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(54) **HEAT EXCHANGER FREEZE PROTECTION**

(57) Preventing freezing in a heat exchanger can include passing first and second cooling fluids through the heat exchanger, monitoring a temperature and/or pressure of the second cooling fluid entering the heat exchanger, heating the second cooling fluid entering the heat exchanger by opening a valve when the monitored temperature and/or monitored pressure is below a trigger

temperature and/or trigger pressure, and closing the valve when a condition is met. The first cooling fluid can have a first freezing temperature and the second cooling fluid can have a second, lower freezing temperature. Opening the valve can cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger.

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## Description

### CROSS REFERENCE TO RELATED APPLICATIONS

**[0001]** This application claims the benefit of US Provisional Patent Application No. 63/413,602 filed October 5, 2022, the entire contents of which are incorporated herein by reference.

### STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

**[0002]** Not applicable.

### REFERENCE TO APPENDIX

**[0003]** Not applicable.

### BACKGROUND OF THE INVENTION

**[0004]** Field of the Invention. The present disclosure relates generally to heat exchanger systems and more specifically relates to refrigerant-based heat exchanger systems used in cold environments.

#### Description of the Related Art.

**[0005]** Some cooling applications utilize split systems, such as where a refrigerant-based cooling system is used to cool a water-based cooling system. In such systems, undesired heat is typically extracted by the water-based cooling system and then exchanged to the refrigerant-based cooling system, where it is typically discharged into the environment. The heat exchangers between these systems may therefore have both refrigerant and water flowing through them.

**[0006]** A problem arises where portions of the refrigerant-based cooling system are located in especially cold environments. In this case, the refrigerant entering the heat exchanger, between the water-based cooling system and the refrigerant-based cooling system, can be so cold as to cause the water therein to freeze, causing damage to the heat exchanger and incurring expensive repair and clean-up costs.

### BRIEF SUMMARY OF THE INVENTION

**[0007]** Applicants have created new and useful devices, systems and methods for heat exchanger freeze protection.

**[0008]** In at least one embodiment, a method for preventing freezing in a heat exchanger can include passing a first cooling fluid and a second cooling fluid through the heat exchanger, monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger, opening a valve, when the monitored temperature is below a trigger temperature and/or the temperature of the second cooling fluid at a

trigger pressure, closing the valve when a condition is met, and/or any combination thereof. In at least one embodiment, the first cooling fluid can have a first freezing temperature and the second cooling fluid can have a second, lower freezing temperature. In at least one embodiment, opening the valve can raise the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger. For example, in at least one embodiment, opening the valve can cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger.

**[0009]** In at least one embodiment, the condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve is closed once the predetermined time has elapsed following any combination of the valve opening, and/or the monitored temperature and/or pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or the predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature, the refrigerant temperature at the trigger pressure, the first freezing temperature, or any combination thereof. In at least one embodiment, the first cooling fluid can include water and/or the second cooling fluid can include a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the heat exchanger.

**[0010]** In at least one embodiment, a method for preventing freezing in an evaporator can include passing a first cooling fluid through a liquid to air heat exchanger to remove heat from a space, passing the first cooling fluid through an evaporator, passing a second cooling fluid through the evaporator, monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator, opening a valve, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve, when a condition is met, and/or any combination thereof. In at least one embodiment, passing the second cooling fluid through the evaporator can cool the first cooling fluid as at least a portion of the second cooling fluid changes from liquid phase to gaseous phase. In at least one embodiment, the first cooling fluid can have a first freezing temperature and the second cooling fluid can have a second, lower freezing temperature.

**[0011]** In at least one embodiment, opening the valve can raise the monitored temperature and/or the monitored pressure of the second cooling fluid entering the evaporator. For example, in at least one embodiment, opening the valve can cause the second cooling fluid, at an elevated temperature and/or an elevated pressure, to mix with the second cooling fluid, at a lower temperature

and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator. In at least one embodiment, the method can include raising the temperature of at least a portion of the second cooling fluid to the elevated temperature.

**[0012]** In at least one embodiment, the condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve is closed once the predetermined time has elapsed following any combination of the valve opening and/or the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator rises to the predetermined temperature and/or the predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature, refrigerant temperature at the trigger pressure, the first freezing temperature, or any combination thereof. In at least one embodiment, the first cooling fluid can include water and/or the second cooling fluid can include a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the evaporator.

**[0013]** In at least one embodiment, a method for preventing freezing in an evaporator can include passing water through a liquid to air heat exchanger to remove heat from a space, passing the water through an evaporator, passing a two-phase refrigerant through the evaporator, passing the refrigerant through a pump, when a first condition is met, passing the refrigerant through a compressor, when the first condition is not met and a space temperature, of the space, is above a setpoint, monitoring a monitored temperature and/or monitored pressure of the refrigerant entering the evaporator, opening a valve, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve, when a second condition is met, and/or any combination thereof. In at least one embodiment, the liquid to air heat exchanger can be located within the space. In at least one embodiment, passing the two-phase refrigerant through the evaporator can cool the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase. In at least one embodiment, the refrigerant can have a refrigerant freezing temperature below a water freezing temperature of the water.

**[0014]** In at least one embodiment, passing the refrigerant through the pump and/or the compressor can increase a refrigerant temperature and/or refrigerant pressure to an elevated temperature and/or elevated pressure. In at least one embodiment, opening the valve can raise the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator. For example, in at least one embodiment, opening the valve

can cause the refrigerant, at the elevated temperature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator.

**[0015]** In at least one embodiment, the second condition can include a predetermined time and/or a predetermined temperature and/or a predetermined pressure. For example, in at least one embodiment, the valve is closed once the predetermined time has elapsed following any combination of the valve opening and/or the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or the predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature, refrigerant temperature at the trigger pressure, the water freezing temperature, or any combination thereof. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the water would freeze as it moves into the evaporator.

**[0016]** In at least one embodiment, the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or a second cooling fluid temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the heat exchanger. In at least one embodiment, the controller can be configured to open the valve and thereby cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger. In at least one embodiment, a condition can include a time, such as a predetermined time, and the controller can be configured to close the valve once the time has elapsed, such as following a valve opening.

**[0017]** In at least one embodiment, a condition can include a temperature and/or pressure, such as a predetermined temperature and/or predetermined pressure, and a controller can be configured to close a valve once the monitored temperature and/or monitored pressure of a cooling fluid, such as a second cooling fluid entering the heat exchanger, rises to the temperature and/or pressure. In at least one embodiment, a predetermined temperature and/or predetermined pressure can be higher than a trigger temperature and/or trigger pressure. In at least one embodiment, a predetermined temperature and/or a second cooling fluid temperature at a predetermined pressure can be higher than a first freezing temperature.

**[0018]** In at least one embodiment, a heat exchanger can include at least one of a liquid to air heat exchanger and an evaporator. In at least one embodiment, A heat exchanger can include a liquid to air heat exchanger configured to remove heat from a space. In at least one embodiment, a heat exchanger can include an evaporator,

and a trigger temperature and/or a second cooling fluid temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the evaporator. In at least one embodiment, a heat exchanger can include an evaporator, and a system can be configured to raise the temperature and/or pressure of at least a portion of a cooling fluid to an elevated temperature and/or elevated pressure, and to cause the cooling fluid, at the elevated temperature and/or elevated pressure, to mix with a cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the cooling fluid entering the evaporator.

**[0019]** In at least one embodiment, a heat exchanger can include a liquid to air heat exchanger and an evaporator, and can be configured to pass water through the liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger being located within the space. In at least one embodiment, the system can be configured to pass a two-phase refrigerant through the evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase. In at least one embodiment, a system can be configured to pass the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when a condition is met. In at least one embodiment, a system can be configured to pass the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to an elevated temperature, when a condition is met, which can include when a condition is not met, and/or when a space temperature, of a space, is above a setpoint.

**[0020]** In at least one embodiment, a system can be configured to close a valve when a second condition is met. In at least one embodiment, the second condition can include a time, such as a predetermined time, and a controller can be configured to close the valve once the predetermined time has elapsed, such as following the valve opening. In at least one embodiment, the second condition can include a predetermined temperature and/or predetermined pressure, and a controller can be configured to close the valve once the monitored temperature and/or monitored pressure of refrigerant entering an evaporator rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the second condition can include a predetermined temperature and/or refrigerant temperature at a predetermined pressure, and a controller can be configured to close the valve once the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

### [0021]

FIG. 1A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 1B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 2A is a block diagram of select components of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 2B is a block diagram of select components of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 3 is a flow chart of one of many embodiments of a method for preventing freezing in a heat exchanger according to the disclosure.

FIG. 4A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 4B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 5A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 5B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 6A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 6B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 7A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

FIG. 7B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure.

## DETAILED DESCRIPTION OF THE INVENTION

**[0022]** The Figures described above and the written description of specific structures and functions below are not presented to limit the scope of what Applicants have invented or the scope of the appended claims. Rather, the Figures and written description are provided to teach any person skilled in the art to make and use the inventions for which patent protection is sought. Those skilled in the art will appreciate that not all features of a commercial embodiment of the inventions are described or shown for the sake of clarity and understanding. Persons of skill in this art will also appreciate that the development of an actual commercial embodiment incorporating aspects of the present inventions will require numerous implementation-specific decisions to achieve the developer's ultimate goal for the commercial embodiment. Such implementation-specific decisions may include, and likely are not limited to, compliance with system-related, business-related, government-related and other constraints, which may vary by specific implementation, location and from time to time. While a developer's efforts might be complex and time-consuming in an absolute sense, such efforts would be, nevertheless, a routine undertaking for those of skill in this art having benefit of this disclosure. It must be understood that the inventions disclosed and taught herein are susceptible to numerous and various modifications and alternative forms.

**[0023]** The use of a singular term, such as, but not limited to, "a," is not intended as limiting of the number of items. Also, the use of relational terms, such as, but not limited to, "top," "bottom," "left," "right," "upper," "lower," "down," "up," "side," and the like are used in the written description for clarity in specific reference to the Figures and are not intended to limit the scope of the inventions or the appended claims. The terms "including" and "such as" are illustrative and not limitative. The terms "couple," "coupled," "coupling," "coupler," and like terms are used broadly herein and can include any method or device for securing, binding, bonding, fastening, attaching, joining, inserting therein, forming thereon or therein, communicating, or otherwise associating, for example, mechanically, magnetically, electrically, chemically, operably, directly or indirectly with intermediate elements, one or more pieces of members together and can further include without limitation integrally forming one functional member with another in a unity fashion. The coupling can occur in any direction, including rotationally. Further, all parts and components of the disclosure that are capable of being physically embodied inherently include imaginary and real characteristics regardless of whether such characteristics are expressly described herein, including but not limited to characteristics such as axes, ends, inner and outer surfaces, interior spaces, tops, bottoms, sides, boundaries, dimensions (e.g., height, length, width, thickness), mass, weight, volume and density, among others.

**[0024]** Process flowcharts discussed herein illustrate the operation of possible implementations of systems,

methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowchart may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the blocks might occur out of the order depicted in the figures. For example, blocks shown in succession may, in fact, be executed substantially concurrently. It will also be noted that each block of a flowchart illustration can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or combinations of special purpose hardware and computer instructions.

**[0025]** Applicants have created new and useful devices, systems and methods for heat exchanger freeze protection.

**[0026]** FIG. 1A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 1B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 2A is a block diagram of select components of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 2B is a block diagram of select components of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 3 is a flow chart of one of many embodiments of a method for preventing freezing in a heat exchanger according to the disclosure. FIG. 4A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 4B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 5A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 5B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 6A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 6B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 7A is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIG. 7B is a block diagram of one of many embodiments of a system for preventing freezing in a heat exchanger according to the disclosure. FIGS. 1-7B are described in conjunction with one another.

**[0027]** In at least one embodiment, a system 100 according to the disclosure can be used to cool a space 110, such as a computer enclosure, server room, building, or any combination thereof. In at least one embodiment, the system 100 includes one or more first heat

exchanger(s) 120. In at least one embodiment, the first heat exchanger 120 can be located within the space 110. In at least one embodiment, the first heat exchanger 120 can be or include a fluid to air heat exchanger, a fluid to fluid heat exchanger, an evaporator, a condenser, a fluid cooled cold plate, or any combination thereof.

**[0028]** In at least one embodiment, a first cooling fluid 122 can be used to extract heat from the first heat exchanger 120. In at least one embodiment, the first cooling fluid 122 can be or include air, water, a water mixture, a refrigerant, another liquid, or any combination thereof. In at least one embodiment, the first cooling fluid 122 can be cooled as it flows through one or more second heat exchanger(s) 130. In at least one embodiment, the second heat exchanger 130 can be located within the space 110, or external thereto. In at least one embodiment, the second heat exchanger 130 can be or include a fluid to air heat exchanger, a fluid to fluid heat exchanger, an evaporator, a condenser, a fluid cooled cold plate, or any combination thereof. In at least one embodiment, a second cooling fluid 132 can be used to extract heat from the second heat exchanger 130, and thereby cool the first cooling fluid 122. In at least one embodiment, the second cooling fluid 132 can be or include water, a water mixture, a refrigerant, another liquid, or any combination thereof.

**[0029]** In at least one embodiment, the second cooling fluid 132 can be pumped through the second heat exchanger 130 using a pump 140 and/or a compressor 150. In at least one embodiment, the second cooling fluid 132 can be cooled as it flows through one or more third heat exchanger(s) 160. In at least one embodiment, the third heat exchanger 160 can be located within the space 110, or external thereto. In at least one embodiment, the third heat exchanger 160 can include a fluid to air heat exchanger, a fluid to fluid heat exchanger, an evaporator, a condenser, a fluid cooled cold plate, or any combination thereof. In at least one embodiment, air and/or another cooling fluid can be used to extract heat from the third heat exchanger 160, and thereby cool the second cooling fluid 132.

**[0030]** In at least one embodiment, the cooling fluids 122, 132 can have different freezing temperatures. In at least one embodiment, the cooling fluids 122, 132 can be different refrigerants, such as R410A, R134A, or another refrigerant. In at least one embodiment, the first cooling fluid 122 can be water and the second cooling fluid 132 can be a water/glycol mixture, or a refrigerant, such that the second cooling fluid 132 can have a much lower freezing temperature compared to the water of the first cooling fluid 122. In at least one embodiment, the first cooling fluid 122 can be a refrigerant and the second cooling fluid 132 can be a different refrigerant, such that the second cooling fluid 132 can have a much lower freezing temperature compared to that of the first cooling fluid 122. In certain situations, such as on startup of the system 100 in colder environments, the second cooling fluid 132 can be so cold so as to cause the first cooling fluid 122,

such as water, to freeze in the second heat exchanger 130.

**[0031]** In at least one embodiment, a valve 170 can be plumbed between the second heat exchanger 130 and the discharge of the pump 140 and/or the compressor 150. In at least one embodiment, the valve 170 can be plumbed between the second heat exchanger 130 and the third heat exchanger 160. In at least one embodiment, a valve 170 can be plumbed between the second heat exchanger 130, the third heat exchanger 160 and/or the discharge of the pump 140, and the discharge of the compressor 150. In at least one embodiment, the valve 170 can be connected to plumbing upstream of the second heat exchanger 130. In at least one embodiment, the valve 170 can be connected to plumbing downstream of the third heat exchanger 160. In at least one embodiment, the valve 170 can be connected to plumbing downstream of the discharge of the pump 140 and/or the compressor 150.

**[0032]** In at least one embodiment, the valve 170 can be a simple on/off valve. In at least one embodiment, the valve 170 can be a mixing valve. For example, in at least one embodiment, the valve 170 can selectively mix the second cooling fluid 132 coming from the third heat exchanger 160 and/or external to the space 110 with the second cooling fluid 132 coming from the discharge of the compressor 150 and/or internal to the space 110, without exiting the space 110 and/or passing through the third heat exchanger 160. In at least one embodiment, the valve 170 can be a three-way valve. In at least one embodiment, the valve 170 can be a diverter valve. For example, in at least one embodiment, the valve 170 can selectively allow the second cooling fluid 132 coming from the discharge of the compressor 150 and/or internal to the space 110, without exiting the space 110 and/or passing through the third heat exchanger 160. In at least one embodiment, the valve 170 can selectively allow the second cooling fluid 132 coming from the third heat exchanger 160 and/or external to the space 110 to flow into the second heat exchanger 130.

**[0033]** In at least one embodiment, the valve 170 can be controlled by a controller 180 based on the temperature or pressure of the second cooling fluid 132 entering the second heat exchanger 130. In at least one embodiment, the controller 180 can obtain the temperature or pressure of the second cooling fluid 132 entering the second heat exchanger 130 using a sensor 190 thermally coupled to, or otherwise connected to, plumbing upstream of the second heat exchanger 130. In at least one embodiment, the valve 170 can be controlled by the sensor 190.

**[0034]** In at least one embodiment, the third heat exchanger 160 comprises a condenser located outside of the space 110. In at least one embodiment, the second heat exchanger 130, the compressor 150, and the valve 170 are located within an enclosure 112, within the space 110, with the first heat exchanger 120 being located within the space 110 but outside the enclosure 112, and the

pump 140 and third heat exchanger 160 located outside of the space 110. In at least one embodiment, the system 100 includes multiple first heat exchanger(s) 120 being located within the space 110 but outside the enclosure 112, with those first heat exchanger(s) 120 being plumbed to the second heat exchanger 130, within the enclosure. Of course, in some embodiments, additional, or fewer components, may be located within the enclosure 112, within the space 110, or external to the space 110. For example, in at least one embodiment, the system 100 includes one or more intermediate heat exchangers, such as multiple second heat exchanger(s) 130, 130a and/or multiple third heat exchanger(s) 160, 160a.

**[0035]** In at least one embodiment, the system 100 includes fewer heat exchangers and may include one or more first heat exchanger(s) 120 or one or more second heat exchanger(s) 130, but not both first and second heat exchanger(s) 120, 130 as described herein. In at least one embodiment, the system 100 includes fewer heat exchangers and may include one or more first heat exchanger(s) 120 and one or more second heat exchanger(s) 130, but not the third heat exchanger 160 as described herein.

**[0036]** In at least one embodiment, a method 200 for preventing (i.e., at least partially resisting) freezing in a heat exchanger can include passing a first cooling fluid 122 through a first heat exchanger 120 and a second heat exchanger 130, as shown in step 202. In at least one embodiment, the method 200 can include passing a second cooling fluid 132 through the second heat exchanger 130 and a third heat exchanger 160, as shown in step 204. In at least one embodiment, the method 200 can include passing the second cooling fluid 132 through a pump 140 and/or a compressor 150, as shown in step 206. In at least one embodiment, the method 200 can include monitoring a temperature and/or pressure of the second cooling fluid 132 upstream of the second heat exchanger 130, as shown in step 208. In at least one embodiment, the method 200 can include opening a valve 170 when the second cooling fluid 132 upstream of the second heat exchanger 130 is below a trigger temperature and/or trigger pressure, as shown in step 210. In at least one embodiment, the method 200 can include heating the second cooling fluid 132 upstream of the second heat exchanger 130 as discussed herein, as shown in step 212. In at least one embodiment, the method 200 can include closing the valve 170 when a condition, such as a time, temperature, pressure, or any combination thereof, is met, as shown in step 214.

**[0037]** In at least one embodiment, a method 200 for preventing freezing in a heat exchanger can include passing a first cooling fluid 122 and a second cooling fluid 132 through the heat exchanger 130, monitoring a monitored temperature and/or monitored pressure of the second cooling fluid 132 entering the heat exchanger 130, opening a valve 170, when the monitored temperature and/or monitored pressure is below a trigger tem-

perature and/or trigger pressure, closing the valve 170 when a condition is met, and/or any combination thereof. In at least one embodiment, the first cooling fluid 122 can have a first freezing temperature and the second cooling fluid can have a second, lower freezing temperature. In at least one embodiment, opening the valve 170 can raise the monitored temperature and/or monitored pressure of the second cooling fluid 132 entering the heat exchanger 130. For example, in at least one embodiment, opening the valve 170 can cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger 130.

**[0038]** In at least one embodiment, the condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve 170 is closed once the predetermined time has elapsed following any combination of the valve 170 opening and/or the monitored temperature and/or the monitored pressure of the second cooling fluid 132 entering the heat exchanger 130 rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature and/or refrigerant temperature at the trigger pressure and/or the first freezing temperature. In at least one embodiment, the first cooling fluid 122 can include water and/or the second cooling fluid 132 can include a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the predetermined pressure can be above a point at which the first cooling fluid 122 would freeze as it moves into the heat exchanger 130, which can be different than the first freezing temperature. For example, a river typically does not freeze at 32 degrees, while it is moving, but will still freeze at a lower temperature. In at least one embodiment, the first cooling fluid 122 would freeze at one temperature, if stationary, but another, lower temperature while moving.

**[0039]** In at least one embodiment, a method 200 for preventing freezing in an evaporator can include passing a first cooling fluid 122 through a liquid to air heat exchanger 120 to remove heat from a space 110, passing the first cooling fluid 122 through an evaporator 130, passing a second cooling fluid 132 through the evaporator 130, monitoring a monitored temperature and/or monitored pressure of the second cooling fluid 132 entering the evaporator 130, opening a valve 170, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve 170, when a condition is met, and/or any combination thereof. In at least one embodiment, passing the second cooling fluid 132 through the evaporator 130 can cool the first cooling fluid 122 as at least a portion of the second cooling fluid 132 changes from liquid phase to gaseous phase. In at least one embodiment, the first cooling fluid 122 can have a first freezing temperature and the second cooling fluid can have a second, lower freez-

ing temperature.

**[0040]** In at least one embodiment, opening the valve 170 can raise the monitored temperature and/or monitored pressure of the second cooling fluid 132 entering the evaporator 130. For example, in at least one embodiment, opening the valve 170 can cause the second cooling fluid 132, at an elevated temperature and/or elevated pressure (such as coming from a pump 140, compressor 150, or other heating element), to mix with the second cooling fluid 132, at a lower temperature and/or lower pressure (such as coming from a condenser 160 or outside the space 110), upstream of the evaporator 130, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid 132 entering the evaporator 130. In at least one embodiment, the method 200 can include raising the temperature and/or pressure of at least a portion of the second cooling fluid 132 to the elevated temperature and/or elevated pressure. Heating the second cooling fluid 132 can be accomplished in a number of ways, including through a pump 140 and/or a compressor - both of which can be used to increase the pressure and/or temperature of the second cooling fluid 132. Heating the second cooling fluid 132 can also be accomplished utilizing a simple heating element.

**[0041]** In at least one embodiment, the condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve 170 is closed once the predetermined time has elapsed following any combination of the valve 170 opening and/or the monitored temperature and/or monitored pressure of the second cooling fluid 132 entering the evaporator 130 rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature and/or refrigerant temperature at the trigger pressure and/or the first freezing temperature. In at least one embodiment, the first cooling fluid 122 can include water and/or the second cooling fluid 132 can include a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the first cooling fluid 122 would freeze as it moves into the evaporator.

**[0042]** In at least one embodiment, a method 200 for preventing freezing in an evaporator can include passing a cooling fluid 122, such as water, through a liquid to air heat exchanger 120 to remove heat from a space 110, passing the water through an evaporator 130, passing a cooling fluid 132, such as a two-phase refrigerant, through the evaporator 130, passing the refrigerant through a pump 140, when a first condition is met, passing the refrigerant through a compressor 150, when the first condition is not met and a space temperature, of the space 110, is above a setpoint, monitoring a monitored temperature and/or monitored pressure of the refrigerant

entering the evaporator 130, opening a valve 170, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve 170, when a second condition is met, and/or any combination thereof. In at least one embodiment, the liquid to air heat exchanger 120 can be located within the space 110. In at least one embodiment, passing the two-phase refrigerant through the evaporator 130 can cool the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase. In at least one embodiment, the refrigerant can have a refrigerant freezing temperature below a water freezing temperature of the water. In at least one embodiment, the first condition includes a low outside temperature, a low space temperature, another criteria (such as those used to decide to switch to a pumped refrigerant process), or any combination thereof

**[0043]** In at least one embodiment, passing the refrigerant through the pump 140 and/or the compressor 150 can increase a refrigerant temperature and/or refrigerant pressure to an elevated temperature and/or elevated pressure. In at least one embodiment, opening the valve 170 can raise the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator 130. For example, in at least one embodiment, opening the valve 170 can cause the refrigerant, at the elevated temperature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator 130, thereby raising the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator 130.

**[0044]** In at least one embodiment, the second condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve 170 is closed once the predetermined time has elapsed following any combination of the valve 170 opening and/or the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator 130 rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature, refrigerant temperature at the trigger pressure, the water freezing temperature, or any combination thereof. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the water would freeze as it moves into the evaporator 130.

**[0045]** In at least one embodiment, a predetermined time can be or include thirty seconds, one minute, two minutes, four minutes, or another time(s) (whether less than or greater than any of the foregoing examples) required or desired for accomplishing the goals of the disclosure in accordance with an implementation of the disclosure, separately or in combination. A second condition can include a combination of a predetermined time, a predetermined temperature, and/or a predetermined pressure. For example, in at least one embodiment, the



valve 170 is closed once the predetermined temperature and/or predetermined pressure has been attained for the predetermined time.

**[0046]** In at least one embodiment, a method for preventing freezing in a heat exchanger can include passing a first cooling fluid and a second cooling fluid through the heat exchanger, monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger, opening a valve, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve when a condition is met, and/or any combination thereof. In at least one embodiment, the first cooling fluid can have a first freezing temperature and the second cooling fluid can have a second, lower freezing temperature. In at least one embodiment, opening the valve can raise the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger. For example, in at least one embodiment, opening the valve can cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger.

**[0047]** In at least one embodiment, the condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve is closed once the predetermined time has elapsed following any combination of the valve opening and/or the monitored temperature and/or the monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature, refrigerant temperature at the trigger pressure, the first freezing temperature, or any combination thereof. In at least one embodiment, the first cooling fluid can include water and/or the second cooling fluid can include a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the heat exchanger.

**[0048]** In at least one embodiment, a method for preventing freezing in an evaporator can include passing a first cooling fluid through a liquid to air heat exchanger to remove heat from a space, passing the first cooling fluid through an evaporator, passing a second cooling fluid through the evaporator, monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator, opening a valve, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve, when a condition is met, and/or any combination thereof. In at least one embodiment, passing the second cooling fluid through the evaporator can cool the first cooling fluid as at least a portion of the second cooling fluid changes from liquid phase to gaseous phase. In at

least one embodiment, the first cooling fluid can have a first freezing temperature and the second cooling fluid can have a second, lower freezing temperature.

**[0049]** In at least one embodiment, opening the valve can raise the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator. For example, in at least one embodiment, opening the valve can cause the second cooling fluid, at an elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator. In at least one embodiment, the method can include raising the temperature of at least a portion of the second cooling fluid to the elevated temperature.

**[0050]** In at least one embodiment, the condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve is closed once the predetermined time has elapsed following any combination of the valve opening and/or the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature and/or refrigerant temperature at the trigger pressure and/or the first freezing temperature. In at least one embodiment, the first cooling fluid can include water and/or the second cooling fluid can include a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the evaporator.

**[0051]** In at least one embodiment, a method for preventing freezing in an evaporator can include passing water through a liquid to air heat exchanger to remove heat from a space, passing the water through an evaporator, passing a two-phase refrigerant through the evaporator, passing the refrigerant through a pump, when a first condition is met, passing the refrigerant through a compressor, when the first condition is not met and a space temperature, of the space, is above a setpoint, monitoring a monitored temperature and/or monitored pressure of the refrigerant entering the evaporator, opening a valve, when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, closing the valve, when a second condition is met, and/or any combination thereof. In at least one embodiment, the liquid to air heat exchanger can be located within the space. In at least one embodiment, passing the two-phase refrigerant through the evaporator can cool the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase. In at least one embodiment, the refrigerant can have a refrigerant freezing temperature below a water freezing temperature

of the water.

**[0052]** In at least one embodiment, passing the refrigerant through the pump and/or the compressor can increase a refrigerant temperature and/or refrigerant pressure to an elevated temperature and/or elevated pressure. In at least one embodiment, opening the valve can raise the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator. For example, in at least one embodiment, opening the valve can cause the refrigerant, at the elevated temperature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator.

**[0053]** In at least one embodiment, the second condition can include a predetermined time, a predetermined temperature, a predetermined pressure, or any combination thereof. For example, in at least one embodiment, the valve is closed once the predetermined time has elapsed following any combination of the valve opening and/or the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the predetermined temperature and/or refrigerant temperature at the predetermined pressure can be higher than the trigger temperature and/or refrigerant temperature at the trigger pressure and/or the water freezing temperature. In at least one embodiment, the trigger temperature and/or refrigerant temperature at the trigger pressure can be above a point at which the water would freeze as it moves into the evaporator.

**[0054]** In at least one embodiment, a system according to the disclosure can include a heat exchanger configured to have a first cooling fluid and a second cooling fluid passed there through, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature, a temperature sensor and/or pressure sensor in sensing communication with a fluid path by which the second cooling fluid enters the heat exchanger, a valve, and a controller. The controller can be configured to monitor a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger, open the valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger, and close the valve when one or more conditions are met. In at least one embodiment, the controller can be or include a plurality of controllers. In at least one embodiment, the controller can be configured to perform any one or more of the method steps disclosed herein, at any time(s) and in any order(s) required or desired for an implementation of the disclosure. In at least one embodiment, a system can include a nontransitory, computer-readable media

having instructions stored thereon that, when executed by a processor, cause the processor to perform any one or more of the method steps disclosed herein, at any time(s) and in any order(s) required or desired for an implementation of the disclosure.

**[0055]** In at least one embodiment, the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant. In at least one embodiment, the trigger temperature and/or a second cooling fluid temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the heat exchanger. In at least one embodiment, the controller can be configured to open the valve and thereby cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger. In at least one embodiment, a condition can include a time, such as a predetermined time, and the controller can be configured to close the valve once the time has elapsed, such as following a valve opening.

**[0056]** In at least one embodiment, a condition can include a temperature and/or pressure, such as a predetermined temperature and/or predetermined pressure, and a controller can be configured to close a valve once the monitored temperature and/or monitored pressure of a cooling fluid, such as a second cooling fluid entering the heat exchanger, rises to the temperature and/or pressure. In at least one embodiment, a predetermined temperature and/or predetermined pressure can be higher than a trigger temperature and/or trigger pressure. In at least one embodiment, a predetermined temperature and/or a second cooling fluid temperature at a predetermined pressure can be higher than a first freezing temperature.

**[0057]** In at least one embodiment, a heat exchanger can include at least one of a liquid to air heat exchanger and an evaporator. In at least one embodiment, A heat exchanger can include a liquid to air heat exchanger configured to remove heat from a space. In at least one embodiment, a heat exchanger can include an evaporator, and a trigger temperature and/or a second cooling fluid temperature at the trigger pressure can be above a point at which the first cooling fluid would freeze as it moves into the evaporator. In at least one embodiment, a heat exchanger can include an evaporator, and a system can be configured to raise the temperature and/or pressure of at least a portion of a cooling fluid to an elevated temperature and/or elevated pressure, and to cause the cooling fluid, at the elevated temperature and/or elevated pressure, to mix with a cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the cooling fluid entering the evaporator.

**[0058]** In at least one embodiment, a heat exchanger can include a liquid to air heat exchanger and an evaporator, and can be configured to pass water through the liquid to air heat exchanger to remove heat from a space,

the liquid to air heat exchanger being located within the space. In at least one embodiment, the system can be configured to pass a two-phase refrigerant through the evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase. In at least one embodiment, a system can be configured to pass the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when a condition is met. In at least one embodiment, a system can be configured to pass the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to an elevated temperature, when a condition is met, which can include when a condition is not met, and/or when a space temperature, of a space, is above a setpoint.

**[0059]** In at least one embodiment, a system can be configured to close a valve when a second condition is met. In at least one embodiment, the second condition can include a time, such as a predetermined time, and a controller can be configured to close the valve once the predetermined time has elapsed, such as following the valve opening. In at least one embodiment, the second condition can include a predetermined temperature and/or predetermined pressure, and a controller can be configured to close the valve once the monitored temperature and/or monitored pressure of refrigerant entering an evaporator rises to the predetermined temperature and/or predetermined pressure. In at least one embodiment, the second condition can include a predetermined temperature and/or refrigerant temperature at a predetermined pressure, and a controller can be configured to close the valve once the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

**[0060]** While the present disclosure refers to exemplary embodiments of systems and methods for preventing freezing in a heat exchanger, it should be understood that embodiments of the disclosure are not limited to freeze prevention. Rather, the teachings of the present disclosure can be applied for other types of critical temperature limit control as well, such as for condensation prevention, whether separately or in combination. For example, in at least one embodiment, systems and methods of the present disclosure can be configured for preventing or otherwise controlling condensation in and/or about a heat exchanger, such as within a server and/or as part of a direct liquid cooling implementation. In such an embodiment, which is but one of many, a system can, but need not, include a dewpoint control or one or more components configured for controlling or monitoring dewpoint in or about a heat exchanger or heat exchange system. In other words, by controlling the temperature and/or change in temperature of a cooling fluid of a heat exchanger, as discussed above, in at least one embodiment, systems and methods of the present disclosure can be configured to control and/or prevent not only freez-

ing but condensation as well. Such control can be applied, for example, to air-to-air heat exchangers, air-to-liquid heat exchangers, liquid-to-liquid heat exchangers, and/or cold plates, such as air-to-cold plate and liquid-to-cold plate heat exchange systems.

**[0061]** Other and further embodiments utilizing one or more aspects of the disclosure can be devised without departing from the spirit of Applicants' disclosure. For example, the devices, systems and methods can be implemented for numerous different types and sizes in numerous different industries. Further, the various methods and embodiments of the devices, systems and methods can be included in combination with each other to produce variations of the disclosed methods and embodiments. Discussion of singular elements can include plural elements and vice-versa. The order of steps can occur in a variety of sequences unless otherwise specifically limited. The various steps described herein can be combined with other steps, interlineated with the stated steps, and/or split into multiple steps. Similarly, elements have been described functionally and can be embodied as separate components or can be combined into components having multiple functions.

**[0062]** The inventions have been described in the context of preferred and other embodiments and not every embodiment of the inventions has been described. Obvious modifications and alterations to the described embodiments are available to those of ordinary skill in the art having the benefits of the present disclosure. The disclosed and undisclosed embodiments are not intended to limit or restrict the scope or applicability of the inventions conceived of by the Applicants, but rather, in conformity with the patent laws, Applicants intend to fully protect all such modifications and improvements that come within the scope or range of equivalents of the following claims.

**[0063]** Below follow a list of numbered items. These items may be combined with any other features described herein in any combination beyond those expressly stated below:

1. A method for preventing freezing in a heat exchanger, the method comprising the steps of:

passing a first cooling fluid and a second cooling fluid through a heat exchanger, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;

monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger;

opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or mon-

itored pressure of the second cooling fluid entering the heat exchanger; and  
closing the valve when a condition is met.

2. The method of item 1, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant. 5

3. The method of item 1, wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger. 10

4. The method of item 1, wherein opening the valve causes the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger. 15 20

5. The method of item 1, wherein the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening. 25

6. The method of item 1, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure. 30 35

7. The method of item 6, wherein the predetermined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure. 40

8. The method of item 6, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature. 45

9. A method for preventing freezing in an evaporator, the method comprising the steps of:

passing a first cooling fluid through a liquid to air heat exchanger to remove heat from a space, the first cooling fluid having a first freezing temperature; 50  
passing a second cooling fluid through an evaporator, thereby cooling the first cooling fluid as at least a portion of the second cooling fluid changes from liquid phase to gaseous phase, the second cooling fluid having a second freezing temperature, wherein the second freezing 55

temperature is lower than the first freezing temperature;

monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator;

opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and

closing the valve when a condition is met.

10. The method of item 9, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

11. The method of item 9, wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator.

12. The method of item 9, further including raising the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and wherein opening the valve causes the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator.

13. The method of item 9, wherein the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

14. The method of item 9, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator rises to the predetermined temperature and/or predetermined pressure.

15. The method of item 14, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the trigger temperature and/or a second cooling fluid temperature at the trigger pressure.

16. The method of item 14, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

17. A method for preventing freezing in an evaporator, the method comprising the steps of:

passing water through a liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger located within the space; passing a two-phase refrigerant through an evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase, the refrigerant having a refrigerant freezing temperature below a water freezing temperature of the water; passing the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when a first condition is met; passing the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the first condition is not met and a space temperature, of the space, is above a setpoint; monitoring a monitored temperature and/or monitored pressure of the refrigerant entering the evaporator; opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and closing the valve when a second condition is met.

18. The method of item 17, wherein opening the valve causes the refrigerant, at the elevated temperature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator, thereby raising the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator.

19. The method of item 17, wherein the second condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

20. The method of item 17, wherein the second condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure, and wherein the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

**[0064]** Below follow a list of numbered aspects. These items may be combined with any other features described herein in any combination beyond those expressly stated below:

1. A method for preventing freezing in a heat exchanger, the method comprising the steps of:

passing a first cooling fluid and a second cooling fluid through a heat exchanger, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature; monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; and closing the valve when a condition is met.

2. The method of aspect 1, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

3. The method of aspect 1, wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger.

4. The method of aspect 1, wherein opening the valve causes the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger.

5. The method of aspect 1, wherein the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

6. The method of aspect 1, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure.

7. The method of aspect 6, wherein the predeter-

mined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure.

8. The method of aspect 6, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature. 5

9. A method for preventing freezing in an evaporator, the method comprising the steps of: 10

passing a first cooling fluid through a liquid to air heat exchanger to remove heat from a space, the first cooling fluid having a first freezing temperature; 15  
 passing a second cooling fluid through an evaporator, thereby cooling the first cooling fluid as at least a portion of the second cooling fluid changes from liquid phase to gaseous phase, the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature; 20  
 monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; 25  
 opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and 30  
 closing the valve when a condition is met. 35

10. The method of aspect 9, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

11. The method of aspect 9, wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator. 40

12. The method of aspect 9, further including raising the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and wherein opening the valve causes the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator. 45 50 55

13. The method of aspect 9, wherein the condition

comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

14. The method of aspect 9, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator rises to the predetermined temperature and/or predetermined pressure.

15. The method of aspect 14, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the trigger temperature and/or a second cooling fluid temperature at the trigger pressure.

16. The method of aspect 14, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

17. A method for preventing freezing in an evaporator, the method comprising the steps of:

passing water through a liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger located within the space; passing a two-phase refrigerant through an evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase, the refrigerant having a refrigerant freezing temperature below a water freezing temperature of the water; passing the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when a first condition is met; passing the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the first condition is not met and a space temperature, of the space, is above a setpoint; monitoring a monitored temperature and/or monitored pressure of the refrigerant entering the evaporator; opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and closing the valve when a second condition is met.

18. The method of aspect 17, wherein opening the valve causes the refrigerant, at the elevated temper-

ature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator, thereby raising the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator.

19. The method of aspect 17, wherein the second condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

20. The method of aspect 17, wherein the second condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure, and wherein the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

21. A system, comprising:

a heat exchanger configured to have a first cooling fluid and a second cooling fluid passed there through, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;

a temperature sensor and/or pressure sensor in sensing communication with a fluid path by which the second cooling fluid enters the heat exchanger;

a valve; and

a controller;

wherein the controller is configured to

monitor a monitored temperature and/or a monitored pressure of the second cooling fluid entering the heat exchanger;

open the valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; and

close the valve when a condition is met.

22. The system of aspect 21, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

23. The system of aspect 21, wherein the trigger temperature and/or a second cooling fluid temperature

at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger.

24. The system of aspect 21, wherein the controller is further configured to open the valve and thereby cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger.

25. The system of aspect 21, wherein the condition comprises a predetermined time, and wherein the controller is configured to close the valve once the predetermined time has elapsed following the valve opening.

26. The system of aspect 21, wherein the condition comprises a predetermined temperature and/or predetermined pressure, and wherein the controller is configured to close the valve once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure.

27. The system of aspect 26, wherein the predetermined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure.

28. The system of aspect 26, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

29. The system of aspect 21, wherein the heat exchanger comprises at least one of a liquid to air heat exchanger and an evaporator.

30. The system of aspect 21, wherein the heat exchanger comprises a liquid to air heat exchanger configured to remove heat from a space.

31. The system of aspect 21, wherein the heat exchanger comprises an evaporator, and wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator.

32. The system of aspect 21, wherein the heat exchanger comprises an evaporator, and wherein the system is configured to raise the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and to cause the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower tem-

perature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator.

33. The system of aspect 21, wherein

the heat exchanger comprises a liquid to air heat exchanger and an evaporator;  
the system is configured to pass water through the liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger being located within the space; and  
the system is configured to pass a two-phase refrigerant through the evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase.

34. The system of aspect 33, wherein the system is configured to

pass the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when the condition is met;  
pass the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the condition is not met and a space temperature, of the space, is above a setpoint; and  
close the valve when a second condition is met.

35. The system of aspect 34, wherein the second condition comprises a predetermined time, and wherein the controller is configured to close the valve once the predetermined time has elapsed following the valve opening.

36. The system of aspect 34, wherein the second condition comprises a predetermined temperature and/or predetermined pressure, and wherein the controller is configured to close the valve once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure.

37. The system of aspect 34, wherein the second condition comprises a predetermined temperature and/or refrigerant temperature at the predetermined pressure, and wherein the controller is configured to close the valve once the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

**[0065]** Below follow a list of numbered clauses. These clauses may be combined with any other features described herein in any combination beyond those expressly stated below:

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1. A method for preventing freezing in a heat exchanger, the method comprising the steps of:

passing a first cooling fluid and a second cooling fluid through a heat exchanger, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;  
monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger;  
opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; and  
closing the valve when a condition is met.

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2. The method of clause 1, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

3. The method of clause 1 or clause 2, wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger.

4. The method of any one of the preceding clauses, wherein opening the valve causes the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger.

5. The method of any one of clauses 1-4, wherein the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

6. The method of any one of clauses 1-4, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure.

7. The method of clause 6, wherein the predeter-



mined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure.

8. The method of clause 6, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature. 5

9. A method for preventing freezing in an evaporator, the method comprising the steps of: 10

passing a first cooling fluid through a liquid to air heat exchanger to remove heat from a space, the first cooling fluid having a first freezing temperature; 15  
 passing a second cooling fluid through an evaporator, thereby cooling the first cooling fluid as at least a portion of the second cooling fluid changes from liquid phase to gaseous phase, the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature; 20  
 monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; 25  
 opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and 30  
 closing the valve when a condition is met. 35

10. The method of clause 9, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

11. The method of clause 9 or 10, wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator. 40

12. The method of any one of clauses 9-11, further including raising the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and wherein opening the valve causes the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator. 45 50 55

13. The method of any one of clauses 9-12, wherein

the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

14. The method of any one of clauses 9-12, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator rises to the predetermined temperature and/or predetermined pressure.

15. The method of clause 14, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the trigger temperature and/or a second cooling fluid temperature at the trigger pressure.

16. The method of clause 14, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

17. A method for preventing freezing in an evaporator, the method comprising the steps of:

passing water through a liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger located within the space; passing a two-phase refrigerant through an evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase, the refrigerant having a refrigerant freezing temperature below a water freezing temperature of the water; passing the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when a first condition is met; passing the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the first condition is not met and a space temperature, of the space, is above a setpoint; monitoring a monitored temperature and/or monitored pressure of the refrigerant entering the evaporator; opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and closing the valve when a second condition is met.

18. The method of clause 17, wherein opening the valve causes the refrigerant, at the elevated temper-

ature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator, thereby raising the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator.

19. The method of clause 17 or 18, wherein the second condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

20. The method of clause 17 or 18, wherein the second condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure, and wherein the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

21. A system, comprising:

a heat exchanger configured to have a first cooling fluid and a second cooling fluid passed there through, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;  
a temperature sensor and/or pressure sensor in sensing communication with a fluid path by which the second cooling fluid enters the heat exchanger;  
a valve; and  
a controller;  
wherein the controller is configured to

monitor a monitored temperature and/or a monitored pressure of the second cooling fluid entering the heat exchanger;  
open the valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger;  
and  
close the valve when a condition is met.

22. The system of clause 21, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant.

23. The system of clause 21 or 22, wherein the trigger temperature and/or a second cooling fluid tempera-

ture at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger.

24. The system of any one of clauses 21-23, wherein the controller is further configured to open the valve and thereby cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger.

25. The system of any one of clauses 21-24, wherein the condition comprises a predetermined time, and wherein the controller is configured to close the valve once the predetermined time has elapsed following the valve opening.

26. The system of any one of clauses 21-24, wherein the condition comprises a predetermined temperature and/or predetermined pressure, and wherein the controller is configured to close the valve once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure.

27. The system of clause 26, wherein the predetermined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure.

28. The system of clause 26, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

29. The system of clause 21, wherein the heat exchanger comprises at least one of a liquid to air heat exchanger and an evaporator.

30. The system of clause 21, wherein the heat exchanger comprises a liquid to air heat exchanger configured to remove heat from a space.

31. The system of clause 21, wherein the heat exchanger comprises an evaporator, and wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator.

32. The system of clause 21, wherein the heat exchanger comprises an evaporator, and wherein the system is configured to raise the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and to cause the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower tem-

perature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator.

33. The system of clause 21, wherein

the heat exchanger comprises a liquid to air heat exchanger and an evaporator;  
the system is configured to pass water through the liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger being located within the space; and  
the system is configured to pass a two-phase refrigerant through the evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase.

34. The system of any one of clauses 21-33, wherein the system is configured to

pass the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when the condition is met;  
pass the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the condition is not met and a space temperature, of the space, is above a setpoint; and  
close the valve when a second condition is met.

35. The system of clause 34, wherein the second condition comprises a predetermined time, and wherein the controller is configured to close the valve once the predetermined time has elapsed following the valve opening.

36. The system of clause 34, wherein the second condition comprises a predetermined temperature and/or predetermined pressure, and wherein the controller is configured to close the valve once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure.

37. The system of clause 34, wherein the second condition comprises a predetermined temperature and/or refrigerant temperature at the predetermined pressure, and wherein the controller is configured to close the valve once the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

## Claims

1. A method for preventing freezing in a heat exchanger, the method comprising the steps of:

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passing a first cooling fluid and a second cooling fluid through a heat exchanger, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;  
monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger;  
opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; and  
closing the valve when a condition is met.

2. The method of claim 1, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant; or optionally

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wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger; or optionally  
wherein opening the valve causes the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; or optionally  
wherein the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

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3. The method of claim 1, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure.

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4. The method of claim 3, wherein the predetermined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure; or optionally  
wherein the predetermined temperature and/or a second cooling fluid temperature at the predeter-

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mined pressure is higher than the first freezing temperature.

5. A method for preventing freezing in an evaporator, the method comprising the steps of:

passing a first cooling fluid through a liquid to air heat exchanger to remove heat from a space, the first cooling fluid having a first freezing temperature;

passing a second cooling fluid through an evaporator, thereby cooling the first cooling fluid as at least a portion of the second cooling fluid changes from liquid phase to gaseous phase, the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;

monitoring a monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator;

opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and

closing the valve when a condition is met.

6. The method of claim 5, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant; or optionally

wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator; or optionally

further including raising the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and wherein opening the valve causes the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; or optionally

wherein the condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed following the valve opening.

7. The method of claim 5, wherein the condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once

the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator rises to the predetermined temperature and/or predetermined pressure.

8. The method of claim 7, wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the trigger temperature and/or a second cooling fluid temperature at the trigger pressure; or optionally wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

9. A method for preventing freezing in an evaporator, the method comprising the steps of:

passing water through a liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger located within the space; passing a two-phase refrigerant through an evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase, the refrigerant having a refrigerant freezing temperature below a water freezing temperature of the water;

passing the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when a first condition is met;

passing the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the first condition is not met and a space temperature, of the space, is above a setpoint; monitoring a monitored temperature and/or monitored pressure of the refrigerant entering the evaporator;

opening a valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator; and

closing the valve when a second condition is met.

10. The method of claim 9, wherein opening the valve causes the refrigerant, at the elevated temperature and/or elevated pressure, to mix with the refrigerant upstream of the evaporator, thereby raising the monitored temperature and/or the monitored pressure of the refrigerant entering the evaporator; or optionally

wherein the second condition comprises a predetermined time, such that the valve is closed once the predetermined time has elapsed fol-

lowing the valve opening; or optionally wherein the second condition comprises a predetermined temperature and/or predetermined pressure, such that the valve is closed once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure, and wherein the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure.

**11. A system, comprising:**

a heat exchanger configured to have a first cooling fluid and a second cooling fluid passed there through, the first cooling fluid having a first freezing temperature and the second cooling fluid having a second freezing temperature, wherein the second freezing temperature is lower than the first freezing temperature;

a temperature sensor and/or pressure sensor in sensing communication with a fluid path by which the second cooling fluid enters the heat exchanger;

a valve; and

a controller;

wherein the controller is configured to

monitor a monitored temperature and/or a monitored pressure of the second cooling fluid entering the heat exchanger;

open the valve when the monitored temperature and/or monitored pressure is below a trigger temperature and/or trigger pressure, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger; and

close the valve when a condition is met.

**12. The system of claim 11, wherein the first cooling fluid comprises water and the second cooling fluid comprises a two-phase refrigerant; or optionally**

wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the heat exchanger; or optionally

wherein the controller is further configured to open the valve and thereby cause the second cooling fluid, in gaseous phase, to mix with the second cooling fluid, in liquid phase, upstream of the heat exchanger; or optionally wherein the condition comprises a predetermined time, and

wherein the controller is configured to close the valve once the predetermined time has elapsed following the valve opening; or optionally wherein the heat exchanger comprises at least one of a liquid to air heat exchanger and an evaporator; or optionally

wherein the heat exchanger comprises a liquid to air heat exchanger configured to remove heat from a space; or optionally

wherein the heat exchanger comprises an evaporator, and wherein the trigger temperature and/or a second cooling fluid temperature at the trigger pressure is above a point at which the first cooling fluid would freeze as it moves into the evaporator; or optionally

wherein the heat exchanger comprises an evaporator, and wherein the system is configured to raise the temperature and/or pressure of at least a portion of the second cooling fluid to an elevated temperature and/or elevated pressure, and to cause the second cooling fluid, at the elevated temperature and/or elevated pressure, to mix with the second cooling fluid, at a lower temperature and/or lower pressure, upstream of the evaporator, thereby raising the monitored temperature and/or monitored pressure of the second cooling fluid entering the evaporator.

**13. The system of claim 11, wherein the condition comprises a predetermined temperature and/or predetermined pressure, and wherein the controller is configured to close the valve once the monitored temperature and/or monitored pressure of the second cooling fluid entering the heat exchanger rises to the predetermined temperature and/or predetermined pressure; or optionally**

wherein the predetermined temperature and/or predetermined pressure is higher than the trigger temperature and/or trigger pressure.

wherein the predetermined temperature and/or a second cooling fluid temperature at the predetermined pressure is higher than the first freezing temperature.

**14. The system of claim 11, wherein**

the heat exchanger comprises a liquid to air heat exchanger and an evaporator;

the system is configured to pass water through the liquid to air heat exchanger to remove heat from a space, the liquid to air heat exchanger being located within the space; and

the system is configured to pass a two-phase refrigerant through the evaporator, thereby cooling the water as at least a portion of the refrigerant changes from liquid phase to gaseous phase.

15. The system of claim 14, wherein the system is configured to

pass the refrigerant through a pump, thereby increasing a refrigerant temperature of the refrigerant to an elevated temperature, when the condition is met; 5

pass the refrigerant through a compressor, thereby increasing the refrigerant temperature of the refrigerant to the elevated temperature, when the condition is not met and a space temperature, of the space, is above a setpoint; and 10

close the valve when a second condition is met; or optionally

wherein the second condition comprises a predetermined time, and wherein the controller is configured to close the valve once the predetermined time has elapsed following the valve opening; or optionally 15

wherein the second condition comprises a predetermined temperature and/or predetermined pressure, and wherein the controller is configured to close the valve once the monitored temperature and/or monitored pressure of the refrigerant entering the evaporator rises to the predetermined temperature and/or predetermined pressure; or optionally 20

wherein the second condition comprises a predetermined temperature and/or refrigerant temperature at the predetermined pressure, and wherein the controller is configured to close the valve once the predetermined temperature and/or refrigerant temperature at the predetermined pressure is higher than the water freezing temperature and the trigger temperature and/or refrigerant temperature at the trigger pressure. 25 30 35

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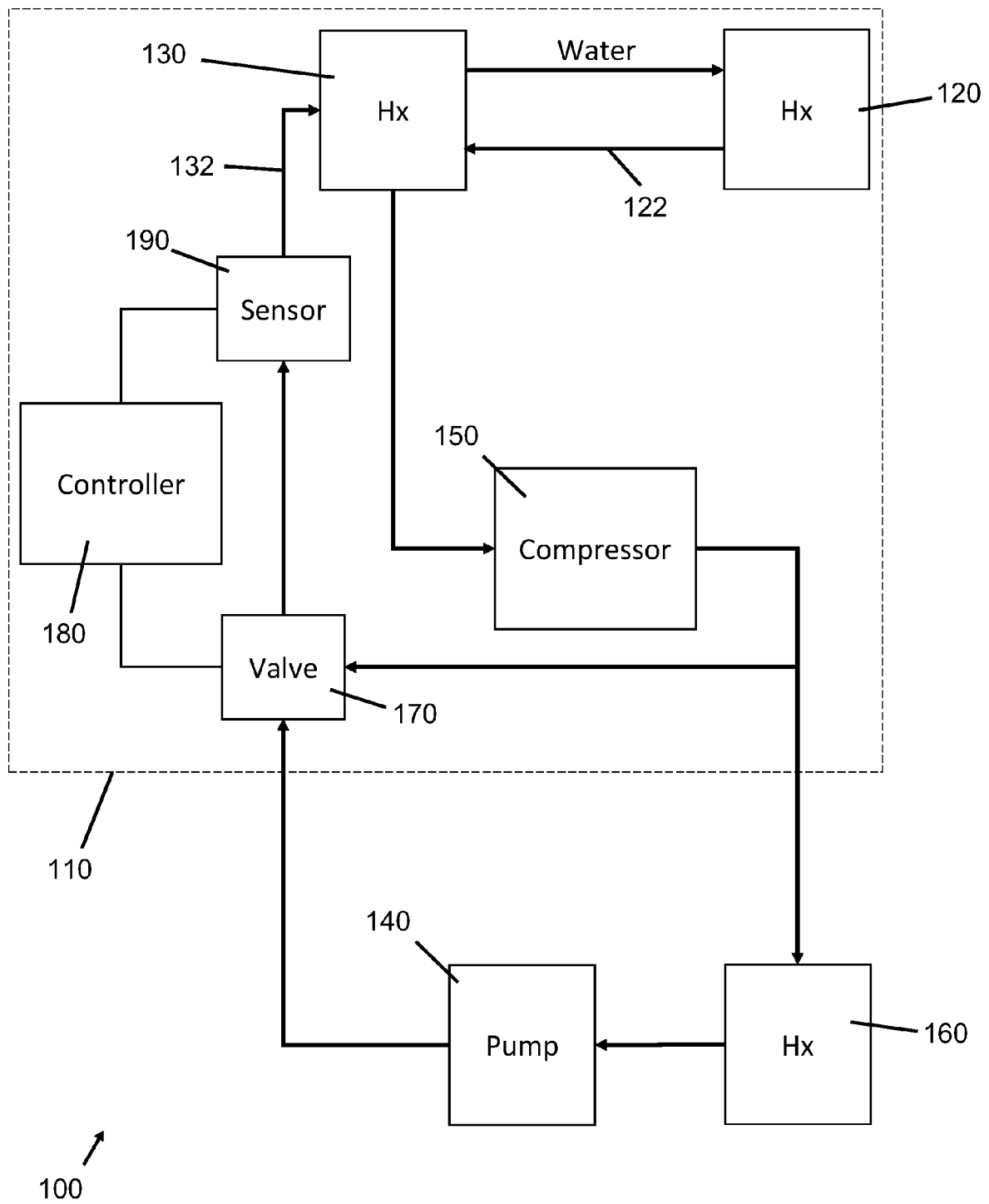


FIG. 1A

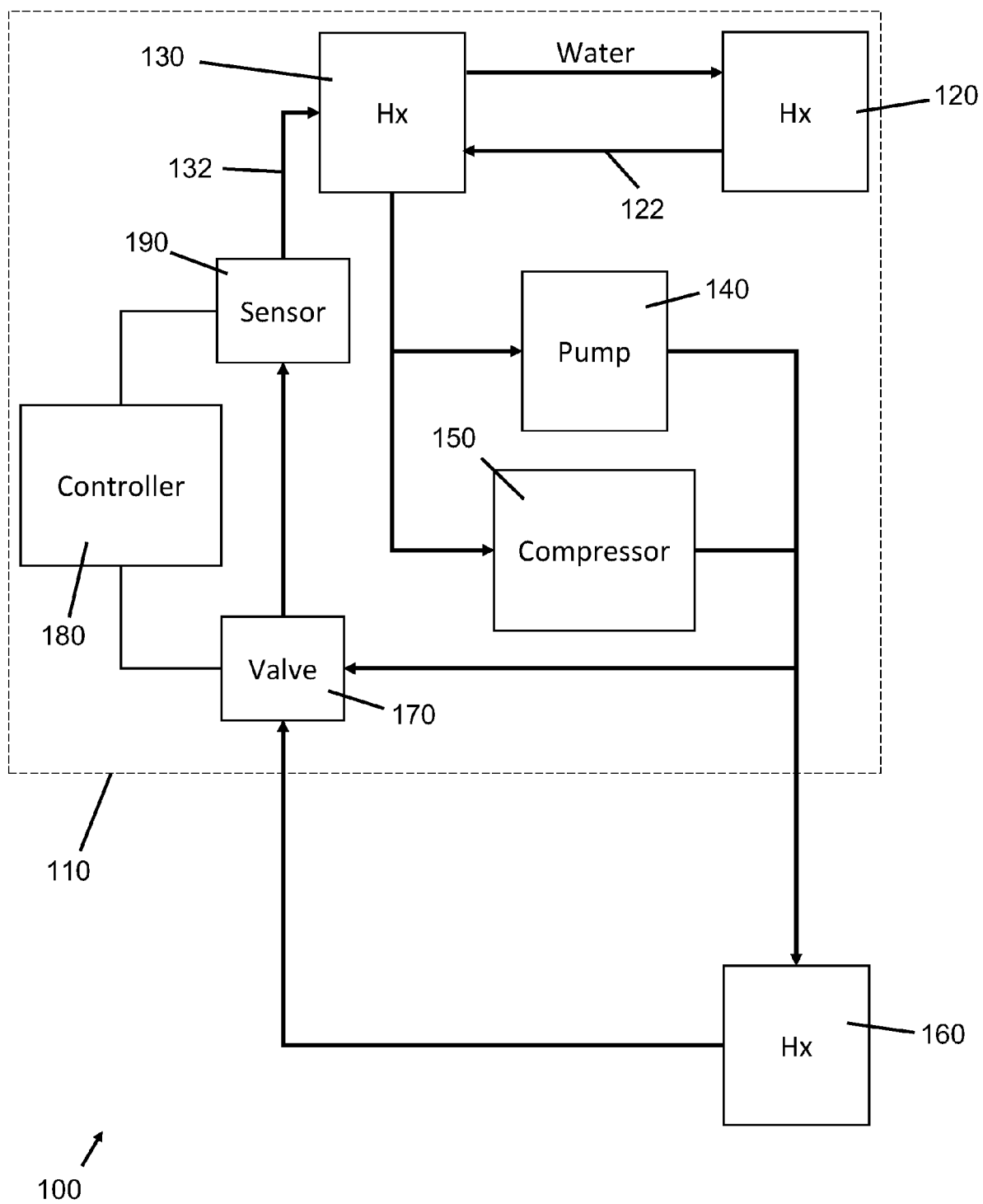


FIG. 1B



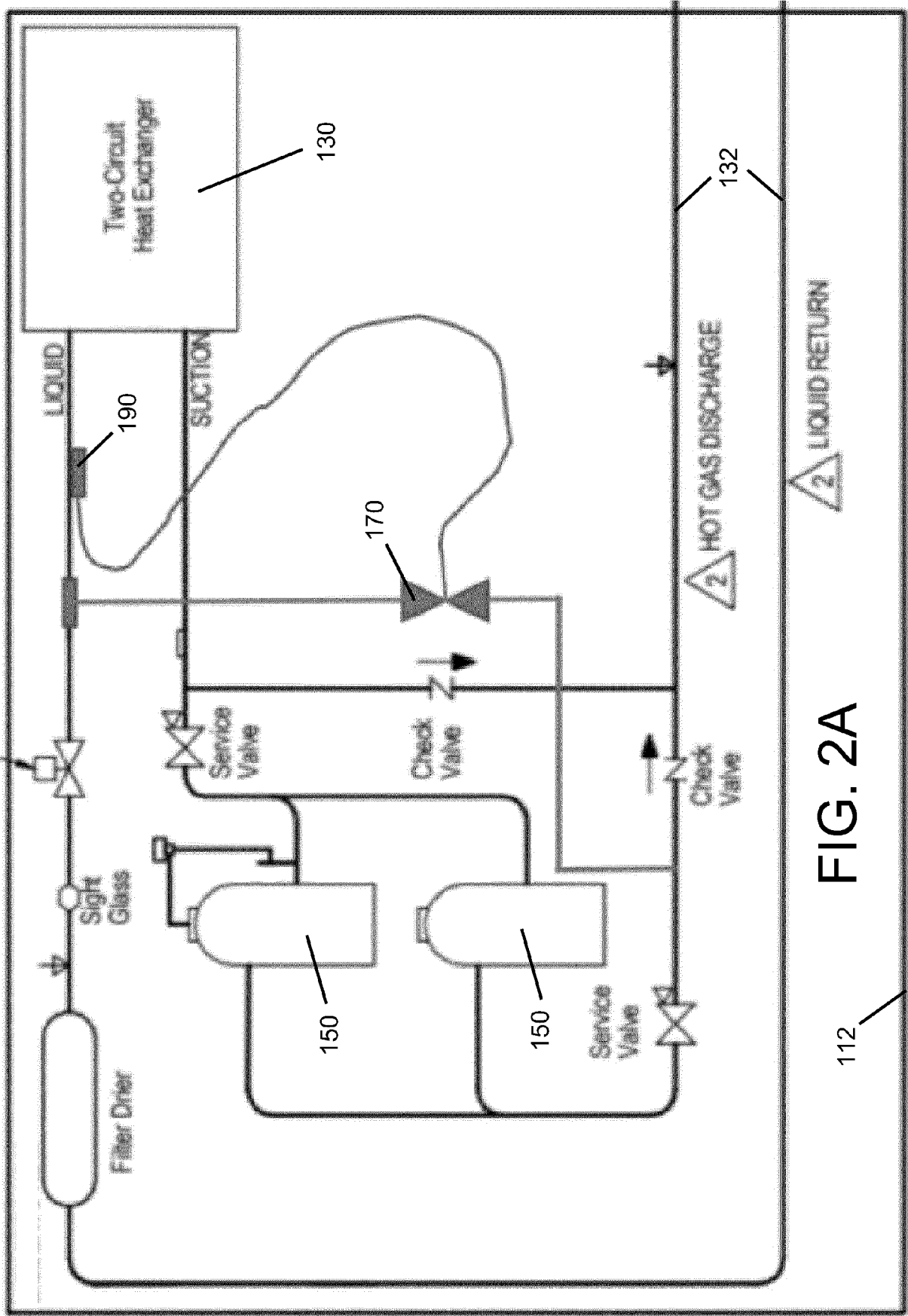


FIG. 2A

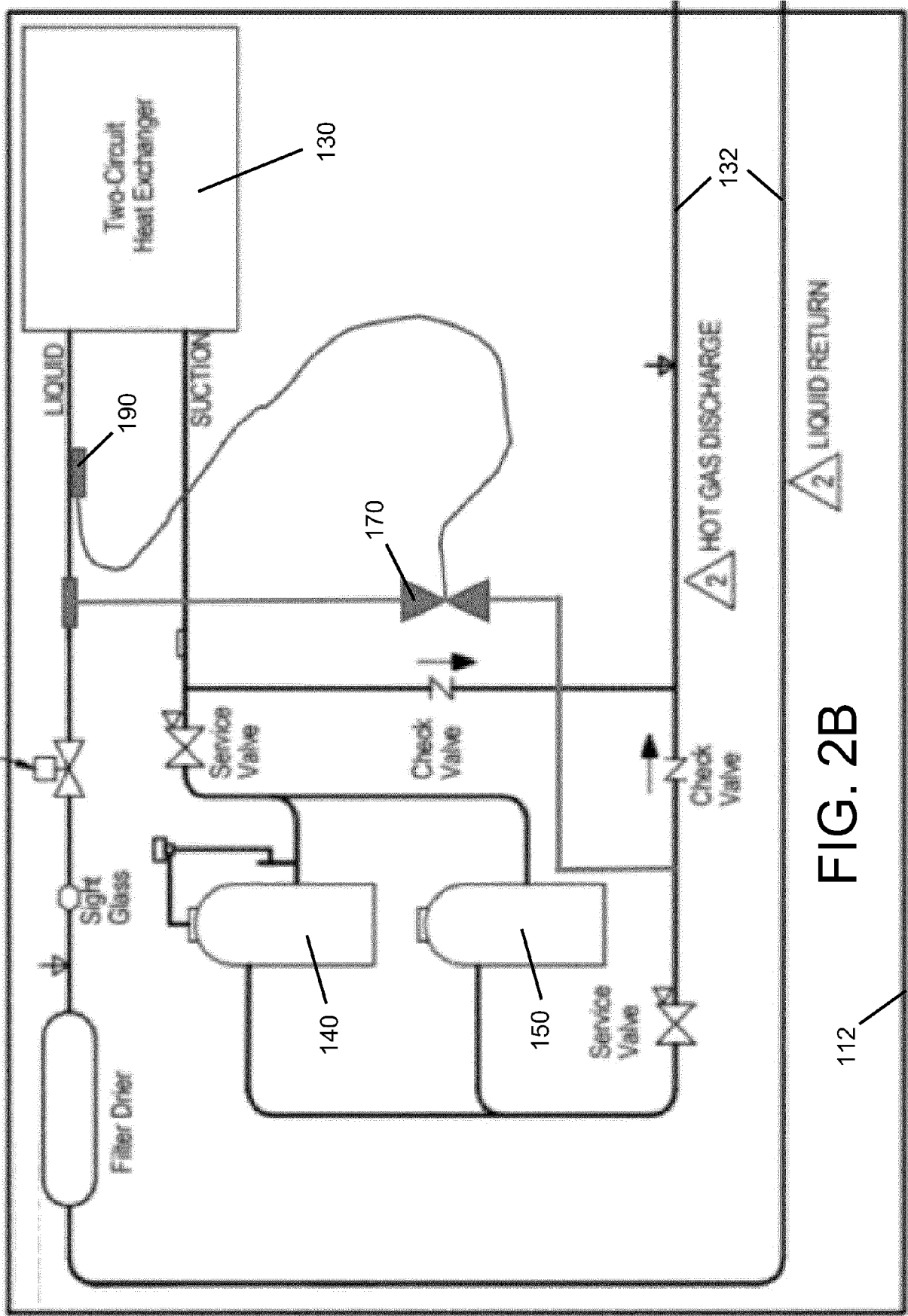


FIG. 2B

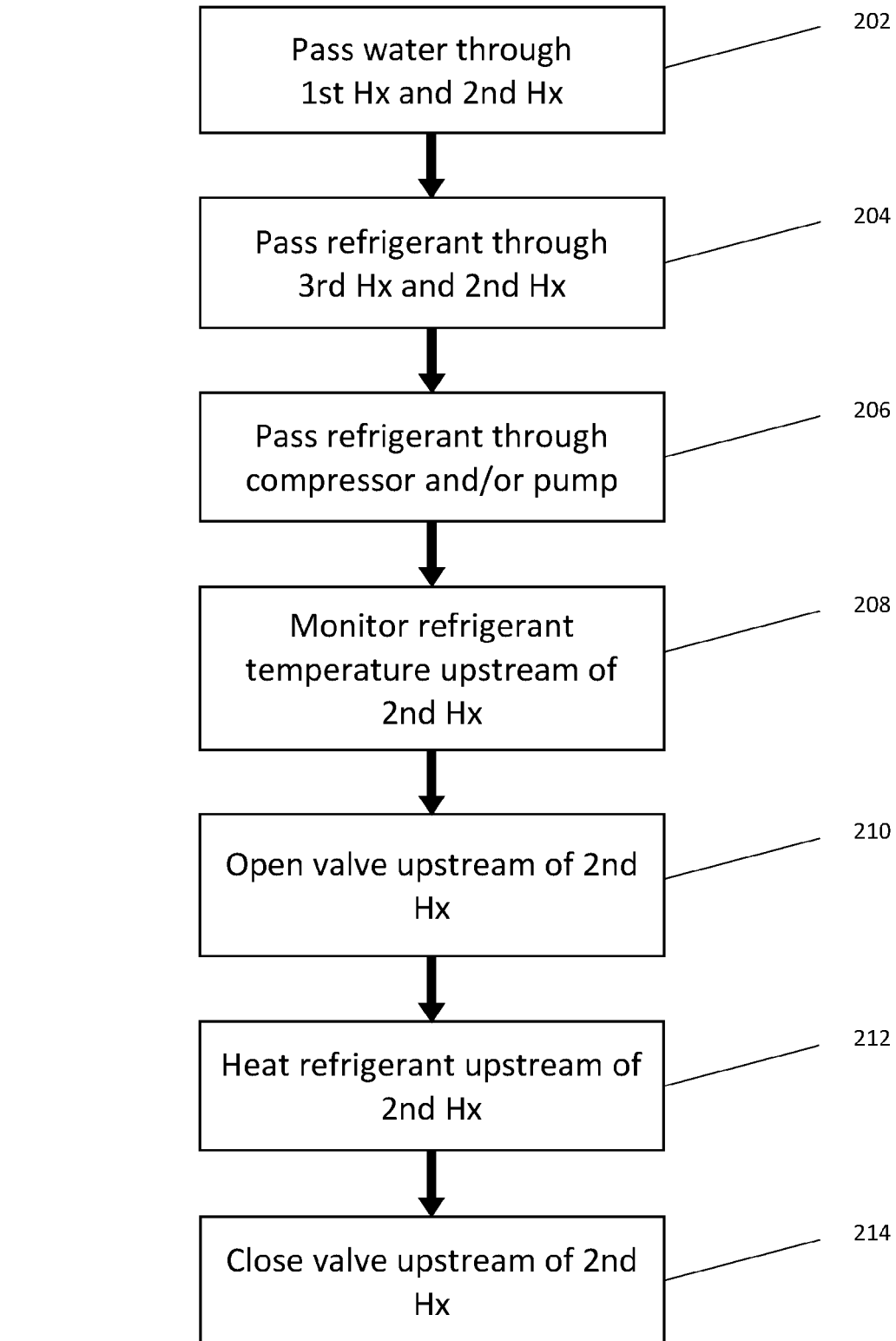


FIG. 3

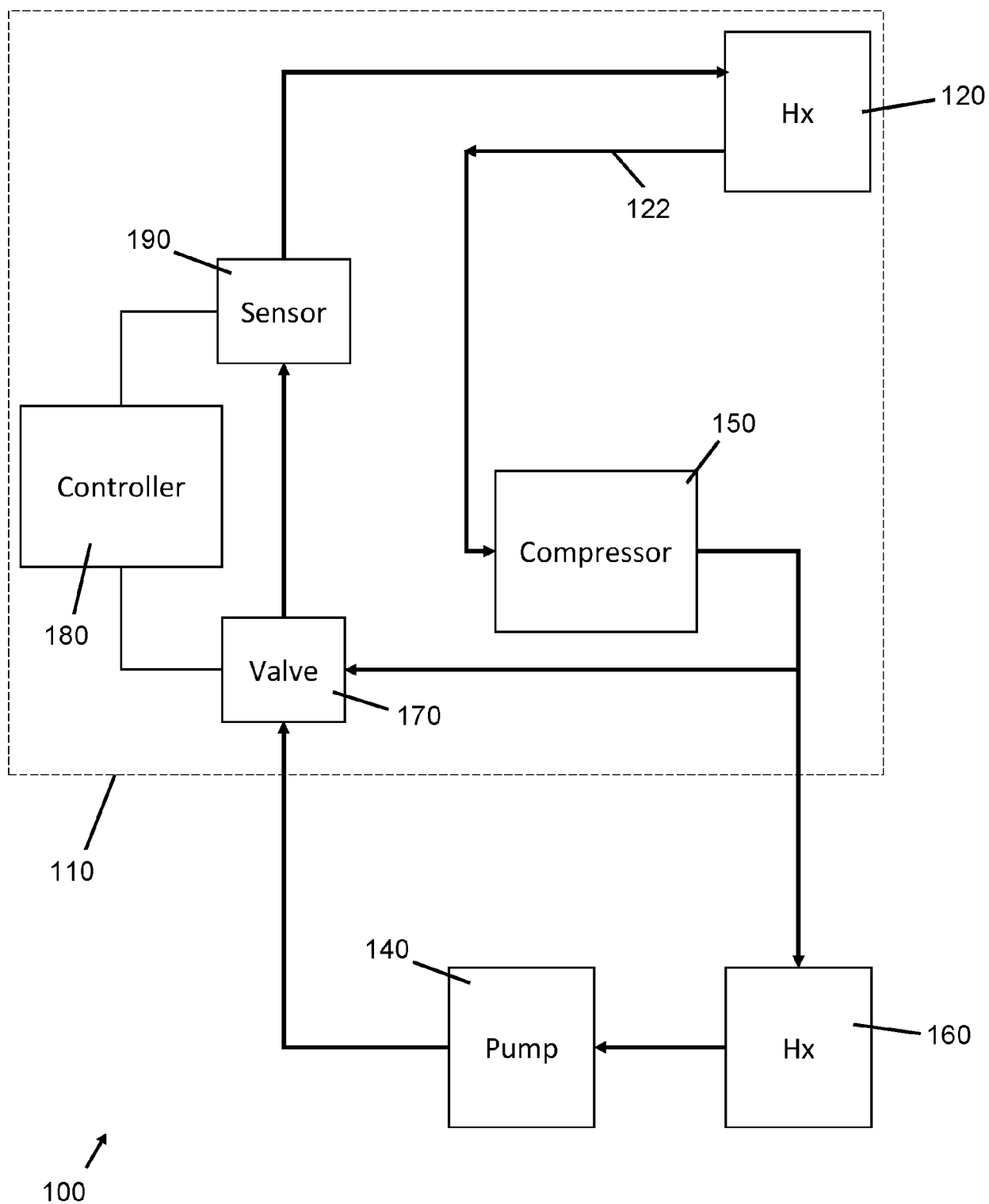


FIG. 4A

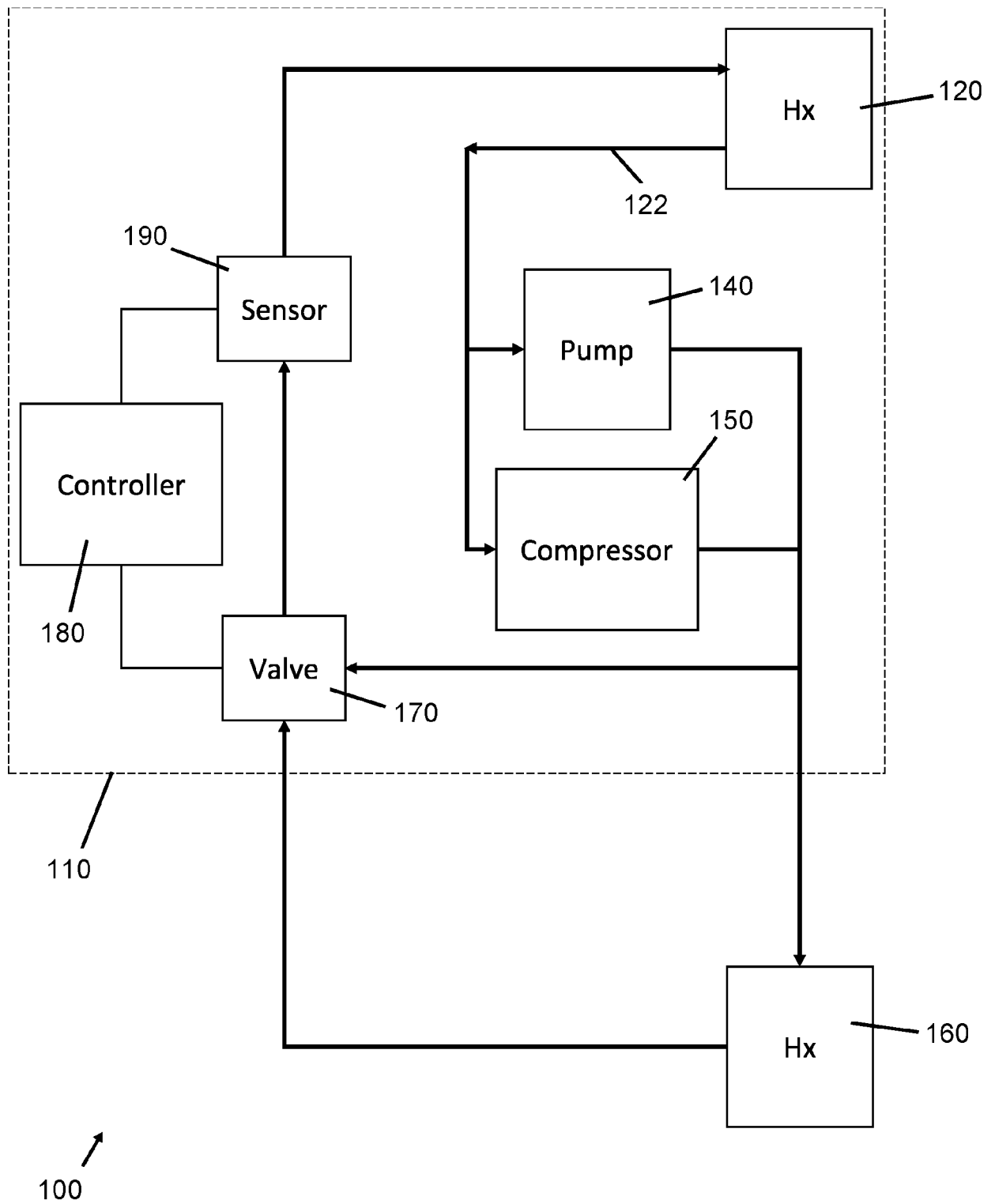


FIG. 4B

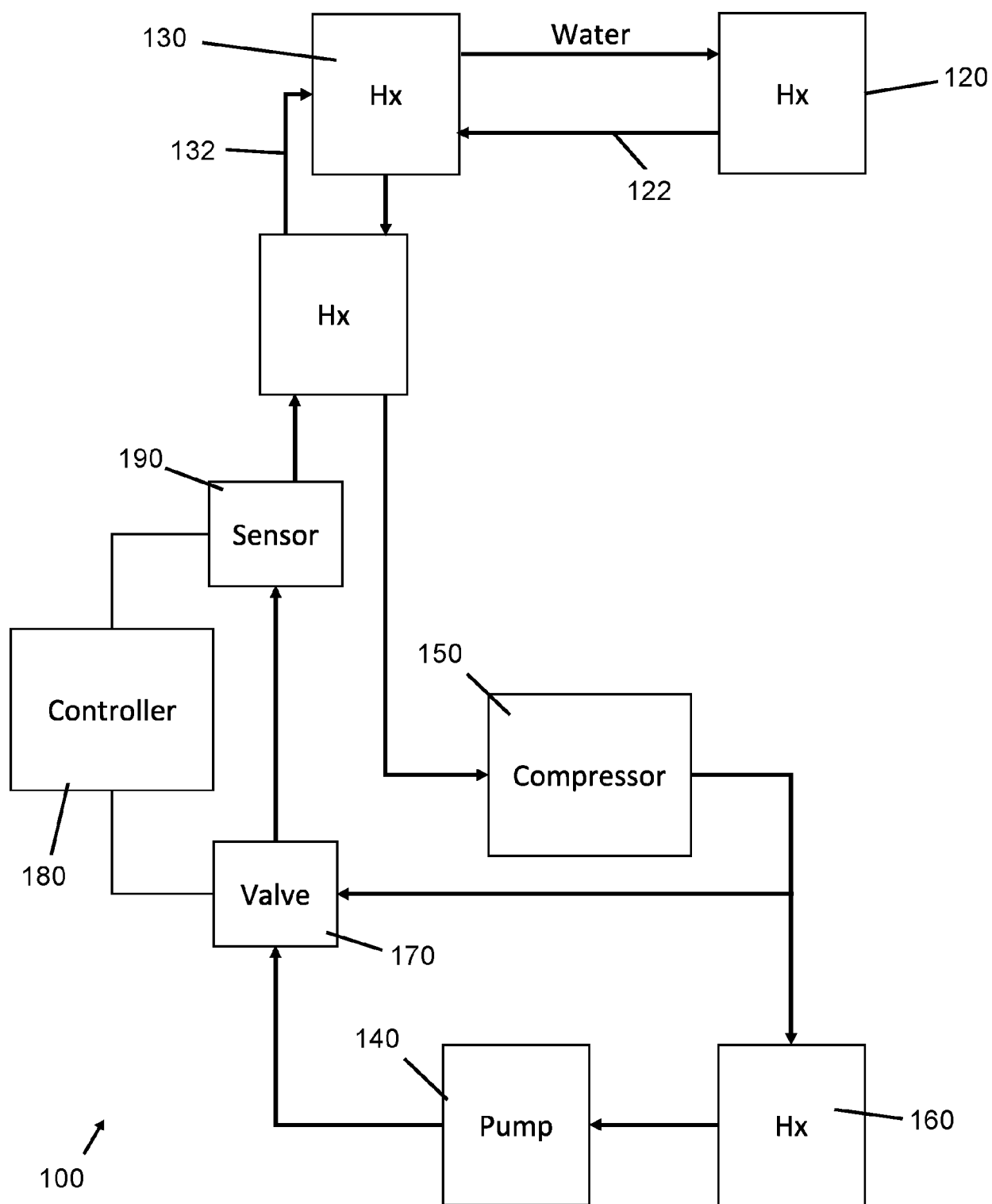


FIG. 5A

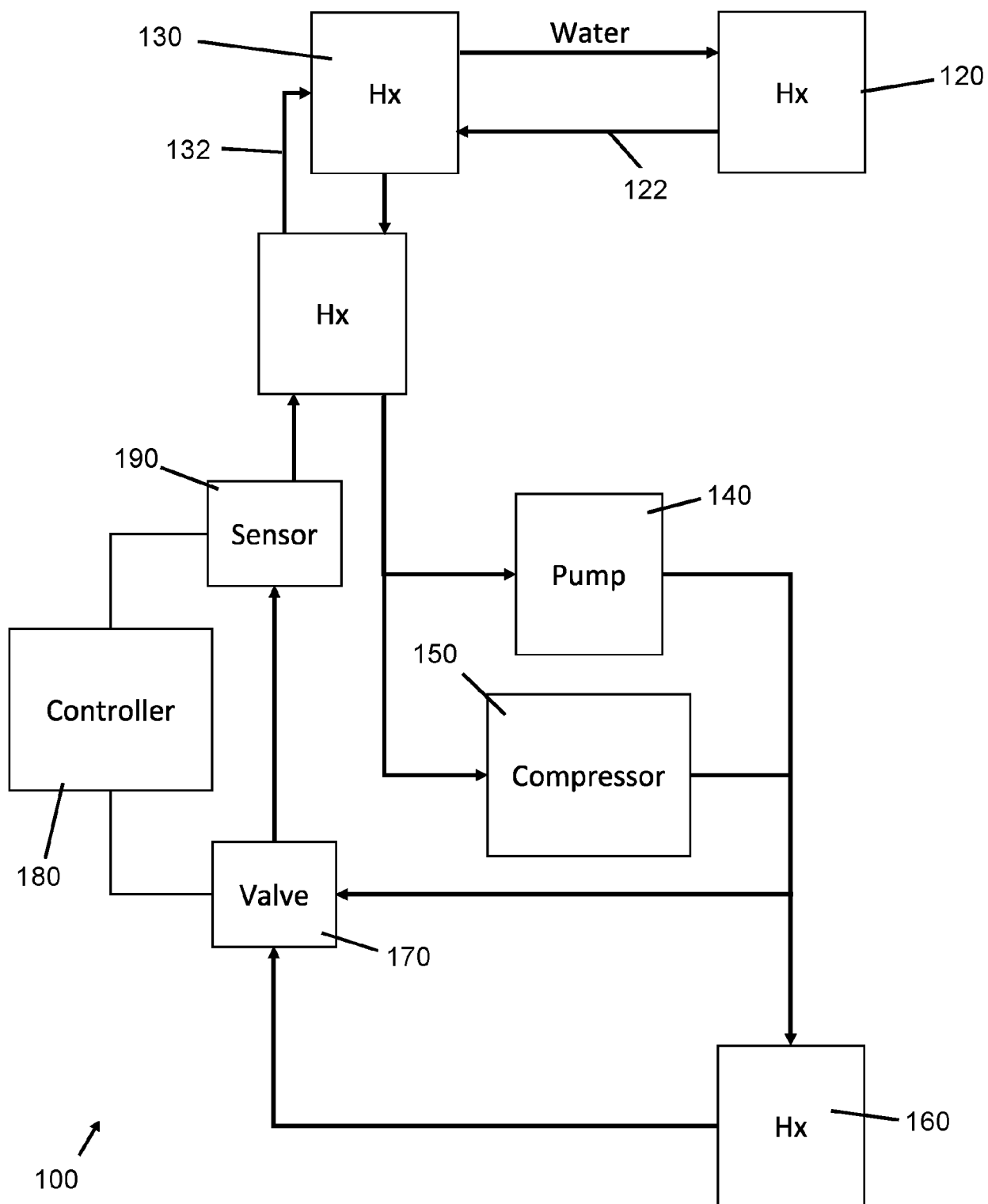


FIG. 5B

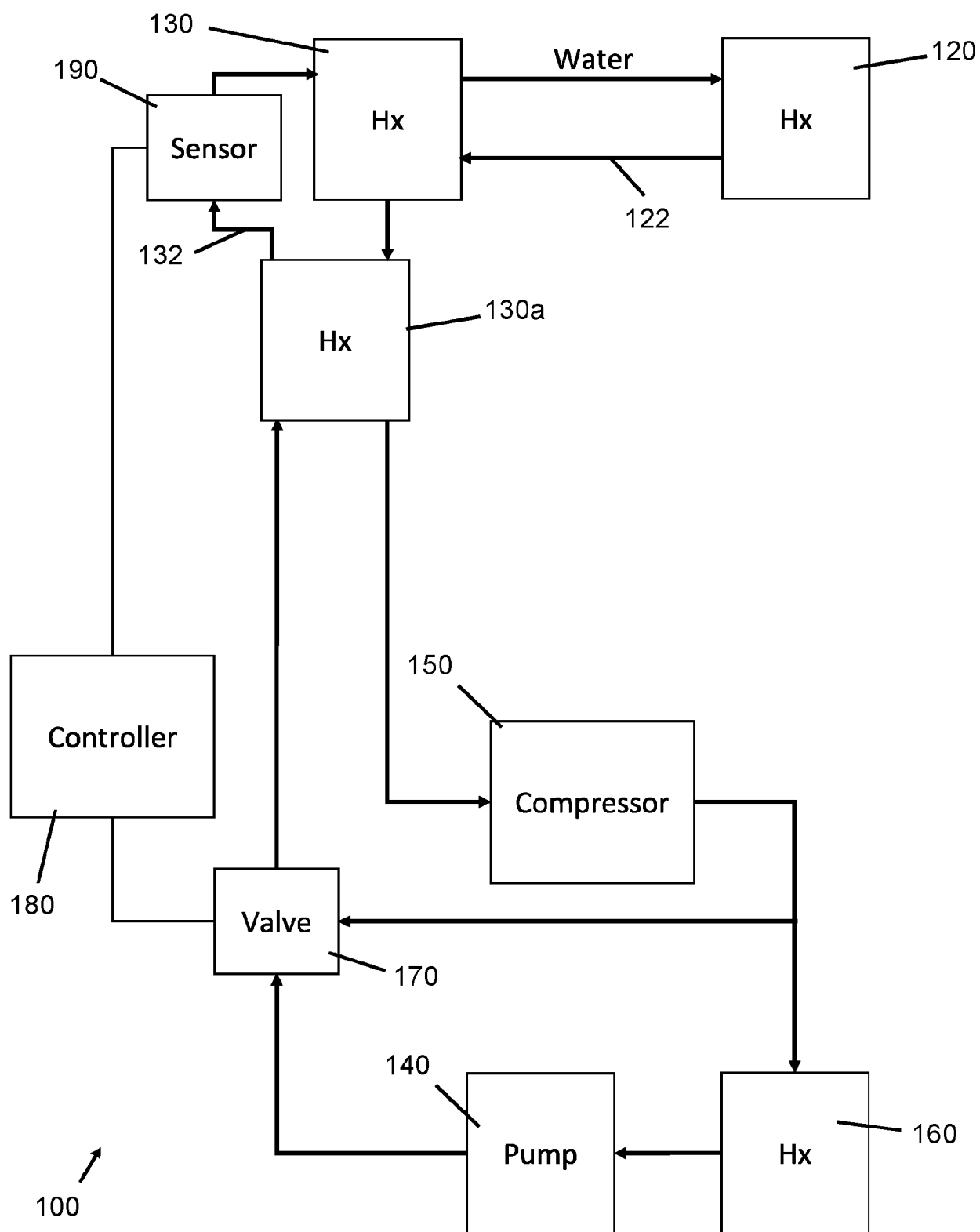


FIG. 6A



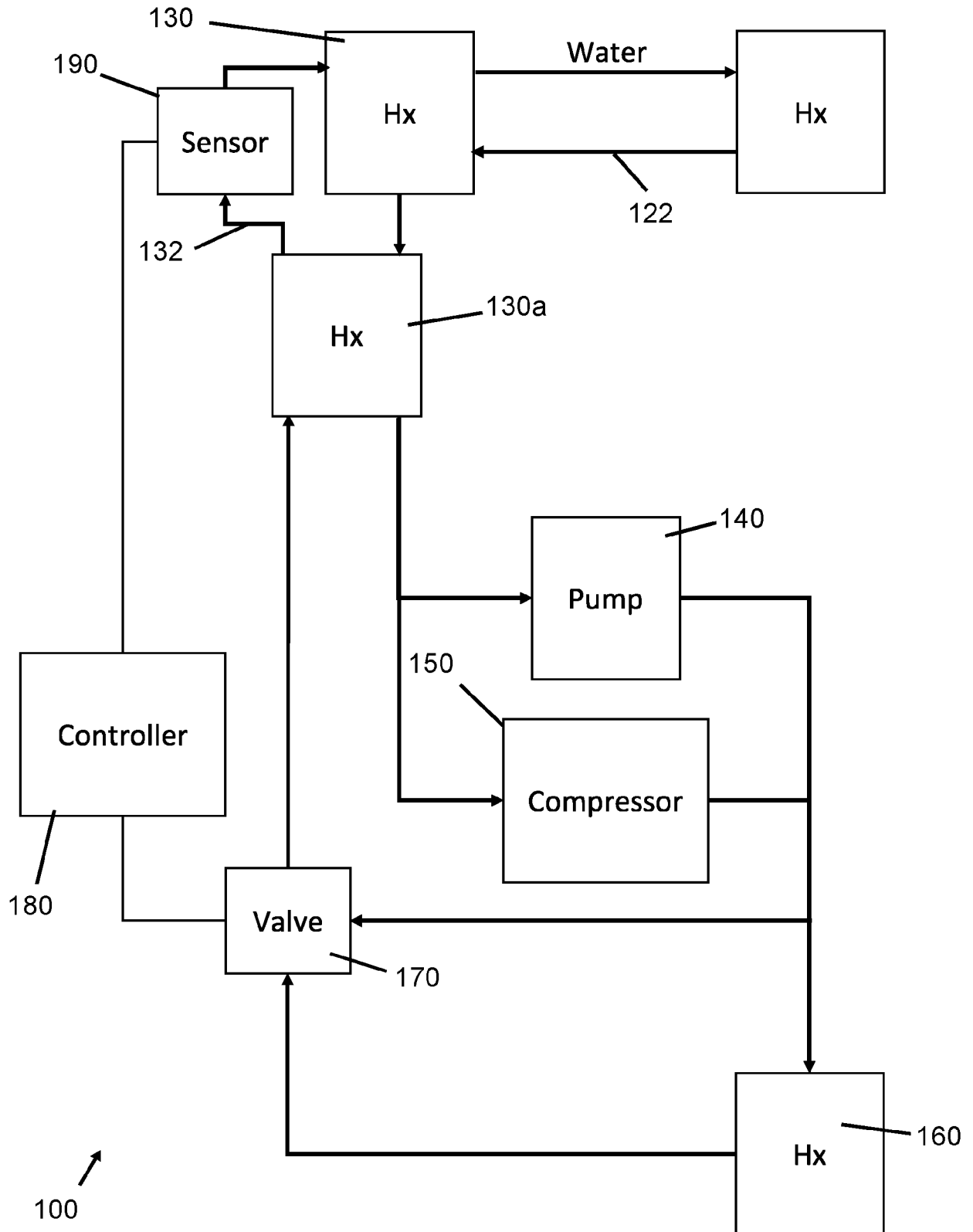


FIG. 6B

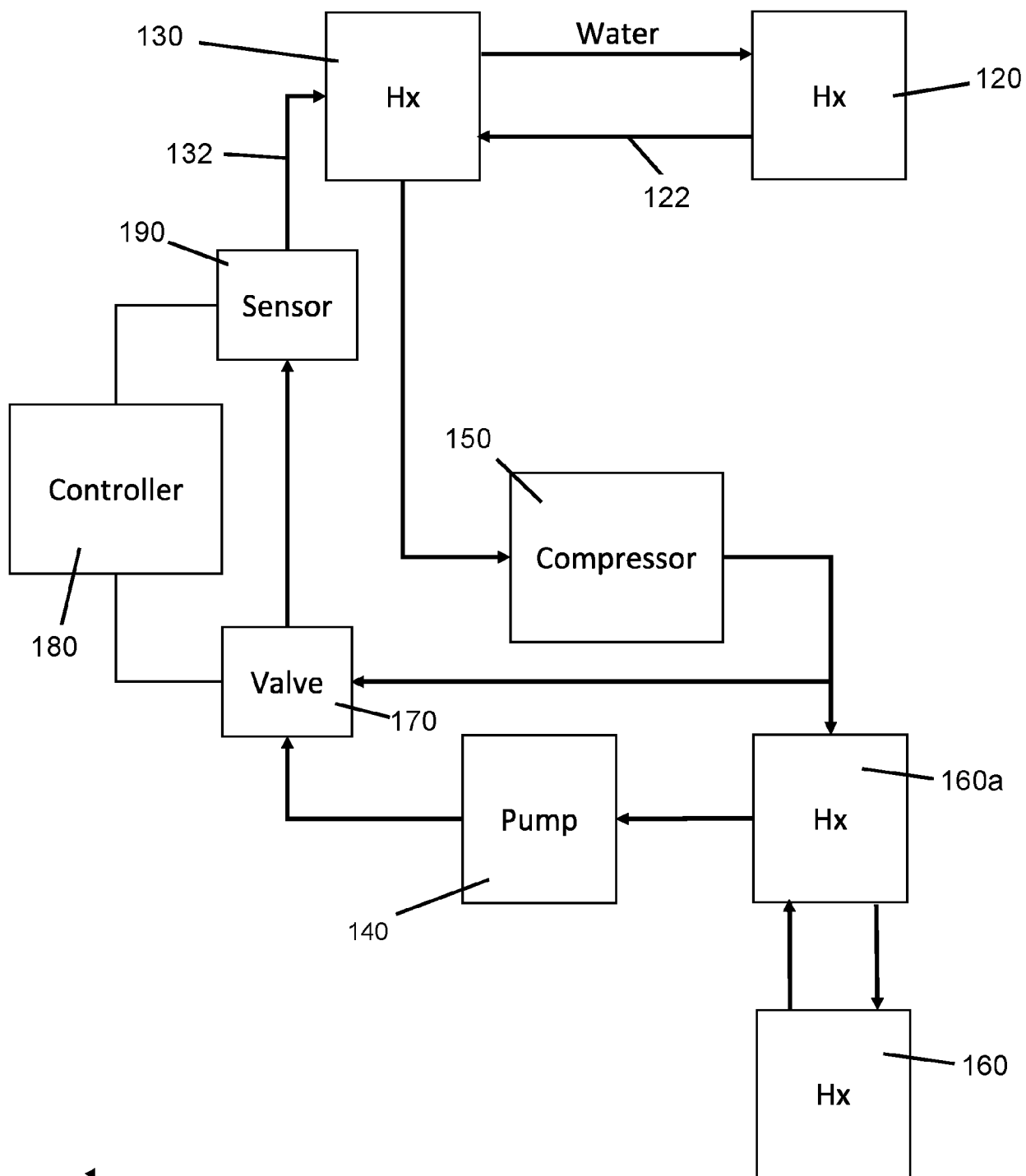


FIG. 7A

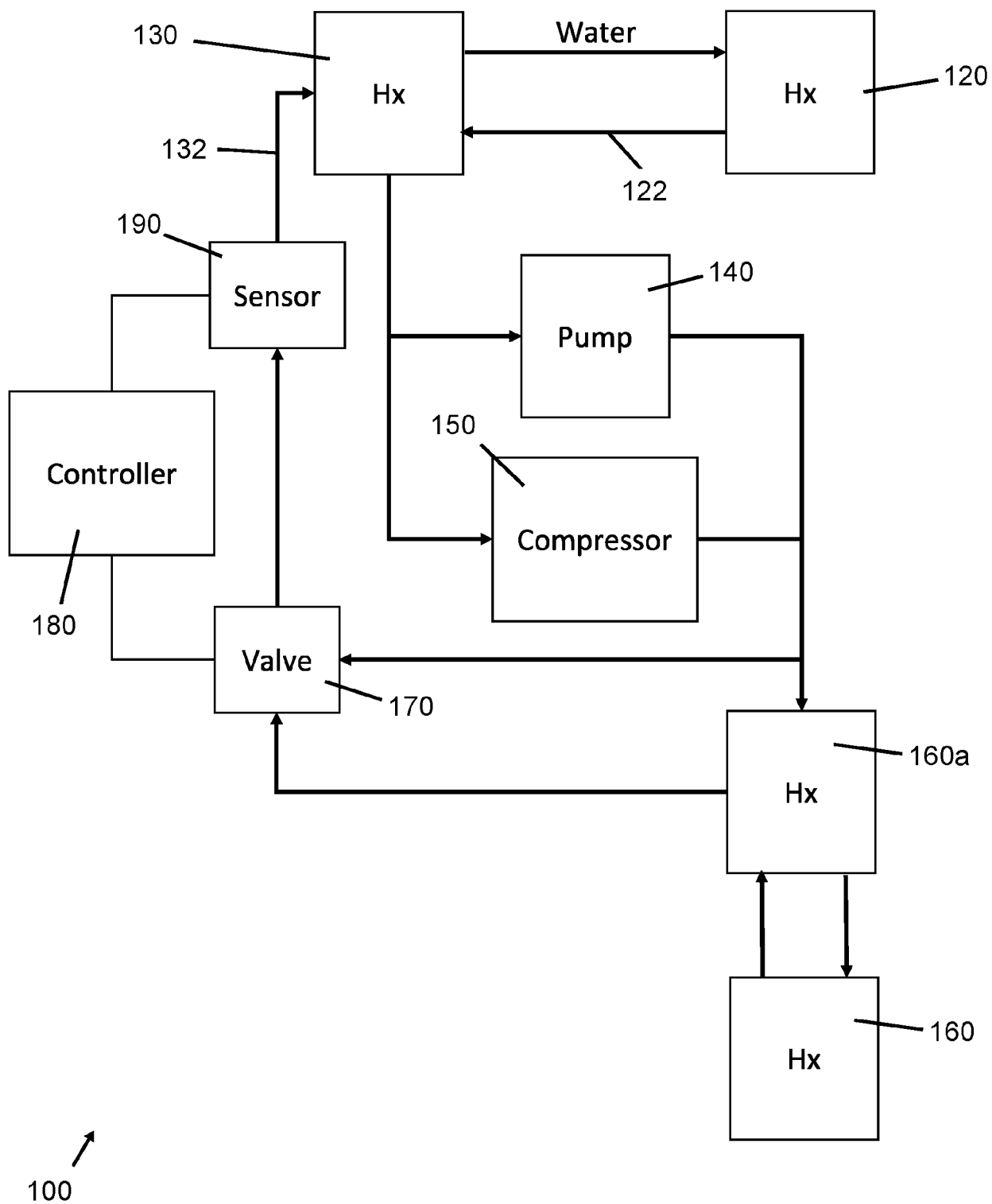


FIG. 7B

**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

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