obtain the desired mass flow rate, obtain a mass flow rate through the outlet valve 324, and control expander 318 based on the mass flow rate through the outlet valve 324 such that a sum of the mass flow rate through the outlet valve 324 and the mass flow rate through the expander 318 sum to match the desired mass flow rate. When the outlet valve 324 is opened and provides flow, the flow through expander 318 can be correspondingly reduced by the controller 332 so as to maintain the sta-

bility of the total mass flow rate, avoiding or reducing impacts on parameters of the HVACR system 300 such as suction superheat or the like.

[0075] Controller 332 can also control the inlet valve 322, outlet valve 324, and compressor discharge injection valve 328 to control the amount of working fluid circulating in HVACR system 300 and the amount of working fluid stored in dynamic receiver 320. Controller 332 can control the amount of working fluid stored in dynamic receiver 320 to achieve a target amount or to be within a defined range for the amount of working fluid stored in dynamic receiver 320. Controller 332 is operatively connected to the inlet valve 322, outlet valve 324, and compressor discharge injection valve 328 such that commands can be sent from controller 332 to those valves. The operative connection can be, for example, a direct wired connection or wireless communications. Controller 332 can be configured to open the inlet valve 322 when working fluid is to be added to the dynamic receiver 320. Controller 332 can be configured to open the compressor discharge injection valve 328 and the outlet valve 324 when working fluid is to be removed from the dynamic receiver 320. Controller 332 can be further configured to close the inlet valve 322 when working fluid is being retained in or removed from dynamic receiver 320. Controller 332 can be further configured to close compressor discharge injection valve 328 and outlet valve 324 when working fluid is retained in or added to dynamic receiver 320.

[0076] Controller 332 can further be configured to determine the target amount or the defined range for the amount of working fluid stored in the dynamic receiver 320. In an embodiment, the target amount or defined range can be determined based on a current operating mode for the HVACR system 300, such as the cooling mode shown in Figure 3, a heating mode, or a combined heating and cooling mode. In an embodiment, the target amount or defined range can be determined based on operating conditions for the HVACR system 300, such as a position on an operating map for the HVACR system 300. In an embodiment, the target amount or defined range can be based on a subcooling value for the HVACR system 300, such as the subcooling value when compared to a subcooling threshold value. The subcooling threshold value can in turn be associated with particular operating modes or operating conditions. In an embodiment, there is a fixed subcooling threshold set for each operating mode. In an embodiment, the subcooling threshold can be adapted to either optimize efficiency, or to allow a larger operating envelope for the HVACR system 300, for example by providing a range or otherwise allowing some measure of deviation from the subcooling threshold. Controller 332 can further be configured to control levels of fluid in dynamic receiver 320 not only in particular operating modes, but during transitions between operating modes, such as transition from heating only to heating and cooling, heating only to cooling only, cooling only to heating only, and the like.

[0077] Pressure sensors 334 are provided at locations in HVACR system 300 such that pressure differentials affecting mass flows through expander 318 and outlet valve 324 can be determined. In the embodiment shown in Figure 3, the pressure sensors 334 include a pressure sensor 334 configured to detect pressure at the dynamic receiver 320. The pressure sensors 334 can optionally further include a pressure sensor 334 configured to detect pressure upstream of the expander, for example along a liquid line of the HVACR system 300, and a pressure sensor 334 configured to detect pressure downstream of the expander 318. The pressure sensors 334 can be any suitable pressure sensors for detecting pressure within the HVACR system 300. The pressure sensors 334 are connected to the controller 332 such that controller 332 can receive pressure readings from each of the pressure sensors 334 such that controller 332 can determine mass flow rates through the expander 318 and the outlet valve 324, and control the mass flow rate through the expander 318 to achieve a desired mass flow rate. In an embodiment, reference pressures, for example the reference pressure at the suction of the compressor or any other suitable reference pressure used for superheat control. In an embodiment, the pressures used for determining mass flow rates assume the pressure downstream of expander 318 and the pressure downstream of the outlet valve 324 are the same.

[0078] Additional sensors 336 can be included to measure the pressure, temperature, or any other suitable parameters of the working fluid at other locations within HVACR system 300. Additional sensors 336 can be any suitable temperature sensors for measuring the temperature of the working fluid at a point within HVACR system 300. In an embodiment, additional sensors 336 can be configured to provide measurements to controller 332, for example by a wired connection or wireless communications. In an embodiment, at least one of the additional sensors 336 can be included along a liquid line of HVACR system 300 between either first heat exchanger 306 or second heat exchanger 310, depending on which is serving as a condenser in the current operating mode, and the expander 318. In an embodiment, the sensor 336 provided along the liquid line can be positioned just upstream from the expander 318 with respect to a direction of flow of the working fluid. In an embodiment, at least one sensor 336 can be provided at the suction of the one or more compressors 302. In an embodiment, at least one sensor 336 can be provided at the discharge of the one or more compressors 302. Sensors 336 can be further provided at other points of interest along the HVACR system 300, for example providing a temperature sensor just upstream of the third heat exchanger 314 with respect to the direction of flow of the working fluid through HVACR system 300.

[0079] The system in Figure 3 can alternatively be operated in other modes by manipulating the various valves including the first, second, and third heat exchanger isolation valves 308, 312, and 316, cooling valve 350, heat

pump valve 344, and defrost valve 342, and four-way valve 304 can be positioned in combination with one another to achieve other operation modes for the HVACR system 300 including a heating mode such as the heating mode shown in Figure 1B, a combined heating and cooling mode such as the heating and cooling mode shown in Figure 1C, or other modes such as purging, defrosting, or lubricant separation modes.

[0080] While Figure 3 shows an HVACR system including three heat exchangers and piping to select among them to meet different heating and/or cooling needs including simultaneous heating and cooling, it is understood that embodiments can include other HVACR system designs such as air conditioners, ordinary heat pump systems, or the like. An example of an air conditioner or chiller according to an embodiment could include, for example, only the active elements of the HVACR system 300 when in the cooling mode shown in Figure 3. An example of a heat pump could include, for example, only the active elements of HVACR system used in the heating mode. These embodiments will continue to include the dynamic receiver 320, inlet valve 322, and outlet valve 324 in parallel with an expander such as expander 318, and further include compressor discharge injection line 326. These embodiments also further include controller 332 controlling a controllable expander 318 so as to control the total mass flow through the heat exchanger downstream of expander 318. HVACR systems according to embodiments can include any two heat exchangers, such as two of the first, second, and third heat exchangers 306, 310, and 314, with one of those heat exchangers operating as a condenser and the other as an evaporator. While the HVACR system 300 shown in Figure 3 includes first, second, and third heat exchangers 306, 310, and 314, any one or more can be excluded depending on the particular system, for example in systems that are strictly providing heating or cooling, or that are standard reversible heat pumps.

[0081] Figure 4 shows a flowchart of a method for controlling an HVACR system according to an embodiment. Method 400 includes obtaining a desired total mass flow 402, determining a mass flow from a drain of a dynamic receiver 404, and controlling an expander to achieve the desired total mass flow 406.

[0082] A desired total mass flow is obtained at 402. In an embodiment, the desired total mass flow is derived based on operational conditions of the HVACR system, such as suction superheat or any other suitable control parameter on which mass flow can be based. The total desired mass flow can be a desired mass flow through a heat exchanger such as an evaporator or any other suitable heat exchanger downstream of the expander. The desired total mass flow can be based on a mass flow prior to an opening of a drain valve of a dynamic receiver. The desired total mass flow can be determined by a controller for the HVACR system.

[0083] A mass flow from a drain of a dynamic receiver is obtained at 404. The mass flow can be obtained by

any suitable means. For example, the mass flow can be derived from a state of a drain valve and a pressure differential across said drain valve. In an embodiment, the pressure differential can be determined based on a pressure measurement from a pressure transducer at the dynamic receiver and a known pressure in the line downstream from the expander. The mass flow from the dynamic receiver is the flow through the drain valve rejoining flow from the expander and passing to the heat exchanger downstream of the expander. The mass flow from the dynamic receiver obtained at 404 can result from operation of the dynamic receiver in controlling a charge of working fluid in the HVACR system, for example according to method 200 discussed above and shown in Figure 2. The mass flow can result from removal of working fluid from the dynamic receiver at 212 of method 200 shown in Figure 2.

[0084] The expander is controlled to achieve the desired total mass flow at 406. The expander can be any suitable expander having a controllable mass flow rate, for example, an electronic expansion valve. The expander can be controlled at 406 such that the mass flow rate through the expander and the mass flow from the drain obtained at 404 sum to the desired mass flow rate obtained at 402. The mass flow rate through the expander can be controlled through any suitable control method. For example, the mass flow rate through the expander can be calculated based on a state of the expander and the pressure differential across the expander. The state of the expander can be controlled such that the mass flow rate achieves a particular value for the pressure differential currently detected in the HVACR system. The pressure differential can be a pressure difference between a liquid line pressure upstream of the expander and a pressure downstream of the expander.

[0085] In an embodiment, method 400 iterates continuously or periodically during operation of the HVACR system. In an embodiment, the method 400 iterates continuously or periodically while the outlet valve is in a state allowing flow from the dynamic receiver to the main circuit of the HVACR system. In an embodiment, the method 400 iterates when there is a change to the operational parameters of the HVACR system affecting the desired mass flow rate. In an embodiment, the method 400 iterates when the state of the outlet valve of the dynamic receiver changes.

Aspects:

[0086] It is understood that any of aspects 1-10 can be combined with any of aspects 11-14, 15-20, or 21-24. It is understood that any of aspects 11-14 can be combined with any of aspects 15-20 or 21-24. It is understood that any of aspects 15-20 can be combined with any of aspects 21-24.

[0087] Aspect 1. A heating, ventilation, air conditioning, and refrigeration (HVACR) system, comprising:

a compressor;
 a first heat exchanger;
 an expander;
 a second heat exchanger;
 a dynamic receiver, the dynamic receiver in parallel with the expander with respect to the fluid circuit; and
 a fluid line configured to convey discharge from the compressor to the dynamic receiver.

[0088] Aspect 2. The HVACR system according to aspect 1, further comprising a four-way valve.

[0089] Aspect 3. The HVACR system according to aspect 2, further comprising a third heat exchanger, and wherein the first heat exchanger is configured to exchange heat between a working fluid in the fluid circuit and a first process fluid, the second heat exchanger is configured to exchange heat between the working fluid and a second process fluid, and the third heat exchanger is configured to exchange heat with ambient air.

[0090] Aspect 4. The HVACR system according to any of aspects 1-3, further comprising a controller configured to operate an inlet valve positioned directly upstream of the dynamic receiver, an outlet valve positioned directly downstream of the dynamic receiver, and a compressor discharge injection valve positioned along the fluid line to regulate a quantity of a working fluid stored in the dynamic receiver.

[0091] Aspect 5. The HVACR system according to aspect 4, wherein the controller is configured to determine a target quantity of working fluid to be stored in the dynamic receiver based on a measured liquid line subcooling value and a subcooling threshold value.

[0092] Aspect 6. The HVACR system according to aspect 5, wherein the measured liquid line subcooling value is based on a liquid line temperature measurement and a liquid line pressure measurement.

[0093] Aspect 7. The HVACR system according to any of aspects 5-6, wherein the target quantity of working fluid is further based on a K_p value.

[0094] Aspect 8. The HVACR system according to any of aspects 5-7, wherein the controller is configured to reduce the quantity of working fluid stored in the dynamic receiver by opening the outlet valve and the compressor discharge injection valve until the target quantity of working fluid is stored in the dynamic receiver.

[0095] Aspect 9. The HVACR system according to any of aspects 5-8, wherein the controller is configured to increase the quantity of working fluid stored in the dynamic receiver by opening the inlet valve until a target quantity of working fluid is stored in the dynamic receiver.

[0096] Aspect 10. The HVACR system according to any of aspects 5-9, wherein the subcooling threshold value is based on an operating mode of the HVACR system.

[0097] Aspect 11. A method of controlling a heating, ventilation, air conditioning, and refrigeration (HVACR) system, comprising:

determining, using a controller, a target quantity of

working fluid to be stored in a dynamic receiver included in the HVACR system, the target quantity based on a subcooling threshold value and a measured subcooling value;

comparing a quantity of working fluid in the dynamic receiver to the target quantity;

when the quantity of working fluid in the dynamic receiver exceeds the target quantity, removing working fluid from the dynamic receiver by opening an outlet valve directly downstream of the dynamic receiver and opening a compressor discharge injection valve disposed along a fluid line connecting the discharge of a compressor of the HVACR system to the dynamic receiver.

when the quantity of working fluid in the dynamic receiver is less than the target quantity, adding working fluid to the dynamic receiver by opening an inlet valve directly upstream of the dynamic receiver with respect to the working fluid flow path in the HVACR system, wherein the dynamic receiver is in parallel with an expander included in the HVACR system.

[0098] Aspect 12. The method according to aspect 11, wherein the measured liquid line subcooling value is based on a liquid line temperature measurement and a liquid line pressure measurement.

[0099] Aspect 13. The method according to any of aspects 11-12, wherein the target quantity of working fluid is further based on a K_p value.

[0100] Aspect 14. The method according to any of aspects 11-13, wherein the subcooling threshold value is based on an operating mode of the HVACR system.

[0101] Aspect 15. A heating, ventilation, air conditioning, and refrigeration (HVACR) system), comprising:

a fluid circuit, including:

a compressor;
 a first heat exchanger;
 an expander; and
 a second heat exchanger;

a dynamic receiver, the dynamic receiver in parallel with the expander with respect to the fluid circuit; an outlet valve, configured to control flow from the dynamic receiver to the fluid circuit; and a controller, configured to determine a mass flow rate through the outlet valve, and to control the expander based on the flow rate through the outlet valve.

[0102] Aspect 16. The HVACR system according to aspect 15, further comprising a first pressure sensor configured to measure pressure at the dynamic receiver and a second pressure sensor configured to measure pressure between the expander and the second heat exchanger.

[0103] Aspect 17 The HVACR system according to as-

pect 16, wherein the controller is configured to determine the mass flow rate through the outlet valve based on a differential between a first pressure reading from the first pressure sensor and a second pressure reading from the second pressure sensor.

[0104] Aspect 18. The HVACR system according to any of aspects 15-17, wherein the controller is configured to determine a desired total mass flow rate, and the control of the expander based on the flow through the outlet valve includes controlling the expander such that a sum of the mass flow rate through the outlet valve and a mass flow rate through the expander equals the desired total mass flow rate.

[0105] Aspect 19. The HVACR system according to any of aspects 15-18, further comprising a four-way valve.

[0106] Aspect 20. The HVACR system according to aspect 19, further comprising a third heat exchanger, and wherein the first heat exchanger is configured to exchange heat between a working fluid in the fluid circuit and a first process fluid, the second heat exchanger is configured to exchange heat between the working fluid and a second process fluid, and the third heat exchanger is configured to exchange heat with ambient air.

[0107] Aspect 21. A method of controlling a heating, ventilation, air conditioning, and refrigeration (HVACR) system including a circuit including an expander, a dynamic receiver in parallel with the expander, and an outlet valve configured to control flow from the dynamic receiver to the circuit, the method comprising:

determining a mass flow rate through the outlet valve and;

controlling the outlet valve based on the mass flow rate through the outlet valve.

[0108] Aspect 22. The method according to aspect 21, further comprising receiving a first pressure measurement from a first pressure sensor configured to measure pressure at the dynamic receiver and receiving a second pressure measurement from a second pressure sensor configured to measure pressure downstream of the expander, and wherein determining the mass flow rate through the outlet valve is based on a differential between the first pressure and the second pressure.

[0109] Aspect 23. The method according to any of aspects 21-22, further comprising determining a desired total mass flow rate.

[0110] Aspect 24. The method according to aspect 23, wherein controlling the outlet valve includes controlling a mass flow rate through the expander such that a sum of the mass flow rate through the outlet valve and the mass flow rate through the expander equals the desired total mass flow rate.

[0111] The examples disclosed in this application are to be considered in all respects as illustrative and not limitative. The scope of the invention is indicated by the appended claims rather than by the foregoing descrip-

tion; and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

Claims

1. A heating, ventilation, air conditioning, and refrigeration (HVACR) system), comprising:

a fluid circuit, including:

a compressor;
a first heat exchanger;
an expander; and
a second heat exchanger;

a dynamic receiver, the dynamic receiver in parallel with the expander with respect to the fluid circuit;

an outlet valve, configured to control flow from the dynamic receiver to the fluid circuit; and
a controller, configured to determine a mass flow rate through the outlet valve, and to control the expander based on the flow rate through the outlet valve.

2. The HVACR system of claim 1, further comprising a first pressure sensor configured to measure pressure at the dynamic receiver and a second pressure sensor configured to measure pressure between the expander and the second heat exchanger.

3. The HVACR system of claim 2, wherein the controller is configured to determine the mass flow rate through the outlet valve based on a differential between a first pressure reading from the first pressure sensor and a second pressure reading from the second pressure sensor.

4. The HVACR system of any of claims 1-3, wherein the controller is configured to determine a desired total mass flow rate, and the control of the expander based on the flow through the outlet valve includes controlling the expander such that a sum of the mass flow rate through the outlet valve and a mass flow rate through the expander equals the desired total mass flow rate.

5. The HVACR system of any of claims 1-4, further comprising a four-way valve.

6. The HVACR system of claim 5, further comprising a third heat exchanger, and wherein the first heat exchanger is configured to exchange heat between a working fluid in the fluid circuit and a first process fluid, the second heat exchanger is configured to exchange heat between the working fluid and a second

process fluid, and the third heat exchanger is configured to exchange heat with ambient air.

7. A method of controlling a heating, ventilation, air conditioning, and refrigeration (HVACR) system including a circuit including an expander, a dynamic receiver in parallel with the expander, and an outlet valve configured to control flow from the dynamic receiver to the circuit, the method comprising:
- determining a mass flow rate through the outlet valve and;
controlling the outlet valve based on the mass flow rate through the outlet valve.
8. The method of claim 7, further comprising receiving a first pressure measurement from a first pressure sensor configured to measure pressure at the dynamic receiver and receiving a second pressure measurement from a second pressure sensor configured to measure pressure downstream of the expander, and wherein determining the mass flow rate through the outlet valve is based on a differential between the first pressure and the second pressure.
9. The method of claim 7 or claim 8, further comprising determining a desired total mass flow rate.
10. The method of claim 9, wherein controlling the outlet valve includes controlling a mass flow rate through the expander such that a sum of the mass flow rate through the outlet valve and the mass flow rate through the expander equals the desired total mass flow rate.

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Fig. 1A

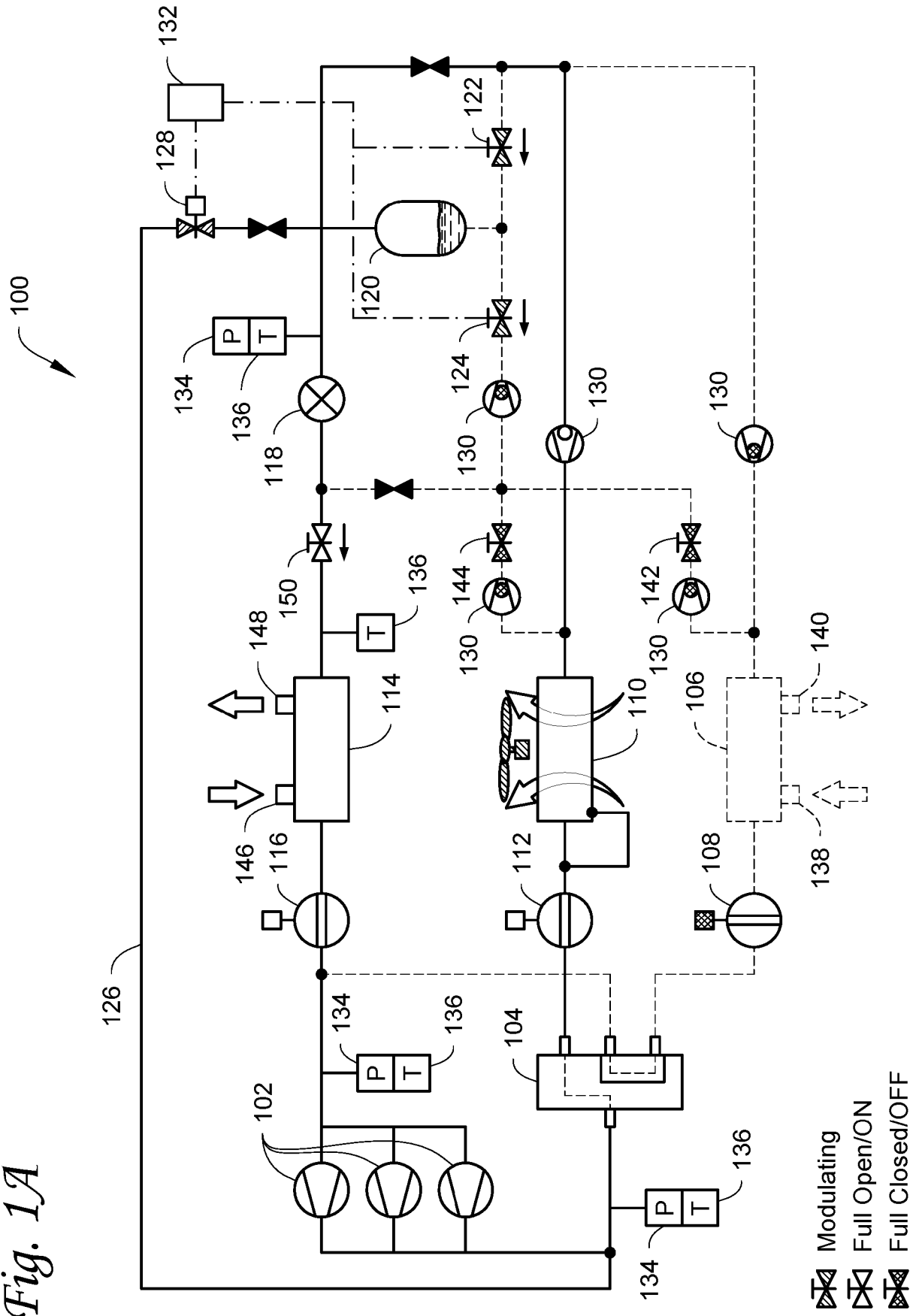


Fig. 1B

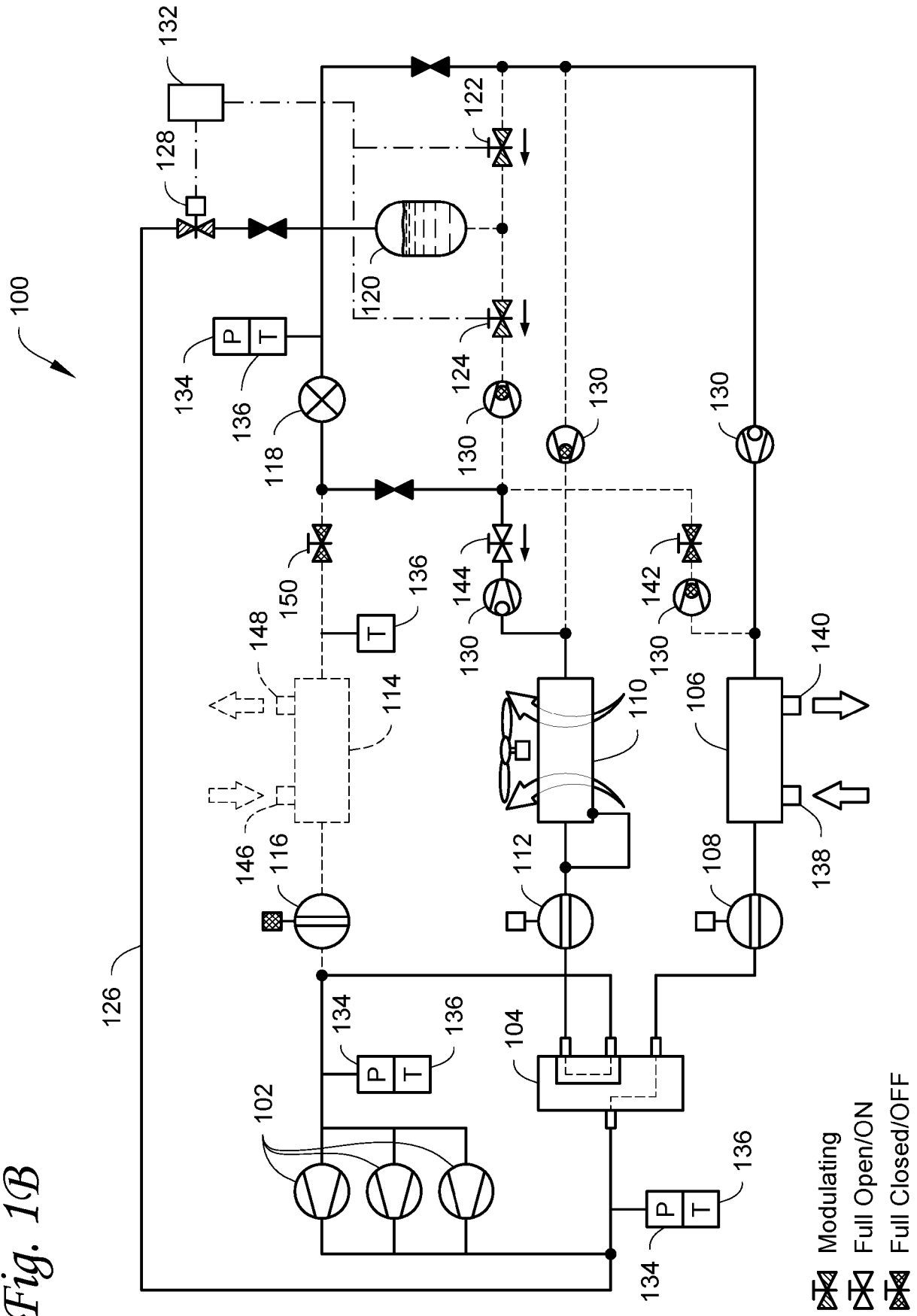


Fig. 1C

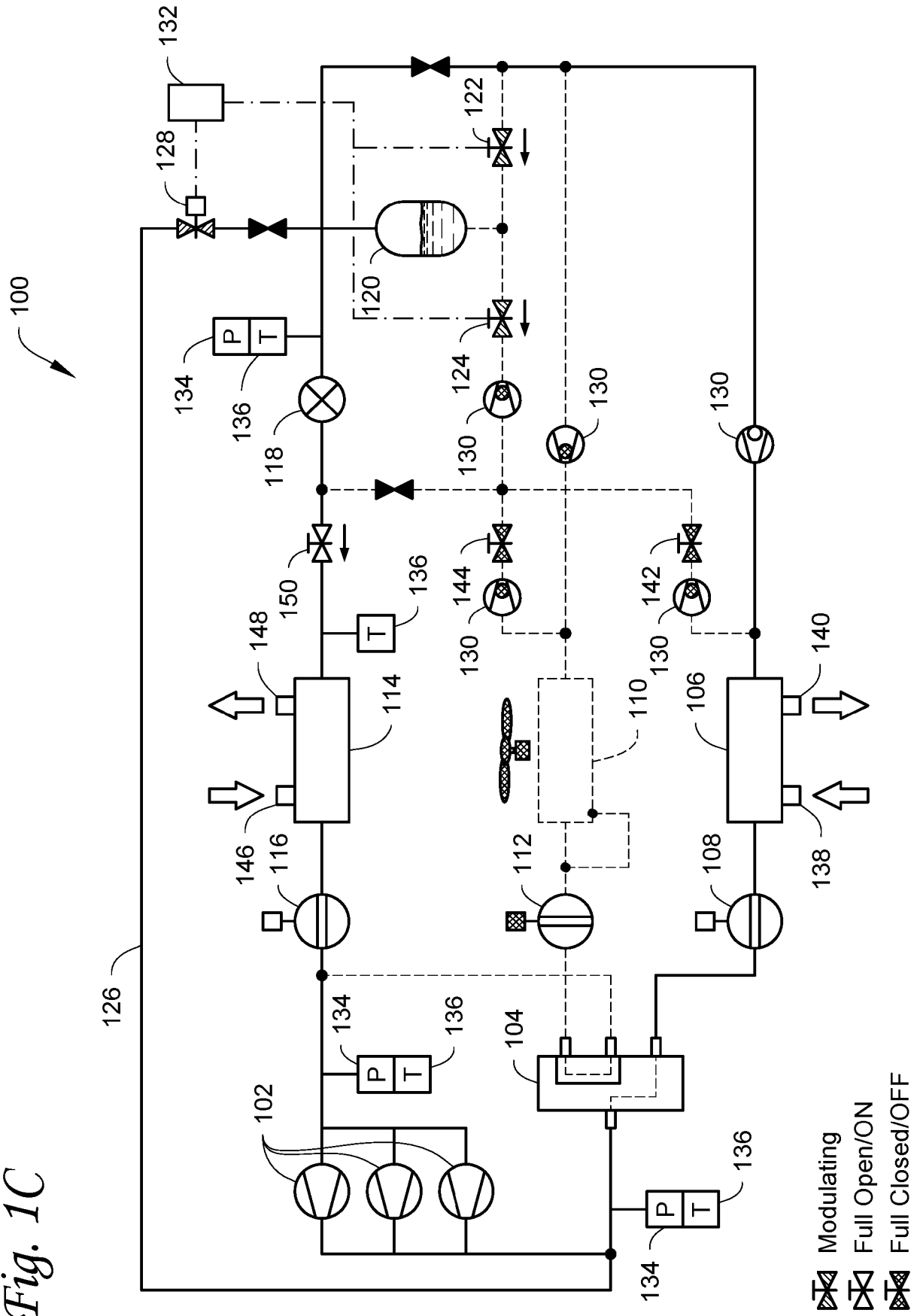


Fig. 2

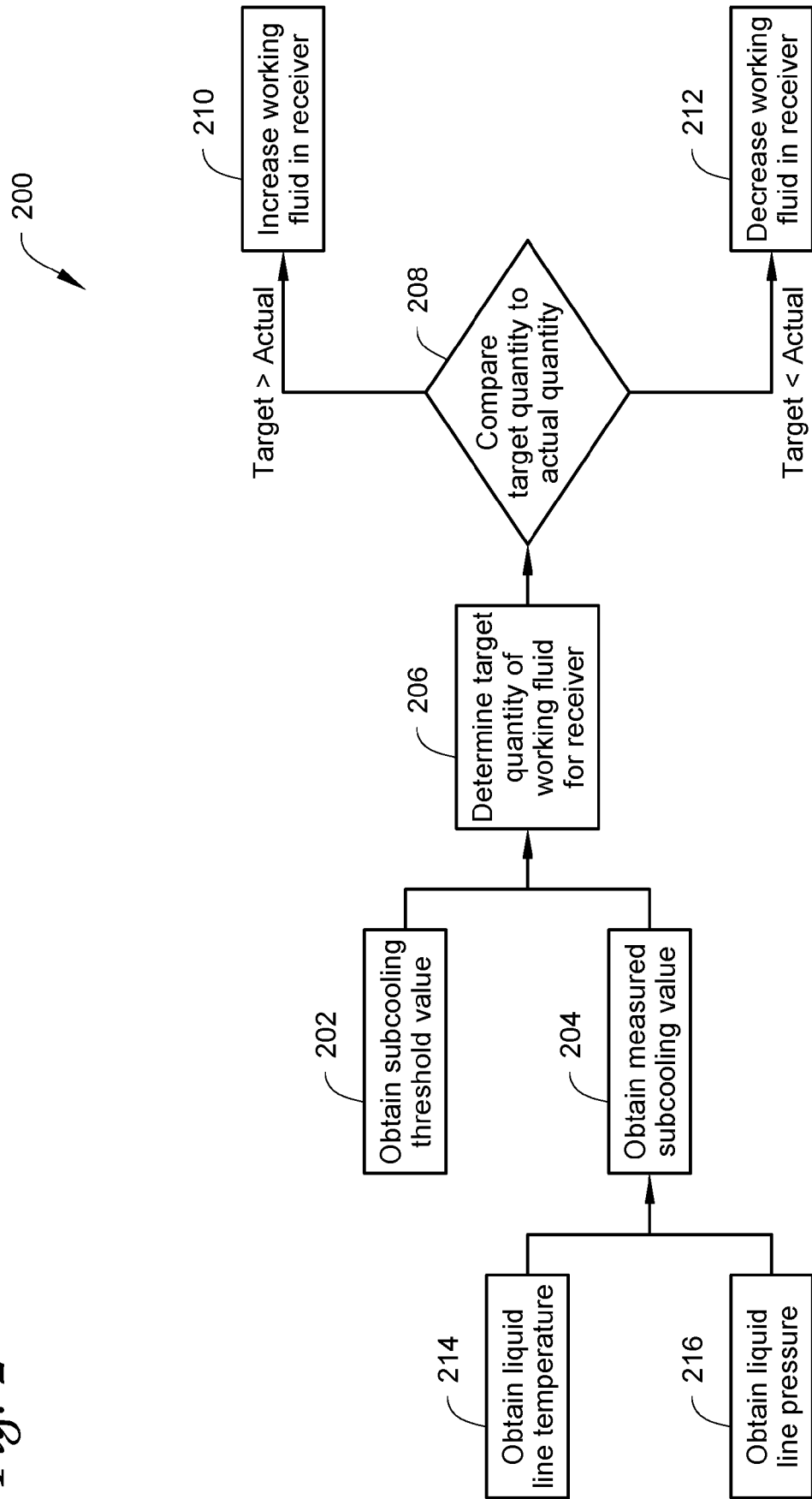


Fig. 3

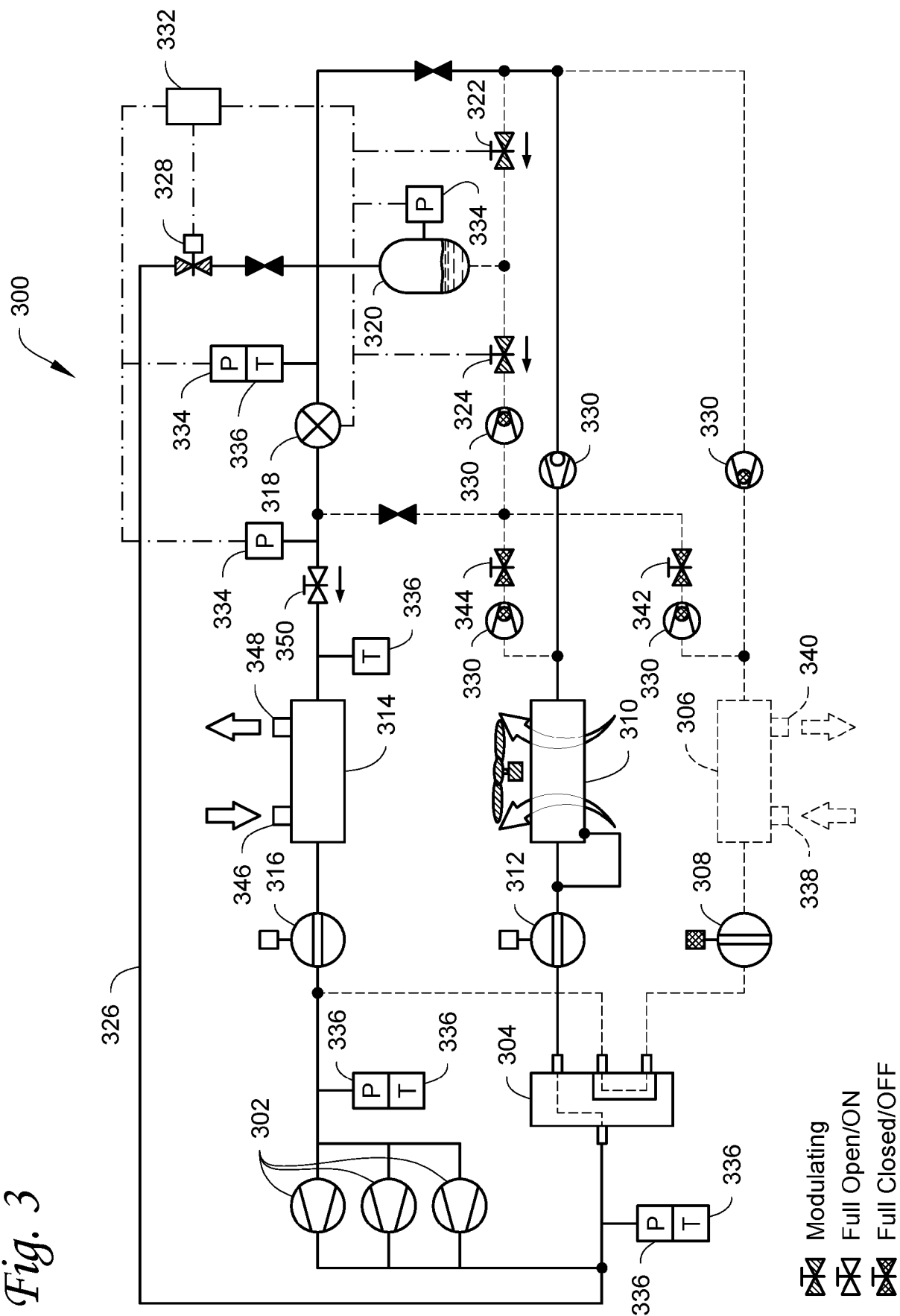
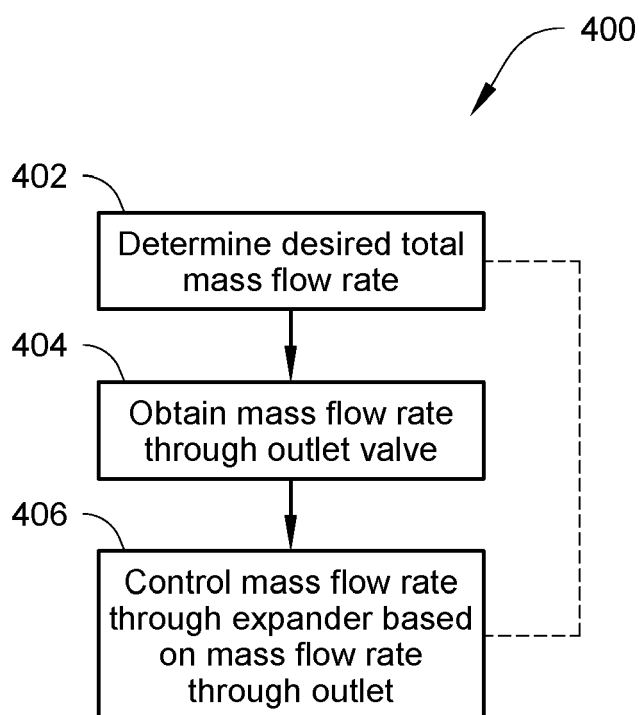


Fig. 4



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Application Number

EP 23 17 5483

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 10 October 2023	Examiner Lepers, Joachim
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
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