



EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.10.2026 Bulletin 2026/43

(51) International Patent Classification (IPC):
F25B 13/00 ^(2006.01)

(21) Application number: **26167226.5**

(52) Cooperative Patent Classification (CPC):
F25B 13/00; F25B 2500/26; F25B 2600/21;
F25B 2600/2513; F25B 2700/1931;
F25B 2700/1933; F25B 2700/21151

(22) Date of filing: **24.03.2026**

(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:
GE KH LA MA MD TN

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(30) Priority: **26.03.2025 CN 202510368646**

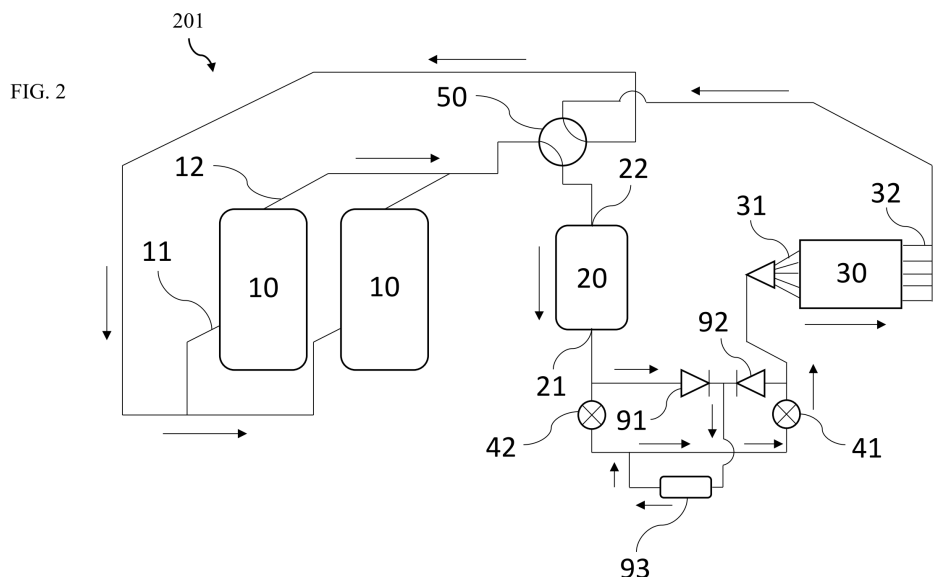
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(54) **EXPANDER CONTROL IN HVACR SYSTEMS**

(57) An HVACR system includes a compressor having a suction port and a discharge port, a first expander configured to regulate working fluid flow, and a controller. When the system transitions directly from a stop phase to a heating mode, the controller is configured to determine a degree of opening of the first expander; when a duration of the stop phase is less than a first duration threshold, apply a first factor to the de-

gree of opening to configure the first expander; when the duration of the stop phase is not less than the first duration threshold and is less than a second duration threshold, apply a second factor to the degree of opening to configure the first expander; and when the duration of the stop phase is not less than the second duration threshold, apply a third factor to the degree of opening to configure the first expander.



Description

FIELD

[0001] The embodiments described herein pertain generally to systems and methods for expander control of a heating, ventilation, air conditioning, and refrigeration (HVACR) system. More specifically, the embodiments described herein pertain to expander control in an HVACR system when the system transitions to a heating mode and/or when the system is in the heating mode.

BACKGROUND

[0002] An HVACR system typically includes a compressor, a condenser, an expander, and an evaporator, forming a refrigeration circuit. In a cooling cycle or cooling mode, refrigerant vapor is generally compressed by the compressor, and then condensed to liquid refrigerant in the condenser. The liquid refrigerant can then be directed through the expander to reduce the temperature and become a liquid/vapor refrigerant mixture (two-phase refrigerant mixture). The two-phase refrigerant mixture can be directed into the evaporator to exchange heat with, for example, air or water moving across the evaporator. The two-phase refrigerant mixture can be vaporized to refrigerant vapor in the evaporator.

[0003] Some HVACR systems may be able to operate in a heating cycle. These HVACR systems are typically called heat pumps. During a heating cycle or heating mode, the process is generally reversed from the process in the cooling cycle. In the heating cycle, the evaporator in the cooling cycle functions as a condenser, and the condenser functions as an evaporator. After being compressed by the compressor, the compressed refrigerant vapor is typically directed to the evaporator first to release heat to, for example, the indoor air, which also condenses the refrigerant vapor to liquid refrigerant. The liquid refrigerant is then typically directed to the condenser through the expander to become a two-phase refrigerant mixture.

SUMMARY

[0004] In an example embodiment, an HVACR system such as a heat pump system can enter a heating mode by (1) directly entering the heating mode from a stop phase (e.g., a system shutdown), (2) transitioning to the heating mode from a warm-up phase, and/or (3) transitioning to the heating mode from a defrosting mode. For example, if the system has been shut down (e.g., in the stop phase) for more than a period of time, the system may need to perform a warm-up (a phase in a cooling mode e.g., with the outdoor fan being stopped or turned off) for a period of time before switching or transitioning to the heating mode. In another example,

if the system has been shut down for less than the period of time, the system can go into the heating mode directly from the shutdown without the warm-up phase or a defrosting mode. In yet another example, a thick frost layer may cause a decrease in cooling capacity, and thus defrosting may be required; and the system can transition or switch from the defrosting mode to the heating mode.

[0005] It is to be understood that during the above processes, if the degree of opening of the heating expander (e.g., the expander operates in the heating mode) is too large, it may lead to an excessive supply of refrigerant, causing compressor liquid slugging which can result in liquid compression or a lack of lubrication oil, potentially damaging the compressor. On the other hand, if the degree of opening of the heating expander is too small, it may lead to insufficient liquid supply, causing a low suction pressure alarm. It is also to be understood that during transitions (e.g., to the heating mode), the temperature sensor's sampling rate may be slower than the rate of temperature changing, making the control of the suction superheat difficult, which may result in low suction superheat (LSSH) alarms and/or low suction pressure (low pressure cut-off, LPC) alarms. Features in the embodiments disclosed herein may provide a solution to balance the issues of LSSH caused by an excessively large degree of opening of the heating expander, and the issues of LPC caused by an excessively small degree of opening of the heating expander, and to give priority to controlling with a smaller degree of opening of the heating expander to avoid LSSH. If the suction pressure becomes low and approaches the LPC alarm threshold, the degree of opening of the heating expander can be increased based on conditions; and such adjustment may end when the low suction pressure recovers, or the suction superheat decreases to a certain threshold.

[0006] Features in the embodiments disclosed herein may provide a direct startup process (e.g., transitioning directly to the heating mode from the stop phase without a warm-up phase and/or without going through the defrosting mode), in which the initial degree of opening of the heating expander can be set based on a length of the shutdown period (e.g., how long the system is stopped or turned off).

[0007] Features in the embodiments disclosed herein may provide a process of transitioning from the warm-up phase (or the defrosting mode) to the heating mode, to pre-open the heating expander, before turning on the compressor and/or switching the flow control device (e.g., a four-way valve) to switch to the heating mode, and then start the fan (e.g., the outdoor fan) after a period of time. Features in the embodiments disclosed herein may also provide a process, in which during the initial period of time of startup, the heating expander can be controlled based on the saturated suction temperature. Features in the embodiments disclosed herein may further provide a process that during the mode

transitions or in the startup phase of the heating mode, the expander(s), fans, etc., can be controlled to avoid or reduce liquid slug into the compressor suction port and to avoid or reduce LPC alarms, thereby improving the reliability of the system.

[0008] In an example embodiment, a heating, ventilation, air conditioning, and refrigeration (HVACR) system is provided. The HVACR system includes a compressor having a suction port and a discharge port, a first expander configured to regulate working fluid flow, and a controller. When the system transitions directly from a stop phase to a heating mode, the controller is configured to determine a degree of opening of the first expander; when a duration of the stop phase is less than a first duration threshold, apply a first factor to the degree of opening of the first expander to configure the first expander; when the duration of the stop phase is not less than the first duration threshold and is less than a second duration threshold, apply a second factor to the degree of opening of the first expander to configure the first expander; when the duration of the stop phase is not less than the second duration threshold, apply a third factor to the degree of opening of the first expander to configure the first expander; and when a saturated suction temperature is less than a first temperature threshold, control the first expander based on a suction superheat.

[0009] In an example embodiment, a heating, ventilation, air conditioning, and refrigeration (HVACR) system is provided. The HVACR system includes a compressor having a suction port and a discharge port; a first expander and a second expander; and a controller. The controller is configured to determine a flow coefficient based on a suction pressure, a discharge pressure, and a mass flow of working fluid; allocate the flow coefficient to determine a degree of opening of the first expander and a degree of opening of the second expander; and control the first expander and the second expander to regulate working fluid flow. The first expander and the second expander are arranged in parallel. A capacity of the first expander is less than a capacity of the second expander.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings illustrate various embodiments of systems, methods, and embodiments of various other aspects of the disclosure. Any person with ordinary skill in the art will appreciate that the illustrated element boundaries (e.g. boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. It may be that in some examples one element may be designed as multiple elements or that multiple elements may be designed as one element. In some examples, an element shown as an internal component of one element may be implemented as an external component in another, and vice versa. Non-limiting and non-exhaustive descriptions

are described with reference to the following drawings. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating principles. In the detailed description that follows, embodiments are described as illustrations only since various changes and modifications may become apparent to those skilled in the art from the following detailed description.

FIG. 1 illustrates a schematic diagram of an HVACR system including a refrigerant circuit, arranged in accordance with at least some embodiments described herein.

FIG. 2 illustrates a schematic diagram of an HVACR system in the heating mode, arranged in accordance with at least some embodiments described herein.

FIG. 3 illustrates a schematic diagram of an HVACR system in the cooling mode, arranged in accordance with at least some embodiments described herein.

FIG. 4 is a flow chart illustrating an example processing flow for directly starting a heating mode, arranged in accordance with at least some embodiments described herein.

FIG. 5 is a flow chart illustrating an example processing flow for transitioning to a heating mode, arranged in accordance with at least some embodiments described herein.

FIG. 6 is a flow chart illustrating an example processing flow for avoiding low suction pressure alarms, arranged in accordance with at least some embodiments described herein.

FIG. 7 is a flow chart illustrating an example processing flow for controlling dual or multiple heating expanders, arranged in accordance with at least some embodiments described herein.

FIG. 8 illustrates a schematic diagram of dual or multiple heating expanders, arranged in accordance with at least some embodiments described herein.

DETAILED DESCRIPTION

[0011] In the following detailed description, particular embodiments of the present disclosure are described herein with reference to the accompanying drawings, which form a part of the description. In this description, as well as in the drawings, like-referenced numbers represent elements that may perform the same, similar, or equivalent functions, unless context dictates otherwise. Furthermore, unless otherwise noted, the description of each successive drawing may reference features from one or more of the previous drawings to provide clearer context and a more substantive explanation of the current example embodiment. Still, the example embodiments described in the detailed description, drawings, and claims are not intended to be

limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the drawings, may be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0012] It is to be understood that the disclosed embodiments are merely examples of the disclosure, which may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure.

[0013] Additionally, the present disclosure may be described herein in terms of functional block components and various processing steps. It is to be understood that such functional blocks may be realized by any number of hardware and/or software components configured to perform the specified functions.

[0014] The scope of the disclosure should be determined by the appended claims and their legal equivalents, rather than by the examples given herein. For example, the steps recited in any method claims may be executed in any order and are not limited to the order presented in the claims. Moreover, no element is essential to the practice of the disclosure unless specifically described herein as "critical" or "essential".

[0015] As referenced herein, "directly" upstream or "directly" downstream may refer to that no other components of a fluid circuit, other than fluid lines/connections/pipes for conveying the fluid are provided between such directly related elements. As referenced herein, "upstream" and "downstream" may refer to the direction of flow of the fluid or a component thereof through the fluid circuit.

[0016] As referenced herein, a "saturated temperature" is a term of art that may refer to a temperature at which a working fluid (e.g., a refrigerant) changes from a liquid to a vapor. It is to be understood that saturated temperature may be referred to as the boiling point. It is also to be understood that the saturation temperature of a liquid may vary depending on the pressure. For example, the saturation temperature of a liquid may increase as pressure increases. It is further to be understood that the "suction saturated temperature" or "saturated suction temperature" may refer to the saturated temperature at, near, or upstream of a suction port of a compressor, and that the "discharge saturated temperature" or "saturated discharge temperature" may refer to the saturated temperature at, near, or downstream of a discharge port of a compressor.

[0017] As referenced herein, an "evaporating temperature" is a term of art that may refer to a temperature at which refrigerant boils and evaporates in the evaporator. In an example embodiment, the evaporating temperature can be the same as or close to the saturated suction temperature. A "condensing temperature" is a term of art that may refer to a temperature at which refrigerant transitions from a vapor to a liquid state within the condenser. In an example embodiment, the condensing temperature can be the same or close to the saturated discharge temperature.

[0018] As referenced herein, a degree of "superheat" is a term of art that may refer to a difference between the refrigerant's temperature and refrigerant's saturated temperature at a given pressure. It is to be understood that the degree of superheat can be the refrigerant's temperature minus the refrigerant's saturated temperature at the given pressure. It is also to be understood that the degree of superheat typically is a positive value and is for a vapor. It is further to be understood that the "suction superheat" may refer to the superheat at, near, or upstream of a suction port of a compressor.

[0019] As referenced herein, a "mass flow" or "mass flow rate" of a fluid (e.g., working fluid, process fluid, etc.) is a term of art that may refer to an amount of fluid (measured by mass, e.g., in the unit of pounds, kilograms, etc.) moving through a system per unit time, essentially indicating how much fluid is actually being transported, regardless of its volume which can change depending on temperature and pressure.

[0020] As referenced herein, the "flow coefficient" of a device (e.g., an expander, a flow control device such as a valve, etc.) is a term of art that may refer to a measure of how much fluid can pass through the device at a given pressure drop. It is to be understood that the flow coefficient can be used to size devices such as the control valves.

[0021] It is to be understood that a device such as an expander and/or a flow control device or the like can be configured to control a fluid (e.g., working fluid, etc.) flow through e.g., a passage (e.g., a pipe, etc.). The device can have an open state and a closed state. For example, the device can have a fully-closed position or state at which the fluid can be prevented from flowing through the passage via the device. The device can also have a fully-open position or state at which the fluid can be flowing through the passage via the without being blocked by the device. The device can further have a partially-open (or partially-closed) position or state at which the fluid can be flowing through the passage via the device with the fluid being partially blocked by the device. A position or state of the device can be controlled from a fully-open position or state, to a partially-open or partially-closed position or state, and/or to a fully-closed position or state; or from a fully-closed position or state, to a partially-closed or partially-open position or state, and/or to a fully-open position or state. A partially-open (or partially-closed) position or state

can be e.g., at or about 10% open or closed, at or about 15% open or closed, at or about 25% open or closed, at or about 50% open or closed (half-open or half-closed), ... at or about 95% open or closed, etc.

[0022] FIG. 1 illustrates a schematic diagram of an HVACR system including a refrigerant circuit 100, arranged in accordance with at least some embodiments described herein.

[0023] In an example embodiment, the refrigerant circuit 100 can include a compressor 120, a condenser 140, an expander 160, and an evaporator 180. The refrigerant circuit 100 may also include a controller 110 configured to communicate with and/or control the operations of the compressor 120, the condenser 140, the expander 160, the evaporator 180, and/or other components (e.g., flow control device, sensor(s), or the like) of the HVACR system.

[0024] In an example embodiment, the controller 110 may include (or be connected to) a memory such as RAM and ROM and execute software (including, e.g., algorithms) that can be stored in the RAM (particularly during execution), the ROM (on a generally permanent basis), or another non-transitory computer readable medium such as other memory or disc. If necessary, the controller 110 can be connected to such memory or a disc drive to read such software. A microprocessor or other programmable device with suitable memory and I/O devices could also be used as the controller 110. It is to be understood that the processes and/or steps described in any of the figures can be conducted, implemented, and/or performed by one or more controllers including e.g., the controller 110 and/or any other suitable controller, unless otherwise specified.

[0025] In an example embodiment, the refrigerant circuit 100 can generally be applied in a variety of systems used to control an environmental condition (e.g., temperature, humidity, air quality, or the like) in a conditioned space. The conditioned space can be a space within an office building, a commercial building, a factory, a laboratory, a data center, a residential building, or the like. In an embodiment, the refrigerant circuit 100 can be configured to be a cooling system (e.g., an air conditioning system) capable of operating in a cooling mode. In an embodiment, the refrigerant circuit 100 can be configured to be a heat pump that can operate in a heating/defrost mode. It is appreciated that the refrigerant circuit 100 can be configured to operate in a cooling mode and/or a heating/defrosting mode. In an example embodiment, an HVACR system can include a refrigerant circuit 100 to heat or cool a process fluid (e.g., air, water and/or glycol, solution, or the like). A working fluid (e.g., one or more refrigerants) can flow through the refrigerant circuit 100 and be utilized to heat or cool the process fluid.

[0026] In an example embodiment, the compressor 120, the condenser 140, the expander 160, and the evaporator 180 can be fluidly connected. An "expander" as described herein may also be referred to as an

expansion device. In an embodiment, the expander 160 can be an expansion valve, expansion plate, expansion vessel, orifice, or the like, or other such types of expansion mechanisms. It is to be understood that the expander 160 may be any suitable type of expander used in the field for expanding a working fluid to cause the working fluid to decrease in pressure and temperature.

[0027] It is to be understood that the refrigerant circuit 100 is an example and can be configured to include more or less components. For example, in an embodiment, the refrigerant circuit 100 can include other components such as, but not limited to, an economizer heat exchanger, one or more flow control devices (e.g., a valve such as a solenoid valve, a check valve, a butterfly valve, a ball valve, and the like; a damper, a pump, or the like.), a lubricant separator, a receiver tank, a dryer, a suction-liquid heat exchanger, one or more sensors (e.g., a temperature sensor, a pressure sensor, etc.), or the like.

[0028] In an example embodiment, the refrigerant circuit 100 can operate according to generally known principles. The refrigerant circuit 100 can be configured to heat and/or cool a liquid process fluid. The liquid process fluid can be a heat transfer fluid or medium (e.g., a liquid such as, but not limited to, water, glycol, mixtures thereof, or the like). The refrigerant circuit 100 may be generally representative of a liquid chiller system. The refrigerant circuit 100 can alternatively be configured to heat and/or cool a gaseous process fluid (e.g., a heat transfer medium or fluid (e.g., a gas such as, but not limited to, air or the like), in which case the refrigerant circuit 100 may be generally representative of an air conditioner and/or heat pump.

[0029] In an example embodiment, the refrigerant circuit 100 can operate as a vapor-compression circuit such that the compressor 120 compresses a working fluid (e.g., a heat transfer fluid such as, but not limited to, refrigerant, fluorine, or the like) from a relatively lower pressure gas to a relatively higher-pressure gas. The relatively higher-pressure gas is at a relatively higher temperature, being discharged from the compressor 120 and flowing through the condenser 140. In accordance with generally known principles, the working fluid flows through the condenser 140 and rejects heat to the process fluid (e.g., water, solution, air, or the like), thereby cooling the working fluid. The cooled working fluid, which is now in a liquid form, flows to the expander 160 that can reduce the pressure of the working fluid. As a result, a portion of the working fluid is converted to a gaseous form. The working fluid, which is now in a mixed liquid and gaseous form flows to the evaporator 180. The working fluid flows through the evaporator 180 and absorbs heat from the process fluid (e.g., a heat transfer medium such as, but not limited to, water, a solution, air, fluorine, or the like, etc.), heating the working fluid, and converting it to a gaseous form. The gaseous working fluid then returns to the

compressor 120. The above-described process continues while the heat transfer circuit is operating, for example, in a cooling mode (e.g., while the compressor 120 is enabled).

[0030] In an example embodiment, the compressor 120 can compress the working fluid. Lubricant can be supplied to the compressor to provide lubrication for its moving parts. A lubricant may include one or more types of lubricants. For example, a lubricant can be, but is not limited to for example, polyolester oils, oil blends, or the like. The lubricant can be discharged from the compressor with the working fluid. Thus, the working fluid discharged from the compressor may contain lubricant. In some refrigerant circuits, the lubricant can also be separated from the working fluid and the separated lubricant can be circulated back to the compressor. In other refrigerant circuits, the lubricant can be circulated with the working fluid and can then be supplied through a suction inlet of the compressor as part of the working fluid. In an example embodiment, the working fluid may also include one or more additional components other than lubricant(s) and/or refrigerant(s), such as for example additives.

[0031] FIG. 2 illustrates a schematic diagram of an HVACR system 201 in the heating mode, FIG. 3 illustrates a schematic diagram of the HVACR system 202 in the cooling mode, arranged in accordance with at least some embodiments described herein. It is to be understood that the systems (201, 202) can be the same (except for the operating modes and the direction of the working fluid flow) and can include the refrigerant circuit 100 of FIG. 1.

[0032] It is to be understood that the direction of the arrows in FIG. 2 indicates the direction of the working fluid flow in a heating mode. The direction of the arrows in FIG. 3 indicates the direction of the working fluid flow in a cooling mode. It is to be understood that the systems (201, 202) can operate in a cooling mode, a heating mode, and/or a defrosting mode. Transitions can be performed among the operating modes. Each mode can include a start phase, an operating phase (which may be combined with the start phase), and a stop phase. The cooling mode can also include a warm-up phase.

[0033] It is also to be understood that hereinafter, a "heat pump" unit or system may refer to an HVACR unit or system, a "coil" may refer to a heat exchanger, and "refrigerant" may refer to a working fluid, a "four-way valve" or a "switching valve" or a "check valve" may refer to a flow control device, an "expansion valve" may refer to an expander, a "vapor"/"gas" or "liquid" may refer to a working fluid in a vapor/gas or liquid state, respectively, unless particularly specified.

[0034] It is to be understood that in FIGS. 2 and 3, the following reference numerals are used: 10. Compressor(s); 11. Inlet end; 12. Outlet end; 20. Heat exchanger; 21. Liquid phase end; 22. Gas phase end; 30. Coil; 31. Distribution end; 32. Reflux (return) end; 41.

First expander; 42. Second expander; 50. Four-way valve; 91. First check valve; 92. Second check valve; 93. Filter dryer.

[0035] As shown in FIGS. 2 and 3, a heat pump system (201, 202) includes a circulation circuit. Refrigerant can flow in the circulation circuit, and heat may be transferred through the refrigerant. The circulation circuit includes at least one compressor 10, a heat exchanger 20, a coil 30 (another heat exchanger), a first expander 41, a second expander 42, and a four-way valve 50 (a flow control device). The compressor 10 can compress low-pressure and low-temperature refrigerant gas into high-pressure and high-temperature refrigerant gas. The heat exchanger 20 and coil 30 can serve as an evaporator or condenser. The evaporator can absorb heat and evaporate the refrigerant liquid into refrigerant gas, and the condenser can dissipate heat and condense the refrigerant gas into refrigerant liquid. The expander (41, 42) can throttle the high-pressure refrigerant liquid to a low-pressure state. The four-way valve 50 can be used to switch the circulation circuit in different operating modes.

[0036] In an example embodiment, the compressor 10, the heat exchanger 20, and the coil 30 are all connected to the four-way valve 50. The compressor 10 has an inlet end 11 (that connects to the suction port of the compressor 10) and an outlet end 12 (that connects to the discharge port of the compressor 10). The four-way valve 50 is used to selectively communicate the coil 30 or the heat exchanger 20 with the outlet end 12 or the inlet end 11. The communication between the heat exchanger 20 and the coil 30 is through the expander (41, 42).

[0037] In an example embodiment, the heat exchanger 20 has a liquid phase end 21 and a gas phase end 22. The liquid phase end 21 can be connected to the expander 42, and the gas phase end 22 can be connected to the compressor 10 through the four-way valve 50. The coil 30 has a distribution end 31 and a reflux end 32. The distribution end 31 can be connected to the expander 41, and the reflux end 32 can be connected to the compressor 10 through the four-way valve 50.

[0038] In an example embodiment, the heat pump system has a heating mode and a cooling mode. As shown in FIG. 2, in the heating mode, the four-way valve 50 communicates the outlet end 12 with the heat exchanger 20 and communicates the inlet end 11 with the coil 30. The heat exchanger 20 is in the condenser mode, and the coil 30 is in the evaporator mode. The refrigerant in the circulation circuit enters the heat exchanger 20 from the outlet end 12 of the compressor 10 through the four-way valve 50, condenses into refrigerant liquid in the heat exchanger 20, enters the expander 41, and then enters the coil 30 from the expander 41. After evaporating into refrigerant gas in the coil 30, the refrigerant returns to the inlet end 11 of the compressor 10 through the four-way valve 50.

[0039] As shown in FIG. 3, in the cooling mode, the four-way valve 50 communicates the outlet end 12 with the coil 30 and communicates the inlet end 11 with the heat exchanger 20. The heat exchanger 20 is in the evaporator mode, and the coil 30 is in the condenser mode. The refrigerant in the circulation circuit enters the coil 30 from the air outlet 12 of the compressor 10 through the four-way valve 50, condenses into refrigerant liquid in the coil 30, enters the expander 42, and then enters the heat exchanger 20 from the expander 42. After evaporating into refrigerant gas in the heat exchanger 20, the refrigerant returns to the air inlet 11 of the compressor 10 through the four-way valve 50.

[0040] It is to be understood that the refrigerant in the heat pump system flows through the first expander 41 (the heating expander or the heating mode expander) in the heating mode and through the second expander 42 (the cooling expander or the cooling mode expander) in the cooling mode. This can ensure that the refrigerant has a suitable expansion process and pressure control in different operating modes, thereby improving the efficiency and heat exchange capacity of the heat pump system.

[0041] It is also to be understood that the circulation circuit optionally includes a first check valve 91 and a second check valve 92 to prevent refrigerant backflow in different operating modes and ensure the correctness of refrigerant flow direction. The first check valve 91 is provided between the liquid phase end 21 of the heat exchanger 20 and the first expansion valve 41 in the heating mode, and the second check valve 92 is provided between the distribution end 31 of the coil 30 and the second expansion valve 42 in the cooling mode.

[0042] In an example embodiment, the heat pump system (201, 202) can optionally include a filter dryer 93 disposed between the heat exchanger 20 and the coil 30, which can effectively filter impurities in the refrigerant, prevent moisture accumulation, improve refrigerant flow efficiency, protect key components in the heat pump system, and extend the service life of the heat pump system. Specifically, the filter dryer 93 is connected between the first check valve 91 and the first expansion valve 41 in the heating mode; and is connected between the second check valve 92 and the second expansion valve 42 in the cooling mode.

[0043] It is to be understood that in the heating mode, the flow path of the refrigerant in the circulation circuit is "compressor 10-heat exchanger 20-first check valve 91-filter dryer 93-first expander 41-coil 30-compressor 10". In the cooling mode, the flow path of the refrigerant in the circulation circuit is "compressor 10-coil 30-second check valve 92-filter dryer 93-second expander 42-heat exchanger 20-compressor 10". It is also to be understood that in some embodiments, the first expander 41 and the second expander 42 can be combined as one expander (e.g., by adding a couple of additional check valves to control which operating mode the com-

bined expander may be in).

[0044] FIG. 4 is a flow chart illustrating an example processing flow 400 for directly starting a heating mode, arranged in accordance with at least some embodiments described herein.

[0045] It is to be understood that the processing flow 400 disclosed herein can be conducted by one or more controllers including e.g., the controller 110 of FIG. 1 and/or any other suitable controller, unless otherwise specified.

[0046] It is also to be understood that the processing flow 400 can include one or more operations, actions, or functions as illustrated by one or more of blocks 410, 420, 430, 440, 450, and 460. These various operations, functions, or actions may, for example, correspond to software, program code, or program instructions executable by a processor (e.g., a controller) that causes the functions to be performed. Although illustrated as discrete blocks, obvious modifications may be made, e.g., two or more of the blocks may be re-ordered; further blocks may be added; and various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. It is to be understood that before the processing flow 400, operations including initializations or the like may be performed. For example, system parameters may be initialized. It is to be understood that the processes, operations, or actions described in FIGS. 1-3 may be implemented or performed by the controller. Processing flow 400 may begin at block 410.

[0047] At block 410 (Initialize), the controller may be configured to perform initialization steps for the heating mode. It is to be understood that in order to directly start the heating mode (e.g., from a stop phase or from a system shutdown, without going through a warm-up phase or a defrosting mode), the period of time during which the system is shutdown needs to be less than a period of time (e.g., a predetermined or desired period of time). If the time during which the system is shutdown is less than the period of time (e.g., the predetermined or desired period of time), the system can start the heating mode directly.

[0048] In an example embodiment, the controller may be configured to determine an evaporating temperature or a saturated suction temperature, based on e.g., an ambient temperature (e.g., the outdoor air temperature). The controller may also be configured to determine a condensing temperature or a saturated discharge temperature, based on e.g., an entering-water temperature. The controller may further be configured to determine a pressure difference (e.g., between the suction pressure and the discharge pressure) based on e.g., the evaporating temperature (or saturated suction temperature) and the condensing temperature (or saturated discharge temperature), or based on the pressure measurements from pressure sensors at or near the suction and/or discharge ports. Also, the controller may be configured to determine a mass flow (or a mass

flow rate) of the working fluid (e.g., refrigerant), based on e.g., the capacity of the running compressors. The controller may be configured to determine an initial degree of opening of the heating expander (e.g., expander 41 of FIGS. 2 and 3) based on the pressure difference and the mass flow of working fluid. Processing may proceed from block 410 to block 420.

[0049] At block 420 (Below first threshold?), the controller may be configured to determine whether the period of time during which the system is shutdown is less than a first duration threshold. If the period of time during which the system is shutdown is less than the first duration threshold, processing may proceed from block 420 to block 430. If the period of time during which the system is shutdown is not less than the first duration threshold, processing may proceed from block 420 to block 440.

[0050] At block 430 (Apply first factor), the controller may be configured to apply a first factor to the initial degree of opening of the heating expander determined at block 410, by e.g., multiplying a first value to the initial degree of opening. It is to be understood that the first value can be less than one (e.g., a number between one and zero) so that after applying the first factor, the degree of opening of the heating expander can be less than the initial degree of opening. Then the controller may be configured to set the opening of the heating expander to the degree of opening (after applying the first factor to the initial degree of opening).

[0051] At block 440 (Exceed second threshold?), the controller may be configured to determine whether the period of time during which the system is shutdown exceeds a second duration threshold (which is greater than the first duration threshold). If the period of time during which the system is shutdown exceeds the second duration threshold, processing may proceed from block 440 to block 460. If the period of time during which the system is shutdown does not exceed the second duration threshold, processing may proceed from block 440 to block 450.

[0052] At block 450 (Apply second factor), the controller may be configured to apply a second factor to the initial degree of opening of the heating expander determined at block 410, by e.g., multiplying a second value (which is less than the first value) to the initial degree of opening. It is to be understood that the second value can be less than one (e.g., a number between one and zero) so that after applying the second factor, the degree of opening of the heating expander can be less than the initial degree of opening. Then the controller may be configured to set the opening of the heating expander to the degree of opening (after applying the second factor to the initial degree of opening).

[0053] At block 460 (Apply third factor), the controller may be configured to apply a third factor to the initial degree of opening of the heating expander determined at block 410, by e.g., multiplying a third value (which is less than the second value) to the initial degree of

opening. It is to be understood that the third value can be less than one (e.g., a number between one and zero) so that after applying the third factor, the degree of opening of the heating expander can be less than the initial degree of opening. Then the controller may be configured to set the opening of the heating expander to the degree of opening (after applying the third factor to the initial degree of opening).

[0054] It is to be understood that the sequences of blocks 420 and 440 can be exchanged. It is also to be understood that compared with a single factor, multiple factors based on time can help to avoid or reduce the LSSH and/or LPC alarms. It is further to be understood that after the processing flow 400, when the saturated suction temperature is less than a first temperature threshold, the controller may be configured to control the heating expander based on e.g., a suction super-heat.

[0055] FIG. 5 is a flow chart illustrating an example processing flow 500 for transitioning to a heating mode, arranged in accordance with at least some embodiments described herein.

[0056] It is to be understood that the processing flow 500 disclosed herein can be conducted by one or more controllers including e.g., the controller 110 of FIG. 1 and/or any other suitable controller, unless otherwise specified.

[0057] It is to be understood that if the time during which the system is shutdown is not less than the period of time (e.g., a predetermined or desired period of time), the system may need to go through a warm-up phase or a defrosting mode, before transitioning to the heating mode, and the processing flow 500 is directed to a process after the warm-up phase or the defrosting mode ends.

[0058] It is also to be understood that the processing flow 500 can include one or more operations, actions, or functions as illustrated by one or more of blocks 510, 520, 530, and 540. These various operations, functions, or actions may, for example, correspond to software, program code, or program instructions executable by a processor (e.g., a controller) that causes the functions to be performed. Although illustrated as discrete blocks, obvious modifications may be made, e.g., two or more of the blocks may be re-ordered; further blocks may be added; and various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. It is to be understood that before the processing flow 500, operations including initializations or the like may be performed. For example, system parameters may be initialized. It is to be understood that the processes, operations, or actions described in FIGS. 1-3 may be implemented or performed by the controller. Processing flow 500 may begin at block 510.

[0059] At block 510 (Open expander), the controller may be configured to open the heating expander (e.g., based on the flow coefficient) so that the heating ex-

pander transitions into an open state (from a closed state). It is to be understood that when in the warm-up phase or a defrosting mode, the heating expander is closed. Processing may proceed from block 510 to block 520.

[0060] At block 520 (Start compressor), after opening the heating expander at block 510, the controller may be configured to start or turn on the compressor(s), based on e.g., the capacity requirements. Processing may proceed from block 520 to block 530.

[0061] At block 530 (Control valve), after opening the heating expander at block 510, the controller may be configured to control the flow control device (e.g., the four-way valve 50 of FIGS. 2 and 3), to transition the circulation circuit to the heating mode. It is to be understood that the sequences of blocks 520 and 530 can be exchanged, or that blocks 520 and 530 can be executed in parallel. Processing may proceed from block 530 to block 540.

[0062] At block 540 (Wait and start fan), after starting the compressor at block 520 and/or controlling the flow control device at block 530, the controller may be configured to start the fan(s) (e.g., outdoor fans) after a period of time.

[0063] It is to be understood that the particular sequences in the processing flow 500 can help to avoid or reduce the LSSH and/or LPC alarms. It is also to be understood that after the processing flow 500, when the saturated suction temperature is less than a first temperature threshold, the controller may be configured to control the heating expander based on e.g., a suction superheat.

[0064] It is further to be understood that, before transitioning to the processing flow 500, when the system is in the warm-up phase or in the defrosting mode, the controller can be configured to increase a degree of opening of the cooling expander (e.g., the expander 42 in FIGS. 2 and 3) to increase the saturated suction temperature and/or a condensing temperature, which may increase the pressure difference (e.g., between the suction pressure and the discharge pressure) and provide sufficient driving force for refrigerant migration.

[0065] FIG. 6 is a flow chart illustrating an example processing flow 600 for avoiding low suction pressure alarms, arranged in accordance with at least some embodiments described herein.

[0066] It is to be understood that the processing flow 600 disclosed herein can be conducted by one or more controllers including e.g., the controller 110 of FIG. 1 and/or any other suitable controller, unless otherwise specified.

[0067] It is also to be understood that the processing flow 600 can include one or more operations, actions, or functions as illustrated by one or more of blocks 610, 620, 630, 640, 650, and 660. These various operations, functions, or actions may, for example, correspond to software, program code, or program instructions executable by a processor (e.g., a controller) that causes the

functions to be performed. Although illustrated as discrete blocks, obvious modifications may be made, e.g., two or more of the blocks may be re-ordered; further blocks may be added; and various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. It is to be understood that before the processing flow 600, operations including initializations or the like may be performed. For example, system parameters may be initialized. It is to be understood that the processes, operations, or actions described in FIGS. 1-3 may be implemented or performed by the controller. Processing flow 600 may begin at block 610.

[0068] At block 610 (Determine SP and SSH), the controller may be configured to determine a suction pressure of the compressor(s) and determine a suction superheat. Processing may proceed from block 610 to block 620.

[0069] At block 620 (Enter condition met?), the controller may be configured to determine whether the suction pressure determined at block 610 is less than a first pressure threshold, and whether the suction superheat determined at block 610 is greater than a first superheat threshold. If the suction pressure is less than the first pressure threshold, and the suction superheat is greater than the first superheat threshold, processing may proceed from block 620 to block 630. If the suction pressure is not less than the first pressure threshold, or the suction superheat is not greater than the first superheat threshold, processing may proceed from block 620 back to block 610.

[0070] At block 630 (Determine opening), the controller may be configured to determine a degree of opening of the heating expander based on, e.g., a suction pressure, a discharge pressure, and a mass flow (or a mass flow rate) of working fluid. Processing may proceed from block 630 to block 640.

[0071] At block 640 (Increase opening), the controller may be configured to increase the degree of opening of the heating expander determined at block 630, to configure the heating expander. In an example embodiment, the increased degree of opening can be at or about 3 or 4 times of the degree of opening determined at block 630. Processing may proceed from block 640 to block 650.

[0072] At block 650 (Exit condition met?), the controller may be configured to determine the suction pressure and the suction superheat. If the determined suction pressure is greater than a second pressure threshold (which can be greater than the first pressure threshold), or the determined suction superheat is less than a second superheat threshold (which can be less than the first superheat threshold), processing may proceed from block 650 to block 660. If the determined suction pressure is not greater than the second pressure threshold and the determined suction superheat is not less than the second superheat threshold, processing may proceed from block 650 back to block 630.

[0073] At block 660 (End), the controller may be configured to stop increasing the degree of opening of the heating expander, e.g., based on the determined suction pressure and suction superheat. It is to be understood that the processing flow 600 describes one iteration of the process, and for next iteration, processing may proceed from block 660 back to block 610.

[0074] It is to be understood that in the heating mode (e.g., during an initialization step), on top of the LPC alarm, the controller can be configured to set a (loading) limit and an (unloading) buffer for a suction pressure. In an example embodiment, the limit can be greater than the buffer. When the suction pressure is lower than the limit, the controller can be configured to stop increasing a load of the system (e.g., stop turning on or stop starting more compressors). When the suction pressure is lower than buffer, the controller can be configured to unload the system (e.g., turning off or stopping one or more compressors).

[0075] It is to be understood that in the heating mode, when the suction superheat is less than a third superheat threshold (which can be less than the second superheat threshold), the controller can be configured to limit (e.g., stop increasing) a load of the system (e.g., stop turning on or stop starting more compressors). During a period of time in a start phase of the heating mode, the controller can be configured to control the opening of the heating expander based on the saturated suction temperature, to avoid excessive suction superheat which may lead to an overly large expander opening, causing excessive liquid refrigerant accumulation in the coil and triggering an LSSH alarm.

[0076] Features in the embodiments disclosed herein may provide a process to set the suction pressure (loading) limit and/or the suction pressure (unloading) buffer, to reduce frequent compressor loading and unloading. Features in the embodiments disclosed herein may also provide a process of adjusting the heating expander initialization value based on the shutdown time, which can significantly reduce the probability of LPC and/or LSSH alarms. Features in the embodiments disclosed herein may further provide a process of optimizing the cooling expander control for the warm-up and/or the defrosting processes, which can improve refrigerant migration effectiveness and reduce the probability of LSSH alarms.

[0077] Features in the embodiments disclosed herein may provide a process of delaying the fan (e.g., outdoor fan) startup after switching to the heating mode, which can allow the heat from the coil to vaporize the liquid refrigerant inside the coil, reducing the amount of liquid refrigerant and the probability of LSSH alarms. Features in the embodiments disclosed herein may also provide a corrective mechanism of a sudden-wide-opening of the heating expander, to prevent LPC alarms due to algorithm errors. Features in the embodiments disclosed herein may further provide a mechanism to limit loading when the suction superheat is low,

to avoid control instability. Also, features in the embodiments disclosed herein may provide a process of using a desired saturated suction temperature to control the opening of the heating expander during a beginning period of time after switching from the warm-up phase and/or the defrosting mode to the heating mode, to avoid LSSH caused by inaccurate suction superheat measurements.

[0078] FIG. 7 is a flow chart illustrating an example processing flow 700 for controlling dual or multiple heating expanders, arranged in accordance with at least some embodiments described herein. FIG. 8 illustrates a schematic diagram of dual or multiple heating expanders, arranged in accordance with at least some embodiments described herein.

[0079] As shown in FIG. 8, the heating expander 41 of FIGS. 2 and 3 can be replaced by, for example, two (or more) heating expanders (82, 84) arranged in parallel with each other. In an example embodiment, a capacity (e.g., how much working fluid the expander can flow through at a given time) of the first expander 82 can be less than a capacity of the second expander 84. In an example embodiment, the capacity of the second expander 84 can be at or about three or four times the capacity of the first expander 82.

[0080] It is to be understood that an HVACR system such as a heat pump system may include at least one heating expander and one or more compressors. When the ambient temperature is low, the evaporating temperature may be low, the mass flow (or mass flow rate) of working fluid may be low, and thus the required degree of opening of the heating expander may be low, which may cause insufficient control precision of the heating expander and insufficient reliability of the system.

[0081] Features in the embodiments disclosed herein may provide a control process on dual or multiple heating expanders, to enhance refrigerant flow controllability especially for low refrigerant flow regime. The flow coefficient can be split between two or more heating expanders. To avoid continuous oscillation between the two or more heating expanders, a deadband (e.g., a predetermined degree of opening) can be added e.g. on top of a threshold.

[0082] Features in the embodiments disclosed herein may compensate for the inaccuracy of individual expander, making the refrigerant flow more reliable, especially when the system is running at a low refrigerant flow. Features in the embodiments disclosed herein may provide a control process to the expanders to control e.g., the suction superheat and/or the saturated suction temperature. Features in the embodiments disclosed herein may control an augmented refrigerant flow for higher tonnage chiller and may ensure smooth transition from smaller expander to larger expander during increased capacity (e.g., flow coefficient) of the system.

[0083] In FIG. 7, it is to be understood that the pro-

cessing flow 700 disclosed herein can be conducted by one or more controllers including e.g., the controller 110 of FIG. 1 and/or any other suitable controller, unless otherwise specified.

[0084] It is also to be understood that the processing flow 700 can include one or more operations, actions, or functions as illustrated by one or more of blocks 710, 720, 730, 740, 750, 760, and 770. These various operations, functions, or actions may, for example, correspond to software, program code, or program instructions executable by a processor (e.g., a controller) that causes the functions to be performed. Although illustrated as discrete blocks, obvious modifications may be made, e.g., two or more of the blocks may be re-ordered; further blocks may be added; and various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. It is to be understood that before the processing flow 700, operations including initializations or the like may be performed. For example, system parameters may be initialized. It is to be understood that the processes, operations, or actions described in FIGS. 1-3 may be implemented or performed by the controller. Processing flow 700 may begin at block 710.

[0085] At block 710 (Determine CV), in a heating mode, the controller may be configured to determine an evaporating temperature or a saturated suction temperature, based on e.g., an ambient temperature (e.g., the outdoor air temperature). The controller may also be configured to determine a condensing temperature or a saturated discharge temperature, based on e.g., an entering-water temperature. The controller may further be configured to determine a pressure difference (e.g., between the suction pressure and the discharge pressure) based on e.g., the evaporating temperature (or saturated suction temperature) and the condensing temperature (or saturated discharge temperature), or based on the pressure measurements from pressure sensors at or near the suction and/or discharge ports. Also, the controller may be configured to determine a mass flow (or a mass flow rate) of the working fluid (e.g., refrigerant), based on e.g., the capacity of the running compressors. The controller may be configured to determine a flow coefficient (e.g., CV, a valve flow coefficient, to determine a required overall degree of opening of the heating expander(s)) based on the pressure difference and the mass flow of working fluid. Processing may proceed from block 710 to block 720.

[0086] At block 720 (Above capacity?), the controller may be configured to determine whether the flow coefficient determined at block 710 corresponds to a degree of opening exceeds the capacity (corresponding to a maximum degree of opening) of the first expander 82 of FIG. 8. If the flow coefficient exceeds the capacity of the first expander 82, processing may proceed from block 720 to block 740. If the flow coefficient does not

exceed the capacity of the first expander 82, processing may proceed from block 720 to block 730.

[0087] At block 730 (Control low flow), the controller may be configured to set the degree (e.g., in the unit of percentage) of opening of the first expander 82 based on the flow coefficient, and to control the first expander 82 to regulate working fluid flow to e.g., control the suction superheat and/or the saturated suction temperature. If the second expander 84 is in a closed state, no action may be taken on the second expander 84. If the second expander 84 is in an open state, the controller may be configured to close the second expander 84. Processing may proceed from block 730 back to block 710.

[0088] At block 740 (Control high flow), the controller may be configured to allocate the flow coefficient to determine the degree (e.g., in the unit of percentage) of opening of the first expander 82 and the degree (e.g., in the unit of percentage) of opening of the second expander 84. That is, the controller may be configured to open the second expander 84 if the second expander 84 is in a closed state. In an example embodiment, the second expander 84 may have a threshold (e.g., at or about 8%) for the degree of opening. To avoid continuous oscillation between expanders, a deadband (a predetermined degree of opening, e.g., at or about 2%) can be added on top of the threshold to form a minimum degree of opening (e.g., at or about 10%). When the second expander 84 transitions from a closed state to an open state, the controller may be configured to set or allocate the degree of opening of the second expander 84 to at least the minimum degree of opening. The controller may be further configured to set or allocate the degree of opening of the first expander 82, to a degree of opening that corresponds to the flow coefficient, minus the set or allocated degree of opening of the second expander 84, such that the allocated degree of opening of the first expander 82 does not exceed the capacity of the first expander 82. As such, the controller may be further configured to control the first expander 82 and/or the second expander 84 to regulate working fluid flow to e.g., control the suction superheat and/or the saturated suction temperature. Also, the controller may be configured to determine the flow coefficient again. If the flow coefficient increases, the controller may be configured to increase the degree of opening of the second expander 84 (and/or to keep the degree of opening of the first expander 82 unchanged). If the flow coefficient decreases, the controller may be configured to decrease the degree of opening of the second expander 84 (and/or to keep the degree of opening of the first expander 82 unchanged). Processing may proceed from block 740 to block 750.

[0089] At block 750 (Below threshold?), the controller may be configured to determine whether the degree of opening of the second expander 84 is below the threshold (e.g., at or about 8%). If the degree of opening of the second expander 84 is below the threshold, proces-

sing may proceed from block 750 to block 760. If the degree of opening of the second expander 84 is not below the threshold, processing may proceed from block 750 to block 770.

[0090] At block 760 (Close and control), the controller may be configured to close the second expander 84. The controller may be further configured to set the degree of opening of the first expander 82 based on the flow coefficient, and to control the first expander 82 to regulate working fluid flow to e.g., control the suction superheat and/or the saturated suction temperature. Processing may proceed from block 760 back to block 710.

[0091] At block 770 (Keep and control), the controller may be configured to determine the flow coefficient again. If the flow coefficient increases (or decreases), the controller is further configured to increase (or decrease) the degree of opening of the second expander 84 (and/or to keep the degree of opening of the first expander 82 unchanged). Processing may proceed from block 770 back to block 750.

ASPECTS:

[0092] It is to be understood that any one of aspects can be combined with each other.

[0093] Aspect 1. A heating, ventilation, air conditioning, and refrigeration (HVACR) system, comprising: a compressor having a suction port and a discharge port; a first expander configured to regulate working fluid flow; and a controller, wherein when the system transitions directly from a stop phase to a heating mode, the controller is configured to: determine a degree of opening of the first expander; when a duration of the stop phase is less than a first duration threshold, apply a first factor to the degree of opening of the first expander to configure the first expander; when the duration of the stop phase is not less than the first duration threshold and is less than a second duration threshold, apply a second factor to the degree of opening of the first expander to configure the first expander; and when the duration of the stop phase is not less than the second duration threshold, apply a third factor to the degree of opening of the first expander to configure the first expander; when a saturated suction temperature is less than a first temperature threshold, control the first expander based on a suction superheat.

[0094] Aspect 2. The system of aspect 1, wherein the controller is further configured to: determine the degree of opening of the first expander based on a suction pressure, a discharge pressure, and a mass flow of working fluid.

[0095] Aspect 3. The system of aspect 1 or aspect 2, wherein the degree of opening of the first expander decreases after applying the first factor, the second factor, or the third factor to the degree of opening of the first expander.

[0096] Aspect 4. The system of any one of aspects

1-3, wherein when the system transitions from a warm-up phase or a defrost mode to the heating mode, the controller is further configured to: control the first expander to an open state before starting the compressor and controlling a flow control device for the heating mode; and start a fan after a period of time.

[0097] Aspect 5. The system of aspect 4, further comprising: a second expander, wherein when the system is in the warm-up phase or the defrost mode before transitioning to the heating mode, the controller is further configured to increase a degree of opening of the second expander to increase the saturated suction temperature and a condensing temperature.

[0098] Aspect 6. The system of any one of aspects 1-5, wherein when a suction pressure is less than a first pressure threshold and the suction superheat is greater than a first superheat threshold, the controller is further configured to increase the degree of opening of the first expander.

[0099] Aspect 7. The system of aspect 6, wherein when the suction pressure is greater than a second pressure threshold or the suction superheat is less than a second superheat threshold, the controller is further configured to stop increasing the degree of opening of the first expander based on the suction pressure and the suction superheat.

[0100] Aspect 8. The system of any one of aspects 1-7, wherein when the suction superheat is less than a superheat threshold, the controller is further configured to limit a load of the system.

[0101] Aspect 9. The system of any one of aspects 1-8, wherein during a period of time in a start phase of the heating mode, the controller is further configured to control the opening of the first expander based on the saturated suction temperature.

[0102] Aspect 10. The system of any one of aspects 1-9, wherein the controller is further configured to set a limit and a buffer for a suction pressure, the limit being greater than the buffer; when the suction pressure is lower than the limit, the controller is further configured to stop increasing a load of the system; when the suction pressure is lower than buffer, the controller is further configured to unload the system.

[0103] Aspect 11. A heating, ventilation, air conditioning, and refrigeration (HVACR) system, comprising: a compressor having a suction port and a discharge port; a first expander and a second expander; and a controller, wherein the controller is configured to: determine a flow coefficient based on a suction pressure, a discharge pressure, and a mass flow of working fluid; allocate the flow coefficient to determine a degree of opening of the first expander and a degree of opening of the second expander; and control the first expander and the second expander to regulate working fluid flow, wherein the first expander and the second expander are arranged in parallel, and a capacity of the first expander is less than a capacity of the second expander.

[0104] Aspect 12. The system of aspect 11, wherein

the first expander and the second expander are configured to regulate working fluid flow in a heating mode.

[0105] Aspect 13. The system of aspect 11 or aspect 12, wherein when the flow coefficient is greater than the capacity of the first expander and the second expander is in a closed state, the controller is further configured to open the second expander and to set the degree of opening of the second expander to be greater than a threshold.

[0106] Aspect 14. The system of aspect 13, wherein when the second expander transitions from the closed state to an open state, a minimum degree of opening of the second expander is a predetermined degree above the threshold.

[0107] Aspect 15. The system of any one of aspects 11-14, wherein when the second expander is in an open state and the flow coefficient increases, the controller is further configured to increase the degree of opening of the second expander and to keep the degree of opening of the first expander unchanged.

[0108] Aspect 16. The system of any one of aspects 11-15, wherein when the second expander is in an open state and the flow coefficient decreases, the controller is further configured to decrease the degree of opening of the second expander and to keep the degree of opening of the first expander unchanged until the degree of opening of the second expander reaches a threshold.

[0109] Aspect 17. The system of aspect 16, wherein when the degree of opening of the second expander reaches the threshold and the flow coefficient decreases, the controller is further configured to close the second expander and to control the degree of opening of the first expander based on the flow coefficient.

[0110] Aspect 18. The system of aspect 16 or aspect 17, wherein when the degree of opening of the second expander reaches the threshold and the flow coefficient increases, the controller is further configured to increase the degree of opening of the second expander and to keep the degree of opening of the first expander unchanged.

[0111] The terminology used in this specification is intended to describe particular embodiments and is not intended to be limiting. The terms "a," "an," and "the" include the plural forms as well, unless clearly indicated otherwise. The terms "comprises" and/or "comprising," when used in this specification, specify the presence of the stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, and/or components.

[0112] With regard to the preceding description, it is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and arrangement of parts without departing from the scope of the present disclosure. This specification and the embodiments de-

scribed are exemplary only, with the true scope of the disclosure being indicated by the claims that follow.

5 Claims

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

a compressor having a suction port and a discharge port;
a first expander configured to regulate working fluid flow; and
a controller,

wherein when the system transitions directly from a stop phase to a heating mode, the controller is configured to:

determine a degree of opening of the first expander;

when a duration of the stop phase is less than a first duration threshold, apply a first factor to the degree of opening of the first expander to configure the first expander;
when the duration of the stop phase is not less than the first duration threshold and is less than a second duration threshold, apply a second factor to the degree of opening of the first expander to configure the first expander; and when the duration of the stop phase is not less than the second duration threshold, apply a third factor to the degree of opening of the first expander to configure the first expander;
when a saturated suction temperature is less than a first temperature threshold, control the first expander based on a suction superheat.

2. The system of claim 1, wherein the controller is further configured to:

determine the degree of opening of the first expander based on a suction pressure, a discharge pressure, and a mass flow of working fluid.

3. The system of claim 1 or claim 2, wherein the degree of opening of the first expander decreases after applying the first factor, the second factor, or the third factor to the degree of opening of the first expander.

4. The system of any one of claims 1-3, wherein when the system transitions from a warm-up phase or a defrost mode to the heating mode, the controller is further configured to:

control the first expander to an open state before starting the compressor and controlling a

flow control device for the heating mode; and start a fan after a period of time.

5. The system of claim 4, further comprising:

a second expander,
wherein when the system is in the warm-up phase or the defrost mode before transitioning to the heating mode, the controller is further configured to increase a degree of opening of the second expander to increase the saturated suction temperature and a condensing temperature.

6. The system of any one of claims 1-5, wherein when a suction pressure is less than a first pressure threshold and the suction superheat is greater than a first superheat threshold, the controller is further configured to increase the degree of opening of the first expander.

7. The system of claim 6, wherein when the suction pressure is greater than a second pressure threshold or the suction superheat is less than a second superheat threshold, the controller is further configured to stop increasing the degree of opening of the first expander based on the suction pressure and the suction superheat.

8. The system of any one of claims 1-7, wherein when the suction superheat is less than a superheat threshold, the controller is further configured to limit a load of the system; or wherein during a period of time in a start phase of the heating mode, the controller is further configured to control the opening of the first expander based on the saturated suction temperature.

9. The system of any one of claims 1-8, wherein the controller is further configured to set a limit and a buffer for a suction pressure, the limit being greater than the buffer;

when the suction pressure is lower than the limit, the controller is further configured to stop increasing a load of the system;
when the suction pressure is lower than buffer, the controller is further configured to unload the system.

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

a compressor having a suction port and a discharge port;
a first expander and a second expander; and
a controller,
wherein the controller is configured to:

determine a flow coefficient based on a suction pressure, a discharge pressure, and a mass flow of working fluid;
allocate the flow coefficient to determine a degree of opening of the first expander and a degree of opening of the second expander; and
control the first expander and the second expander to regulate working fluid flow,

wherein the first expander and the second expander are arranged in parallel, and a capacity of the first expander is less than a capacity of the second expander.

11. The system of claim 10, wherein the first expander and the second expander are configured to regulate working fluid flow in a heating mode.

12. The system of claim 10 or claim 11, wherein when the flow coefficient is greater than the capacity of the first expander and the second expander is in a closed state, the controller is further configured to open the second expander and to set the degree of opening of the second expander to be greater than a threshold.

13. The system of claim 12, wherein when the second expander transitions from the closed state to an open state, a minimum degree of opening of the second expander is a predetermined degree above the threshold.

14. The system of any one of claims 10-13, wherein when the second expander is in an open state and the flow coefficient increases, the controller is further configured to increase the degree of opening of the second expander and to keep the degree of opening of the first expander unchanged; or wherein when the second expander is in an open state and the flow coefficient decreases, the controller is further configured to decrease the degree of opening of the second expander and to keep the degree of opening of the first expander unchanged until the degree of opening of the second expander reaches a threshold.

15. The system of claim 14, wherein when the degree of opening of the second expander reaches the threshold and the flow coefficient decreases, the controller is further configured to close the second expander and to control the degree of opening of the first expander based on the flow coefficient; or wherein when the degree of opening of the second expander reaches the threshold and the flow coefficient increases, the controller is further configured to increase the degree of opening of the second expander and to keep the degree of opening of the

first expander unchanged.

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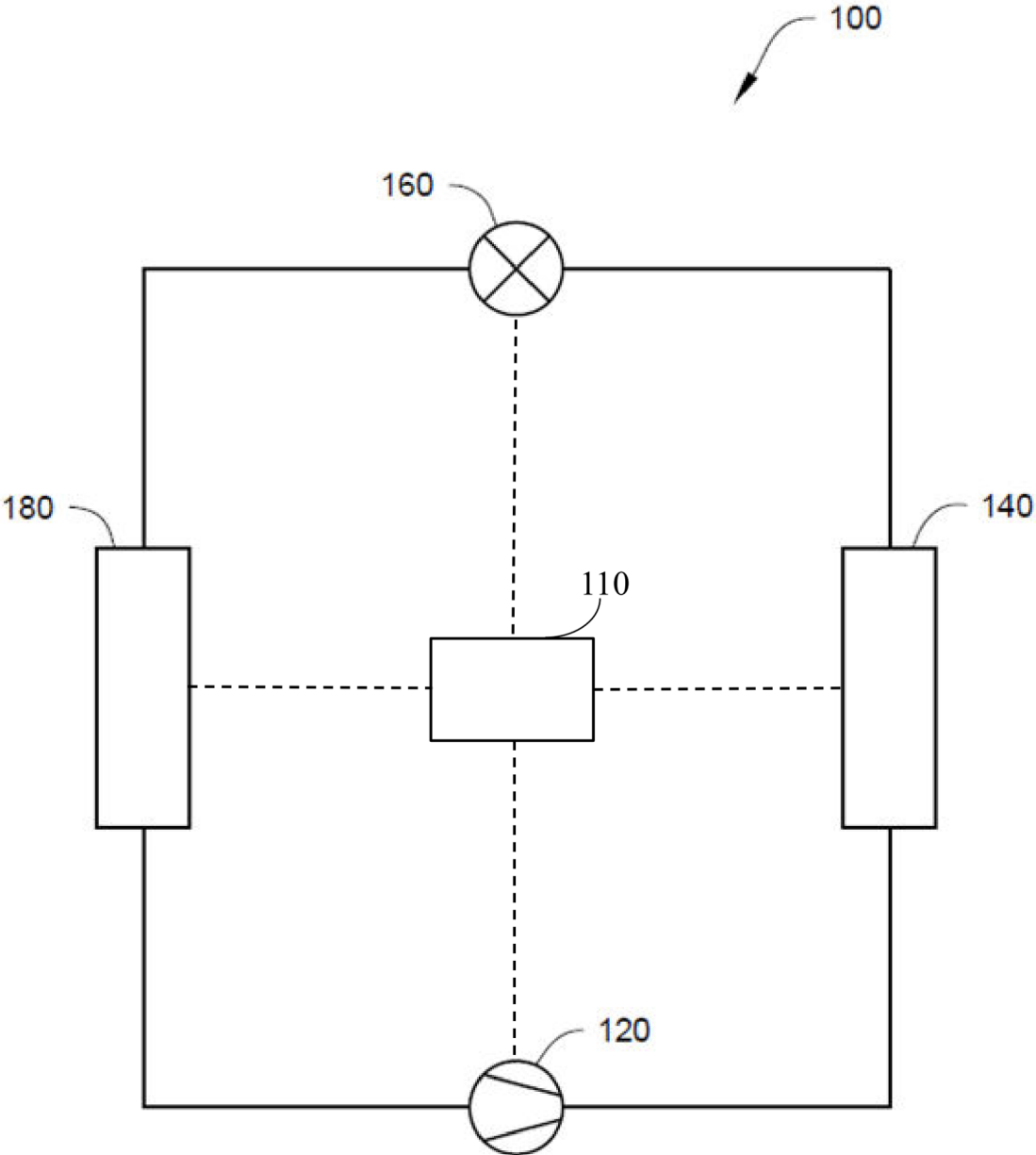


FIG. 1

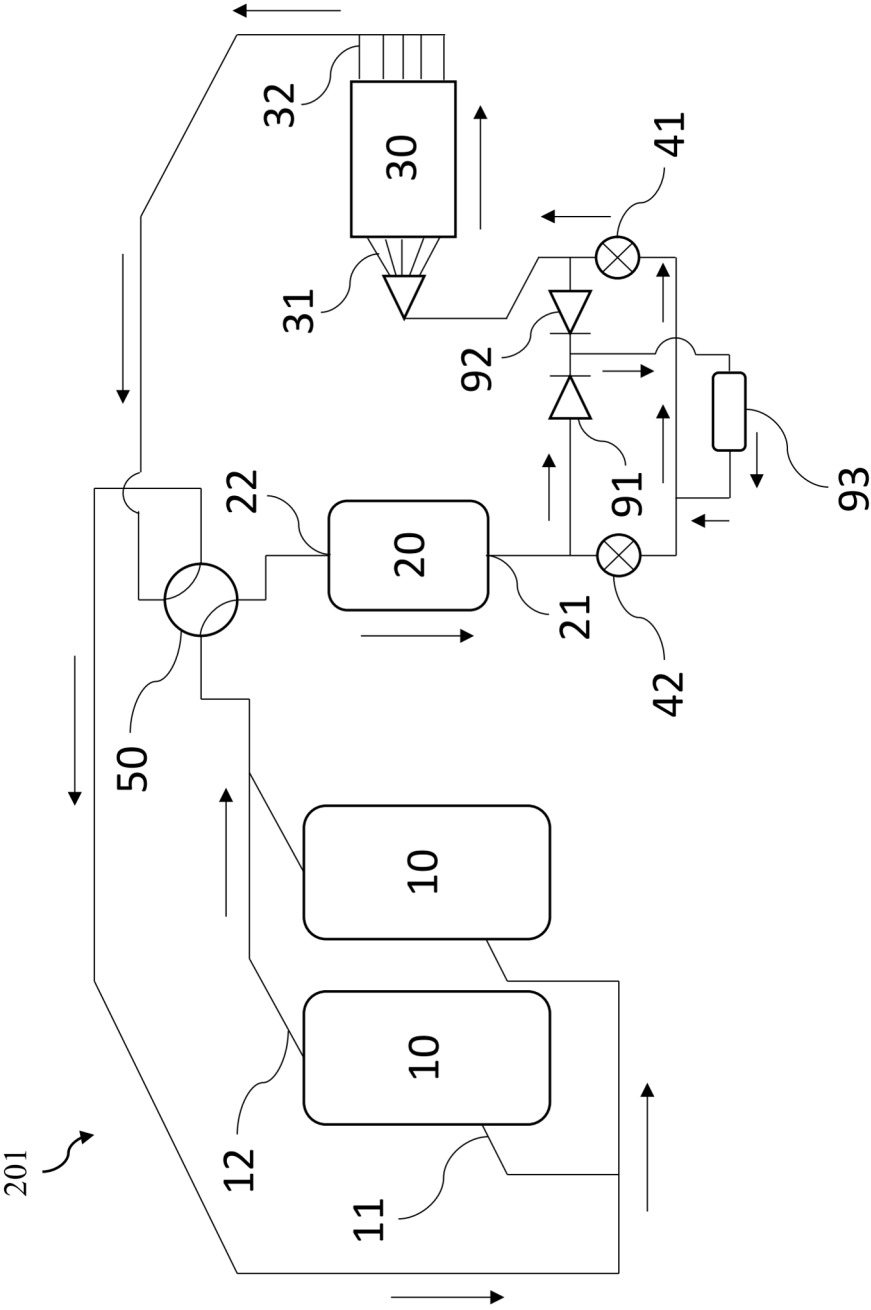


FIG. 2

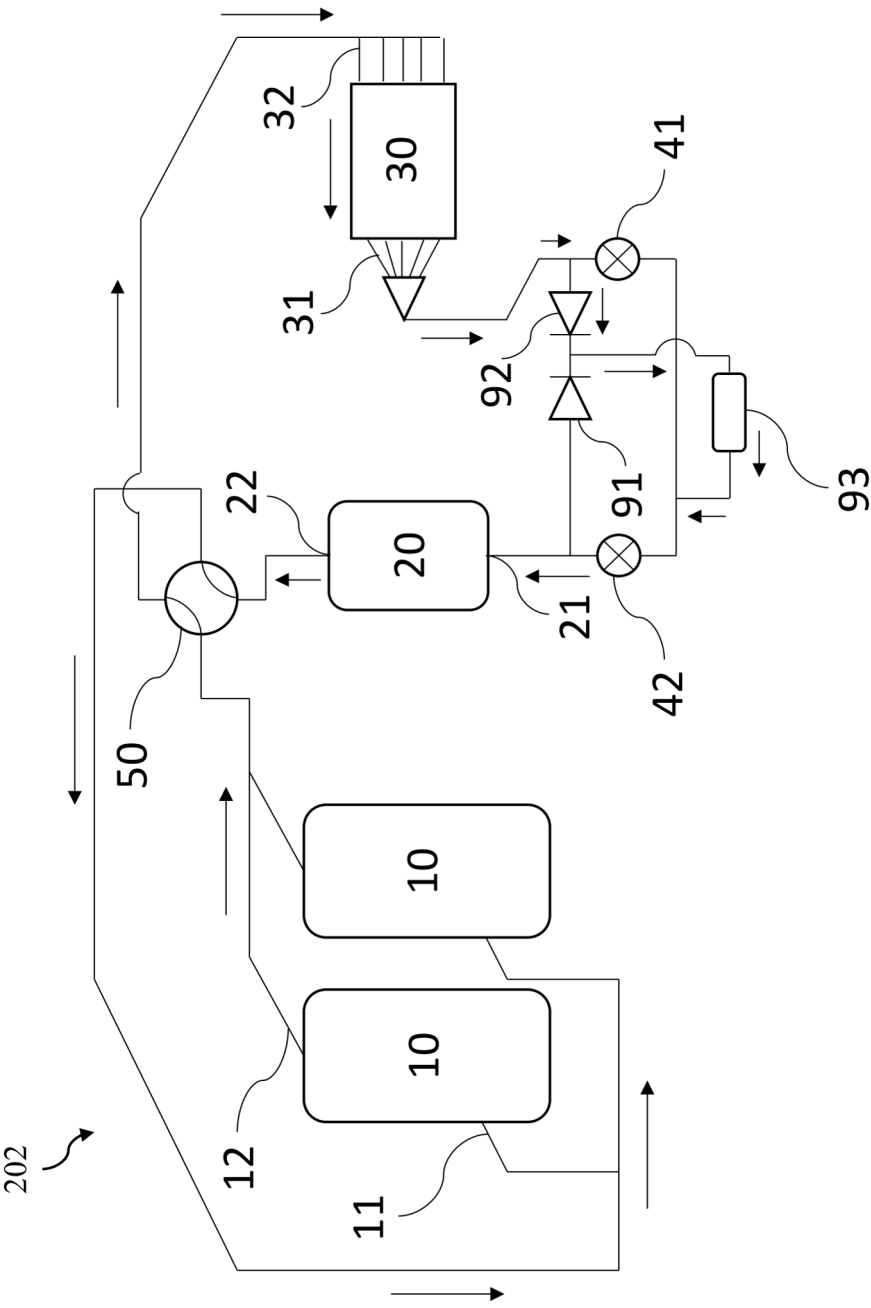


FIG. 3

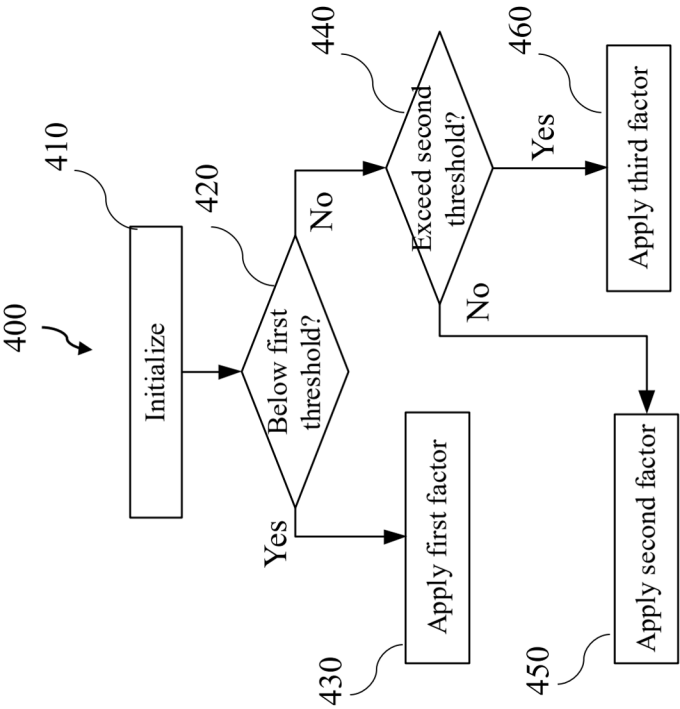


FIG. 4

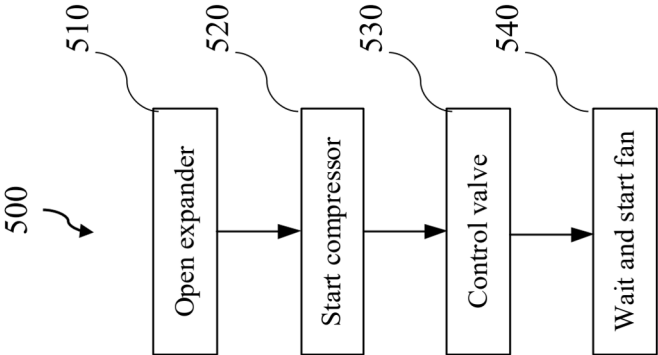


FIG. 5

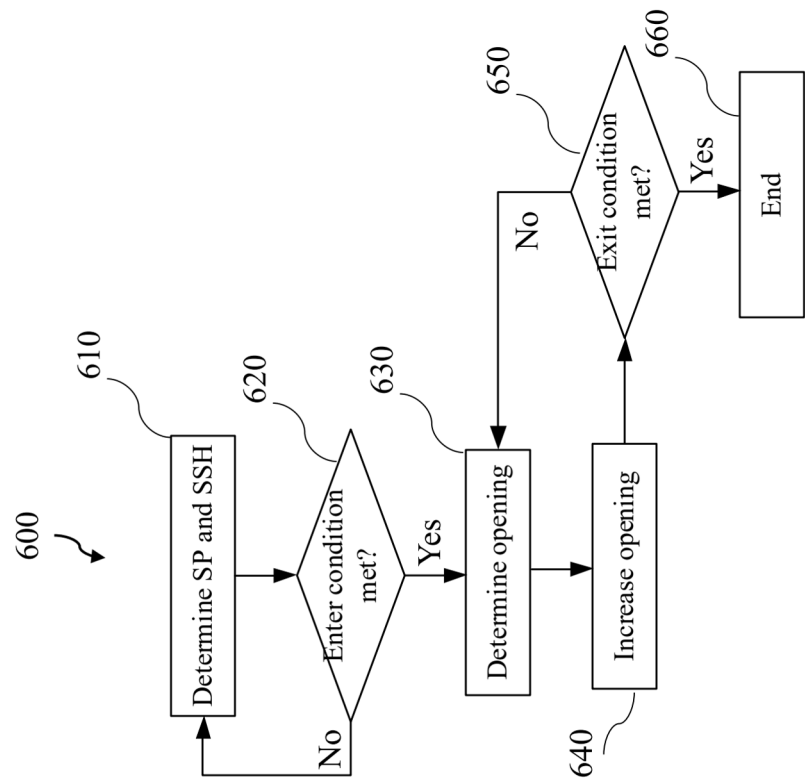


FIG. 6

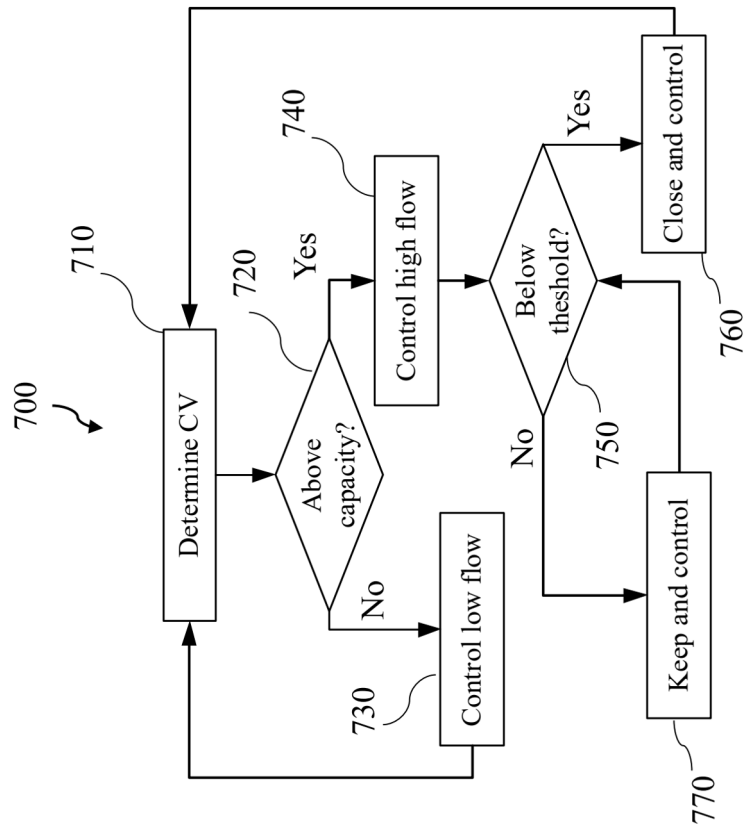


FIG. 7

