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(72) Inventors:
• **KEMPER, Daniel S**
Davidson, North Carolina, 28036 (US)
• **KEYS, Daryl**
Davidson, North Carolina, 28036 (US)
• **GURU, Bhavana Depuru**
Davidson, North Carolina, 28036 (US)
• **GARBERS, Ben R**
Davidson, North Carolina, 28036 (US)

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(71) Applicant: **Trane International Inc.**
Davidson, NC 28036 (US)

(74) Representative: **Haseltine Lake Kempner LLP**
One Portwall Square
Portwall Lane
Bristol BS1 6BH (GB)

(54) **SELECTIVELY OPERABLE HEATING AND COOLING SYSTEM AND METHOD OF OPERATING THEREOF**

(57) A heating and cooling system including a first heat transfer circuit that includes a first heat exchanger and a second heat exchanger; a second heat transfer circuit that includes a third heat exchanger and a fourth heat exchanger; a coolant loop; and a controller. The controller selectively operates the heating and cooling system in: a heating mode, in which the heating and cooling system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a

cascaded operation to heat a first process fluid via heat transfer with the first heat exchanger, and a cooling mode, in which the heating and cooling system is configured to operate the first heat transfer circuit and the second heat transfer circuit in parallel operation to both provide cooling to a second process fluid via heat transfer with the fourth heat exchanger and the second heat exchanger.

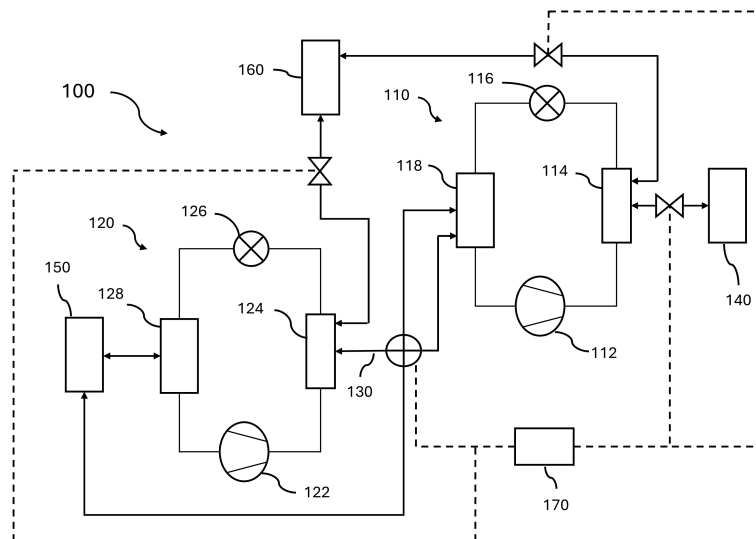


FIG. 1

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Description

FIELD

[0001] This disclosure relates generally to heating and cooling systems that are selectively operable in a cascaded operation or a parallel operation. More specifically, the disclosure relates to a heating, ventilation, air conditioning, and refrigeration (HVACR) system to condition a space and methods for operating heat transfer circuits in cascaded operation or parallel operation.

BACKGROUND

[0002] A heating and cooling system can be used to heat and cool one or more process fluids for a variety of applications. For example, the heating and cooling system can be used to heat a heating load and/or cool a cooling load for industrial processes, such as, heating and/or cooling gas or liquid flows to maintain reaction temperatures or temperature setpoints, cooling industrial waste, providing heat to replace gas boilers, providing refrigeration, or the like. The heating and cooling system can also be used to condition a space, for example, an HVACR system can be used to provide heating and/or provide cooling for the conditioned space. In some cases, the HVACR system can be a hydronic system that includes a heat transfer circuit to provide a liquid process fluid, for example, water, a brine solution, or a glycol solution, as a heat-transfer medium to condition a space in a building or occupied space. The HVACR system often includes a heat transfer circuit system that can include one or more compressors, expanders, a condenser, an evaporator, fans, filters, dampers, circulation pumps, and various other equipment, in which the compressor(s), the condenser, the expander, and the evaporator are fluidly connected.

SUMMARY

[0003] This disclosure relates generally to heating and cooling systems that are selectively operable in a cascaded operation or a parallel operation. More specifically, the disclosure relates to a heating, ventilation, air conditioning, and refrigeration (HVACR) system to condition a space and methods for operating heat transfer circuits in cascaded operation or parallel operation.

[0004] The HVACR system can be a hydronic system in which thermal energy in a heat transfer circuit is exchanged with process fluid(s), e.g., ethylene glycol, propylene glycol, water, a brine solution, or the like, which is used to condition a space. For example, when providing heating to the conditioned space, the heat generated from the compression of a working fluid in the heat transfer circuit can be used to reject thermal energy into the process fluid that is circulated in a heating water circuit of the hydronic system to condition the space. Similarly, for providing cooling to the conditioned space,

the HVACR system can extract heat from a second process fluid that is circulated in a chilled water circuit of the hydronic system to cool the process fluid to condition the space.

[0005] In an embodiment, a heating and cooling system is provided. The heating and cooling system includes a first heat transfer circuit, in which the first heat transfer circuit includes a first compressor, a first heat exchanger, and a second heat exchanger; a second heat transfer circuit, in which the second heat transfer circuit includes a second compressor, a third heat exchanger, and a fourth heat exchanger; a coolant loop including a coolant, the coolant loop configured to thermally communicate thermal energy between the second heat exchanger of the first heat transfer circuit and the third heat exchanger of the second heat transfer circuit; and a controller. The controller is configured to selectively operate the heating and cooling system in: a heating mode, in which the heating and cooling system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat a first process fluid via heat transfer with the first heat exchanger, in which the coolant loop is configured to thermally communicate the thermal energy between the third heat exchanger of the second heat transfer circuit and the second heat exchanger of the first heat transfer circuit, and a cooling mode, in which the heating and cooling system is configured to operate the first heat transfer circuit and the second heat transfer circuit in parallel operation to both provide cooling to a second process fluid via heat transfer with the fourth heat exchanger and the second heat exchanger.

[0006] In another embodiment, a heating, ventilation, air conditioning, and refrigeration (HVACR) system is provided. The HVACR system includes a hydronic system including a first process fluid and a second process fluid for conditioning one or more spaces; a first heat transfer circuit, in which the first heat transfer circuit comprises a first compressor, a first heat exchanger, and a first chiller, in which the first heat exchanger is configured to selectively exchange heat with the first process fluid, and the first process fluid further exchanges heat with a heating load in the one or more spaces, or exchanges heat with cooling fluid; a second heat transfer circuit, in which the second heat transfer circuit includes a second compressor, a cascade heat exchanger, and a second chiller; in which the second chiller is configured to exchange heat between the second process fluid, in which the second process fluid further exchanges heat with a cooling load; a coolant loop including a coolant, the coolant loop configured to thermally communicate thermal energy between the first chiller of the first heat transfer circuit and the cascade heat exchanger of second heat transfer circuit; and a controller. The controller is configured to selectively operate the HVACR system in: a heating mode, in which the HVACR system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat the first process fluid via heat

transfer with the first heat exchanger, in which the coolant loop is configured to thermally communicate the thermal energy between the cascade heat exchanger of the second heat transfer circuit and the first chiller of the first heat transfer circuit, and a cooling mode, wherein the HVACR system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a parallel operation to provide cooling to the second process fluid via heat transfer with the first chiller and the second chiller, in which the first heat exchanger is configured to exchange heat with the cooling fluid.

[0007] In yet another embodiment, a method for heating and/or cooling a system is provided. The system includes a first heat transfer circuit, in which the first heat transfer circuit includes a first compressor, a first heat exchanger, and a second heat exchanger; a second heat transfer circuit, in which the second heat transfer circuit includes a second compressor, a third heat exchanger, and a fourth heat exchanger; a coolant loop including a coolant; and a controller. The method includes selectively operating the system in either one of the following modes: operating the system in a heating mode by operating the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat a first process fluid via heat transfer with the first heat exchanger, in which the operating the system in the heating mode includes thermally communicating, via the coolant loop, thermal energy from the third heat exchanger of the second heat transfer circuit and the second heat exchanger of the first heat transfer circuit; or operating the system in a cooling mode by operating the first heat transfer circuit and the second heat transfer circuit in parallel operation to provide cooling to a second process fluid, in which the operating the system in the cooling mode includes providing the second process fluid to the fourth heat exchanger and the second heat exchanger.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] References are made to the accompanying drawings that form a part of this disclosure and which illustrate the embodiments in which systems and methods described in this specification can be practiced.

FIG. 1 illustrates a schematic diagram of a heating and/or cooling system, according to an embodiment.

FIG. 2 illustrates a schematic diagram of a HVACR system, according to another embodiment.

FIG. 3 illustrates a schematic diagram of a HVACR system operating in a heating mode, according to an embodiment.

FIG. 4 illustrates a schematic diagram of a HVACR system operating in a cooling mode, according to an embodiment.

FIG. 5 illustrates a schematic diagram of a HVACR system, according to yet another embodiment.

FIG. 6 is a flowchart of a control method of heating and/or cooling a system, according to an embodiment.

[0009] Like reference numbers represent like parts throughout.

DETAILED DESCRIPTION

[0010] In the following detailed description, reference is made to the accompanying drawings, which form a part of the description. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Furthermore, unless otherwise noted, the description of each successive drawing may reference features from one or more of the previous drawings to provide clearer context and a more substantive explanation of the current example embodiment. Still, the example embodiments described in the detailed description, drawings, and claims are not intended to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the drawings, may be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0011] Particular embodiments of the present disclosure are described herein with reference to the accompanying drawings; however, it is to be understood that the disclosed embodiments are merely examples of the disclosure, which may be embodied in various forms. Well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present disclosure in virtually any appropriately detailed structure. In this description, as well as in the drawings, like-referenced numbers represent elements that may perform the same, similar, or equivalent functions.

[0012] Additionally, the present disclosure may be described herein in terms of functional block components and various processing steps. It should be appreciated that such functional blocks may be realized by any number of hardware and/or software components configured to perform the specified functions.

[0013] The scope of the disclosure should be determined by the appended claims and their legal equivalents, rather than by the examples given herein. For example, the steps recited in any method claims may be executed in any order and are not limited to the order

presented in the claims. Moreover, no element is essential to the practice of the disclosure unless specifically described herein as "critical" or "essential."

[0014] A heating and cooling system can be used to heat a heating load and/or cool a cooling load for a variety of applications. In some embodiments, the heating and cooling system can be used to heat a heating load and/or cool a cooling load for industrial processes, such as, heating and/or cooling gas or liquid flows to maintain reaction temperatures or temperature setpoints, cooling industrial waste, providing heat to replace gas boilers, providing refrigeration, or the like. In some embodiments, the heating and cooling system can be an HVACR system that can be used to provide comfort heating, e.g., during the cold months or winter season, and provide comfort cooling, e.g., during the hot months or summer season. In some embodiments, the HVACR system can include a hydronic system in which thermal energy in a heat transfer circuit is exchanged with process fluid(s), e.g., ethylene glycol, propylene glycol, water, a brine solution, or the like, which is used to condition a space. The hydronic system can generally be applied in a variety of systems used to control an environmental condition (e.g., temperature, humidity, air quality, or the like) in the conditioned space. The conditioned space can be a space within an office building, a commercial building, a factory, a laboratory, a data center, a residential building, or the like. For example, when providing heating to the conditioned space, the heat generated from the compression of a working fluid in the heat transfer circuit can be used to reject heat to the process fluid that is circulated in a heating water circuit to condition the space. Similarly, for providing cooling to the conditioned space, the HVACR system can extract heat from a second process fluid that is circulated in a chilled water circuit of the hydronic system to cool the process fluid to condition the space.

[0015] In prior heating and cooling systems, the heating and cooling system can include a low temperature circuit and a high temperature circuit, which can be operated in a cascaded operation to achieve the heating temperatures, for example, to provide comfort heating. In other prior heating and cooling systems, the heating and cooling system can include compressors arranged in series (on the refrigerant circuit to provide two stages of lift) to achieve the heating temperatures. However, once the heating season is over, the high temperature circuit (or the compressor in series to provide the additional lift) is idle, while the low temperature circuit (or single compressor) can be used to provide the cooling temperatures, for example, to provide comfort cooling, but at a lower capacity, e.g., only mass flow from a single compressor can be used to provide cooling.

[0016] In order to overcome such deficiencies, the present disclosure relates to systems and methods for improving the utilization and the operability of the heating and cooling system. The systems and methods enable a heat transfer circuit to be selectively operable in a heating

mode to achieve heating temperatures or a cooling mode to provide cooling temperatures such that the heat transfer circuits are configured to be operable during both the heating and cooling seasons. As such, in some embodiments, for example, when the heating and cooling system is the HVACR system, the heat transfer circuit can be configured to provide cooling temperatures for a cooling load, for example, by using a cooling fluid from a cooling tower to reject heat into the atmosphere, during the hot months or summer season, and to provide heating temperatures for a heating load, for example, by using heating air handlers to provide heat to condition a space or building, during the cold months or winter season. In some embodiments, the HVACR system can be configured to provide the heating temperatures by having a first heat transfer circuit and a second heat transfer circuit arranged in a cascaded operation, such that a fluid heated by the second heat transfer circuit, e.g., hot water, is sent to the first heat transfer circuit to boost the temperatures in the first heat transfer circuit. The HVACR system can also be configured to provide the cooling temperatures by having the first heat transfer circuit and the second heat transfer circuit arranged in parallel operation. That is, the HVACR system is configured to be reconfigured from a hydronic series arrangement into a hydronic parallel arrangement, which can provide additional cooling capacity, e.g., using mass flow from at least two compressors for cooling the cooling load. Thus, when there is no heating demand in the summer, the heat transfer circuit can be configured to run as a conventional chiller, whereas, while there is significant heat load in the winter, the heat transfer circuit can be configured to run as a high temperature chiller heater to provide the heating temperatures.

[0017] FIG. 1 shows a schematic diagram of a heating and cooling system 100 for heating and/or cooling process fluid(s) using a compression cycle of a working fluid. The process fluid(s) can be part of an industrial process, for example, process fluids for reactions, industrial waste, refrigeration lines, heating lines, or the like, or for a hydronic system for conditioning a space or building. The working fluid can be any suitable working fluid, such as a refrigerant or blend thereof. In the embodiment shown in FIG. 1, the heating and cooling system 100 is configured to provide cooling in a chiller system, however it is understood that heating and cooling systems including compressors according to embodiments can also be arranged as heat pumps, reversible systems, or any other suitable system providing heating and/or cooling through a compression cycle of a working fluid.

[0018] The heating and cooling system 100 includes a first heat transfer circuit 110, a second heat transfer circuit 120, a coolant loop 130, and a controller 170. The first heat transfer circuit 110 includes a working fluid circuit that includes a compressor 112, a first heat exchanger 114, for example, a condenser, an expansion device 116, and a second heat exchanger 118, for example, an evaporator, and the second heat transfer

circuit 120 includes a working fluid circuit that includes a compressor 122, a third heat exchanger 124, for example, a condenser, an expansion device 126, and a fourth heat exchanger 128, for example, an evaporator. In an embodiment, the first heat transfer circuit 110 and/or the second heat transfer circuit 120 can be modified to include additional components. For example, the first heat transfer circuit 110 and/or the second heat transfer circuit 120, in an embodiment, can include an economizer heat exchanger, one or more flow control devices, a receiver tank, a dryer, a suction-liquid heat exchanger, or the like. While the first heat transfer circuit 110 and the second heat transfer circuit 120 can have different functions and/or components, the operation of the working fluid circuit of the first heat transfer circuit 110 is discussed below, in which the second heat transfer circuit 120 can have the same or different operation.

[0019] The compressor 112 is configured to compress a working fluid. Compressor 112 can be any suitable compressor, such as a screw compressor, a scroll compressor, a centrifugal compressor, or the like. Working fluid from compressor 112 can pass to condenser 114. Condenser 114 is a heat exchanger allowing the working fluid to reject heat to a process fluid, thereby heating the process fluid, e.g., for heating a heating load 140. The rejection of heat to the heating load 140 can be to, for example, an ambient environment, a heating process fluid, a heating load, or any other suitable sink for the heat being rejected by the working fluid at condenser 114. The working fluid can pass from condenser 114 to expander 116. At expander 116 the working fluid is expanded. Expander 116 can be any suitable expander, such as at least one expansion valve, expansion orifice, orifice plate, expansion nozzle, a controllable expander, such as an electronic expansion valve, combinations thereof, or the like. Working fluid can pass from expander 116 to evaporator 118 where the working fluid can extract heat from a source such as for cooling a cooling load or coolant, thereby evaporating the working fluid prior to the working fluid returning to compressor 112. The sources can be, for example, from a process fluid or a conditioned space to be cooled, from an ambient environment, or the like, so as to evaporate the working fluid. Non-limiting examples of evaporator 118 can include an evaporator of a chiller configured to cool a process fluid, coils for cooling air to be distributed to a conditioned space, or the like. Working fluid leaving the evaporator 118 can be returned to a suction of the compressor 112, and the working fluid can continue to be circulated in first heat transfer circuit 110.

[0020] In some embodiments, the first heat exchanger 114, e.g., condenser, of the first heat transfer circuit 110 and/or the third heat exchanger 124, e.g., condenser, of the second heat transfer circuit 120 can be a dual-bundled heat exchanger, such as, a dual-bundled shell and tube heat exchanger or dual-bundled plate heat exchanger. It is appreciated that while the first heat exchanger 114 and the third heat exchanger 124 are dis-

cussed as being a single unit, such disclosure is not intended to be limiting. Rather, the first heat exchanger 114 and/or the third heat exchanger 124 can have different configurations, such as, the heat exchanger including several units, including, but not limited to, a single-bundle condenser and external isolation heat exchanger on one, the other or both of the units, in which one of the condenser or the external isolation heat exchanger receives cooling fluid from the cooling source 160, while the other unit receives the coolant from the coolant loop 130. As such, the first heat exchanger 114 can be selectively configurable to reject heat to either a process fluid for heating a heating load 140 or to reject heat to a cooling fluid from a cooling device 160, for example, cooling water in a cooling fluid loop from a cooling tower or other cooling source or air from a cooling fan, while the third heat exchanger 124 can be selectively configurable to reject heat to either a coolant from the coolant loop 130 or to reject heat to the cooling fluid from the cooling device 160, for example, cooling water from a cooling tower or other cooling source or air from a cooling fan, as will be discussed further below.

[0021] The coolant loop 130 can include a coolant and one or more of valve(s), pump(s), filters, strainers, or the like, for controlling fluid flow between the second heat exchanger 118, e.g., evaporator, of the first heat transfer circuit 110 and the third heat exchanger 124, e.g., condenser, of the second heat transfer circuit 120. The coolant can be, but not limited to, ethylene glycol, propylene glycol, water, a brine solution, or the like. The one or more valves can include a three-way feed valve, e.g., two position valve, or a four-way feed valve, e.g., three position valve, to allow the selectable connection of fluid to be cooled by the evaporator 118, e.g., connection to either the coolant in the coolant loop 130 or the second process fluid for cooling the cooling load 150, as will be discussed further below.

[0022] The controller 170 can be a controller that is programmed, designed, or otherwise configured to control one or more components of the heating and cooling system 100 and/or is a building automation system (BAS) controller for a computerized network of electronic devices that can be configured to control one or more systems (e.g., mechanical, electrical, lighting, security, HVACR, or the like). The controller 170 can include one or more processors and one or more non-volatile storage memories having instructions, which when executed by the one or more processors, carry out control operations, as discussed herein. In some embodiments, the controller 170 can include programmability to enable receiving and/or receiving a signal to heat or cool, e.g., from the BAS controller. For example, a building load can be determined based on seasonality, e.g., winter or summer, such that when there is no heating demand, e.g., in the summer, the first heat transfer circuit can be selectively operated in a cooling mode, whereas, when there is heating demand, e.g., in the winter, the first heat transfer circuit can be selectively operated in a heating mode, in

which the controller 170 is configured to selectively provide one or more of the coolant, the second process fluid from the coolant load, or cooling fluid from the cooling device 160 to one or more of the heat exchanger(s). As such, the heating and cooling system 100 can be optimized for use in either heating or cooling throughout the year.

[0023] For example, in an embodiment, the controller 170 can receive a control request to operate the heating and cooling system 100 in a heating mode, e.g., from the BAS controller when heating is required, such as during winter season. As such, the controller 170 can be configured to operate the heating and cooling system 100 in a cascaded operation, as follows. The controller 170 instructs the coolant loop 130 to supply coolant that is in thermal communication with the second heat exchanger 118 and the third heat exchanger 124, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the second heat exchanger 118 and the third heat exchanger 124, and to heat a process fluid from the heating load 140, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the first heat exchanger 114 and the heating load 140. In some embodiments, the controller 170 can instruct the coolant loop 130 to close valves (and/or stop pump(s)) to isolate or stop supplying any process fluid flow from the cooling load 150 to the second heat exchanger 118. In some embodiments, the controller 170 can also instruct the cooling device 160 to stop the flow of any cooling fluid to the third heat exchanger 124 and the first heat exchanger 114, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the cooling fluid.

[0024] As such, in cascaded operation, the compressor 122 of the second heat transfer circuit 120 compresses the working fluid such that the heat generated during the compression of the working fluid can be rejected in the third heat exchanger 124, e.g., condenser of the second heat transfer circuit 120, to coolant flowing in the coolant loop 130. The coolant in the coolant loop 130 is then used to thermally communicate thermal energy from the third heat exchanger 124 to the second heat exchanger 118 of the first heat transfer circuit 110 to provide thermal lift to heat the working fluid in the first heat transfer circuit 110. Thus, the working fluid compressed by compressor 112 in the first heat transfer circuit 110 is at a higher (e.g., elevated) temperature to provide heating or thermal energy, e.g., reject heat, via the first heat exchanger 114, to the process fluid of the heating load 140, which can be used for heating operations, e.g., heating process flows and/or heating to condition a space or building.

[0025] In another embodiment, the controller 170 can receive a control request to operate the heating and cooling system 100 in a cooling mode, e.g., from the BAS controller when the heating demand of the building is below a threshold value, such as during the summer

season. As such, the controller 170 can be configured to operate the heating and cooling system 100 in parallel operation, as follows. The controller 170 instructs the coolant loop 130 to supply the second process fluid from the cooling load 150 to the second heat exchanger 118, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the second heat exchanger 118 and the cooling load 150, and to provide cooling fluid from the cooling device 160 to the third heat exchanger 124 and to the first heat exchanger 114 to provide cooling of the working fluid, e.g., by sending instructions to open one or more valve(s) and/or to operate one or more pumps between the cooling device 160 and the first heat exchanger 114 and/or the third heat exchanger 124. In some embodiments, the controller 170 can instruct the coolant loop 130 to close valves (and/or stop pump(s)) to isolate or stop supplying any coolant flow from the coolant loop 130 between the second heat exchanger 118 and the third heat exchanger 124. In some embodiments, the controller 170 can also instruct the heating load 140 to stop the flow of any process fluid to the first heat exchanger 114, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the process fluid from the heating load 140.

[0026] As such, in parallel operation, the compressor 112 of the first heat transfer circuit 110 and the compressor 122 of the second heat transfer circuit 120 compress the working fluid such that the heat generated during the compression of the working fluid can be rejected in the first heat exchanger 114 and the third heat exchanger 124, respectively, by the cooling fluid from the cooling device 160. After expansion of the working fluid by the expanders 116, 126, the second heat exchanger 118 and the fourth heat exchanger 128 are both configured to extract heat from the process fluid from the cooling load 150, thereby evaporating the working fluid prior to the working fluid returning to the respective compressors 112, 122.

[0027] It is appreciated that the first heat transfer circuit 110 and the second heat transfer circuit 120 can have the same or matched capacity, e.g., same cooling and/or heating capacity, or can have mis-matched capacities which may further increase efficiency and/or operating stability. For example, in an embodiment, the first heat transfer circuit 110 can have a smaller capacity than the large capacity second heat transfer circuit 120, e.g., 500 ton to 2000 ton unit and 1000 to 2000 ton unit. As such, the heat and cooling system 100 can be designed or otherwise configured to be properly sized for the heating load, e.g., heating of the coolant in the coolant loop 130 to provide the lift for the first heat transfer circuit 110, while providing auxiliary cooling for the cooling load during different seasons. In some embodiments, in which the first heat transfer circuit 110 has a smaller capacity, it is understood that one or more first heat transfer circuit(s) 110 can be used to heat the heating load 140, such that multiple first heat transfer circuit(s) 110 may provide

better low heating load efficiency and operational stability. Furthermore, it is understood that the first heat exchanger 114 and/or the third heat exchanger 124 can have smaller capacities to either match the capacity of the smaller unit first heat transfer circuit(s) 110 or to provide more efficient heating, which may also reduce system cost. That is, in an embodiment, the third heat exchanger 124 can have a capacity that is matched to the heating load.

[0028] Thus, the heating and cooling system 100 is configured to improve the utilization and operability of the heating and cooling system 100, which was not obtainable by the prior heating and cooling systems, by being able to utilize both the first heat transfer circuit 110 and the second heat transfer circuit 120 for both a heating mode to heat a process fluid for a heating load and a cooling mode to cool a process fluid for a cooling load in parallel operation. As such, the heating and cooling system 100 can be used to provide high lift to heat a process fluid for a heating load and provide additional cooling capacity, e.g., capacity to cool by the compressor(s), during periods of high cooling demand that was not previously attainable by prior heating and cooling systems, in which the prior heating and cooling systems had one or more stages or circuits that are idle during different times, e.g., different seasons.

[0029] FIG. 2 shows a schematic diagram of a HVACR system 200 for heating and/or cooling process fluid(s) using a compression cycle of a working fluid, which can have the same or similar features as the heating and cooling system 100, as discussed above. The HVACR system 200 can include a hydronic system that includes a first process fluid loop 202 and a second process fluid loop 205 for conditioning a space or building. The working fluid can be any suitable working fluid, such as a refrigerant or blend thereof. In the embodiment shown in FIG. 2, the HVACR system 200 is configured to provide cooling in a chiller system, however it is understood that heating and cooling systems including compressors according to embodiments can also be arranged as heat pumps, reversible systems, or any other suitable system providing heating and/or cooling through a compression cycle of a working fluid.

[0030] The HVACR system 200 includes a first heat transfer circuit 210, a second heat transfer circuit 220, a coolant loop 230, and a controller, which can be the controller 170 in FIG. 1. The first heat transfer circuit 210 includes a working fluid circuit that includes a compressor (e.g., compressor 112 in FIG. 1), a first heat exchanger 214, for example, a condenser, an expander (e.g., expander 116 in FIG. 1), and a first chiller 218, for example, an evaporator, and the second heat transfer circuit 220 includes a working fluid circuit that includes a compressor (e.g., compressor 122 in FIG. 1), a cascade heat exchanger 224, for example, a condenser, an expander (e.g., expander 126 in FIG. 1), and a second chiller 228, for example, an evaporator.

[0031] In the first heat transfer circuit 210, the com-

pressor is configured to compress a working fluid. Compressor can be any suitable compressor, such as a screw compressor, a scroll compressor, a centrifugal compressor, or the like. Working fluid from the compressor can pass to the first heat exchanger 214. First heat exchanger 214 is a heat exchanger that is configured to selectively exchange heat with the first process fluid to allow the working fluid to reject heat to the process fluid, thereby heating the first process fluid in the first process fluid loop 202, such that the first process fluid can exchange heat for heating a heating load 240. The rejection of heat to the heating load 240 can be to, for example, an ambient environment, a heating load, or any other suitable sink for the heat being rejected by the working fluid at first heat exchanger 214, e.g., for conditioning one or more spaces or buildings. The working fluid can pass from the first heat exchanger 214 to the expander, which is configured to expand the working fluid. Working fluid can pass from the expander to the first chiller 218 where the working fluid can extract heat from a source, such as, for cooling a cooling load or coolant, thereby evaporating the working fluid prior to the working fluid returning to the compressor. The sources can be, for example, from a process fluid or a conditioned space to be cooled, from an ambient environment, or the like, so as to evaporate the working fluid. Working fluid leaving the first chiller 218 can be returned to a suction of the compressor, and the working fluid can continue to be circulated in first heat transfer circuit 210.

[0032] In the second heat transfer circuit 220, the compressor is configured to compress a working fluid. Working fluid from the compressor can pass to the cascade heat exchanger 224. Cascade heat exchanger 224 is a heat exchanger that is configured to selectively exchange heat with coolant in coolant loop 230 to allow the working fluid to reject heat to the coolant, thereby heating the coolant in the coolant loop 230, e.g., to provide lift for refrigerant in the first heat transfer circuit 210, or to exchange heat with cooling fluid from a cooling device 260, such as, a cooling tower, to allow the working fluid to reject heat to the cooling fluid. The working fluid can pass from the cascade heat exchanger 224 to the expander, which is configured to expand the working fluid. Working fluid can pass from the expander to the second chiller 228 where the working fluid can extract heat from the second process fluid of the second process fluid loop 205 for cooling the cooling load 250, thereby evaporating the working fluid prior to the working fluid returning to the compressor. Working fluid leaving the second chiller 228 can be returned to a suction of the compressor, and the working fluid can continue to be circulated in second heat transfer circuit 220.

[0033] In some embodiments, the first heat exchanger 214 of the first heat transfer circuit 210 and/or the cascade heat exchanger 224 of the second heat transfer circuit 220 can be a dual-bundled heat exchanger, such as, a dual-bundled shell and tube heat exchanger or dual-bundled plate heat exchanger. As such, the first heat exchanger 214 can be selectively configurable to reject

heat to either a process fluid for heating a heating load 240 or to reject heat to a cooling fluid from a cooling device 260, for example, cooling water in a cooling fluid loop from a cooling tower or other cooling source or air from a cooling fan, while the cascade heat exchanger 224 can be selectively configurable to reject heat to either a coolant from the coolant loop 230 or to reject heat to the cooling fluid from the cooling device 260.

[0034] The coolant loop 230 can include a coolant and one or more of valve(s), pump(s), filters, strainers, or the like, for controlling fluid flow between the first chiller 218 of the first heat transfer circuit 210 and the cascade heat exchanger 224 of the second heat transfer circuit 220. The coolant can be, but not limited to, ethylene glycol, propylene glycol, water, a brine solution, or the like. The one or more valves can include a three-way feed valve, e.g., two position valve, or a four-way feed valve, e.g., three position valve, to allow the selectable connection of fluid to be cooled by the first chiller 218, e.g., connection to either the coolant in the coolant loop 230 or the second process fluid for cooling the cooling load 250, as will be discussed further below.

[0035] The controller can be a controller that is programmed, designed, or otherwise configured to control one or more components of the HVACR system 200 and/or is a building automation system (BAS) controller for a computerized network of electronic devices that can be configured to control one or more systems (e.g., mechanical, electrical, lighting, security, HVACR, or the like). The controller can include one or more processors and one or more non-volatile storage memories having instructions, which when executed by the one or more processors, carry out control operations, as discussed herein. In some embodiments, the controller can include programmability to enable receiving and/or receiving a signal to heat or cool, e.g., from the BAS controller. For example, a building load can be determined based on seasonality, e.g., winter or summer, such that when there is no heating demand, e.g., in the summer, the first heat transfer circuit can be selectively operated in a cooling mode, whereas, when there is heating demand, e.g., in the winter, the first heat transfer circuit can be selectively operated in a heating mode, in which the controller is configured to selectively provide one or more of the coolant, the second process fluid from the coolant load, or cooling fluid from the cooling device 260 to one or more of the heat exchangers.

[0036] As such, the HVACR system 200 can be optimized for use for either heating or cooling, as illustrated in FIGS. 3 and 4. As illustrated in FIG. 3, in an embodiment, the controller can receive a control request to operate the HVACR system 200 in a heating mode, e.g., from the BAS controller when heating is required, such as during winter season. As such, the controller can be configured to operate the HVACR system 200 in a cascaded operation, as follows, in which the dash-dot lines present fluid lines not in operation. The controller instructs the coolant loop 230 to supply coolant that is in thermal communication

with the first chiller 218 and the cascade heat exchanger 224, e.g., by sending instructions to open one or more of valve(s) 232, 234 and/or to operate one or more pump(s) 236 provided between the first chiller 218 and the cascade heat exchanger 224, and to heat a process fluid from the heating load 240, e.g., by sending instructions to open one or more of valve(s) 203 and/or to operate one or more pump(s) 204 provided between the first heat exchanger 214 and the heating load 240. In some embodiments, the controller can instruct the coolant loop 230 to close valves (and/or stop pump(s)) to isolate or stop supplying any process fluid flow from the cooling load 250 to the first chiller 218. In some embodiments, the controller can also instruct the cooling device 260 to stop the flow of any cooling fluid to the cascade heat exchanger 224 and the first heat exchanger 214, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the cooling fluid.

[0037] As such, in cascaded operation, the compressor of the second heat transfer circuit 220 compresses the working fluid such that the heat generated during the compression of the working fluid can be rejected in the cascade heat exchanger 224 to coolant flowing in the coolant loop 230, for example, to raise the temperature of the coolant from 85°F to 95°F, e.g., $Q = mC_p\Delta T$, in which the working fluid is subsequently cooled by the second chiller 228, e.g., extracts heat from the second process fluid of the second process fluid loop 205, e.g., lowers the temperature of the second process fluid from 52°F to 42°F. The coolant in the coolant loop 230 is then used to thermally communicate thermal energy from the cascade heat exchanger 224 to the first chiller 218 of the first heat transfer circuit 210 to provide thermal lift to heat the working fluid in the first heat transfer circuit 210, e.g., since the coolant from the coolant loop 230 has an increased amount of heat, the working fluid in the first heat transfer circuit 210 has a higher lift, such that when the working fluid in the first heat transfer circuit 210 is compressed, the compressed working fluid has a higher temperature, e.g., an increased amount of heat which can raise the temperature of the first process fluid in the first process fluid loop 202 from 140°F to 160°F to heat the heating load 240, e.g., heating water supply. Thus, the working fluid compressed by compressor in the first heat transfer circuit 210 is at a higher (e.g., elevated) temperature to provide heating or thermal energy, via the first heat exchanger 214, to the process fluid of the first process fluid loop 202 for heating the heating load 240, which can be used for heating operations, e.g., heating to condition a space or building.

[0038] As illustrated in FIG. 4, in another embodiment, the controller can receive a control request to operate the HVACR system 200 in a cooling mode, e.g., from the BAS controller when the heating demand of the building is below a threshold value, such as during the summer season. As such, the controller can be configured to operate the HVACR system 200 in parallel operation,

as follows, in which the dash-dot lines present fluid lines not in operation. The controller instructs the coolant loop 230 to supply the second process fluid from the cooling load 250 to the first chiller 218, e.g., by sending instructions to open one or more of valve(s) 232, 234 and/or to operate one or more pump(s) provided between the first chiller 218 and the cooling load 250, and to provide cooling fluid from the cooling device 260 to the cascade heat exchanger 224 and to the first heat exchanger 214 to provide cooling of the working fluid, e.g., by sending instructions to open one or more valve(s) and/or to operate one or more pumps between the cooling device 260 and the first heat exchanger 214 and/or the cascade heat exchanger 224. In some embodiments, the controller can instruct the coolant loop 230 to close valves 232, 234 (and/or stop pump(s) 236) to isolate or stop supplying any coolant flow from the coolant loop 230 between the first chiller 218 and the cascade heat exchanger 224. In some embodiments, the controller can also instruct the heating load 240 to stop the flow of any process fluid in the first fluid process loop 202 to the first heat exchanger 214, e.g., by sending instructions to close one or more valves 203 and/or stopping operation of one or more pumps 204 supplying the process fluid for heating the heating load 240.

[0039] As such, in parallel operation, the compressor of the first heat transfer circuit 210 and the compressor of the second heat transfer circuit 220 compress the working fluid such that the heat generated during the compression of the working fluid can be rejected in the first heat exchanger 214 and the cascade heat exchanger 224, respectively, by the cooling fluid from the cooling device 260, for example, rejecting heat to the cooling fluid which increases the temperature of the cooling fluid from 85°F to 95°F. After expansion of the working fluid by the expanders, the first chiller 218 and the second chiller 228 are both configured to extract heat from the process fluid for providing cooling to the cooling load 250, e.g., extracts heat from the second process fluid of the second process fluid loop 205, e.g., lowers the temperature of the second process fluid from 52°F to 42°F.

[0040] Thus, the HVACR system 200 is configured to improve the utilization and operability of the HVACR system 200, which was not previously obtainable by the prior HVACR systems, by being able to utilize both the first heat transfer circuit 210 and the second heat transfer circuit 220 for both a heating mode to heat a process fluid for a heating load (in a cascade hydronic series arrangement) and a cooling mode to cool a process fluid for a cooling load in parallel operation (in a hydronic parallel arrangement) that provides additional cooling capacity. As such, the HVACR system 200 can be used to provide high lift to heat a process fluid for a heating load and provide additional cooling capacity, e.g., capacity to cool by the compressor(s), during periods of high cooling demand that was not previously attainable by prior HVACR systems, in which the prior HVACR systems had one or more stages or circuits that

are idle during different times, e.g., different seasons.

[0041] FIG. 5 shows a schematic diagram of a HVACR system 500 for heating and/or cooling process fluid(s) using a compression cycle of a working fluid, which can have the same or similar features as the heating and cooling system 100 or the HVACR system 200, as discussed above. The HVACR system 500 can include a hydronic system that includes a first process fluid loop 502 and a second process fluid loop 504 for conditioning a space or building. The working fluid can be any suitable working fluid, such as a refrigerant or blend thereof. In the embodiment shown in FIG. 5, the HVACR system 500 is configured to provide cooling in a chiller system and heating using a heat pump system, however, it is understood that heating and cooling systems including compressors according to embodiments can also be arranged as heat pumps, reversible systems, or any other suitable system providing heating and/or cooling through a compression cycle of a working fluid.

[0042] The HVACR system 500 includes a first heat transfer circuit 510, a second heat transfer circuit 520, a coolant loop 530, and a controller, which can be the controller 170 in FIG. 1. The first heat transfer circuit 510 includes a working fluid circuit that includes a compressor (e.g., compressor 112 in FIG. 1), a first heat exchanger 514, for example, a condenser, an expander (e.g., expander 116 in FIG. 1), and a first chiller 518, for example, an evaporator, and the second heat transfer circuit 520 includes a working fluid circuit that includes a compressor (e.g., compressor 122 in FIG. 1), a cascade heat exchanger 524, an auxiliary or isolation heat exchanger 525, an expander (e.g., expander 126 in FIG. 1), and a second chiller 528, for example, an evaporator.

[0043] In the first heat transfer circuit 510, the compressor is configured to compress a working fluid. Compressor can be any suitable compressor, such as a screw compressor, a scroll compressor, a centrifugal compressor, or the like. Working fluid from the compressor can pass to the first heat exchanger 514. First heat exchanger 514 is a heat exchanger that is configured to selectively exchange heat with the first process fluid (or cooling fluid (not shown) to allow the working fluid to reject heat to the process fluid, thereby heating the first process fluid in the first process fluid loop 502, such that the first process fluid can exchange heat for heating a heating load 540. The rejection of heat to the heating load 540 can be to, for example, an ambient environment, a heating load, or any other suitable sink for the heat being rejected by the working fluid at first heat exchanger 514, e.g., for conditioning one or more spaces or buildings. The working fluid can pass from the first heat exchanger 514 to the expander, which is configured to expand the working fluid. Working fluid can pass from the expander to the first chiller 518 where the working fluid can extract heat from a source, such as, for cooling a cooling load or coolant, thereby evaporating the working fluid prior to the working fluid returning to the compressor. The sources can be, for example, from a process fluid or a

conditioned space to be cooled, from an ambient environment, or the like, so as to evaporate the working fluid. Working fluid leaving the first chiller 518 can be returned to a suction of the compressor, and the working fluid can continue to be circulated in first heat transfer circuit 510.

[0044] In the second heat transfer circuit 520, the compressor is configured to compress a working fluid. Working fluid from the compressor can pass to either the cascade heat exchanger 524 and/or the auxiliary or isolation heat exchanger 525. Cascade heat exchanger 524 is a heat exchanger that is configured to selectively exchange heat with coolant in coolant loop 530 to allow the working fluid to reject heat to the coolant, thereby heating the coolant in the coolant loop 530, e.g., to provide lift for refrigerant in the first heat transfer circuit 510. The auxiliary or isolation heat exchanger 525 is a heat exchanger configured to exchange heat with cooling fluid from a cooling device 560, such as, a cooling tower, to allow the working fluid to reject heat to the cooling fluid. The working fluid can pass from the cascade heat exchanger 524 and/or the auxiliary or isolation heat exchanger 525 to the expander, which is configured to expand the working fluid. Working fluid can pass from the expander to the second chiller 528 where the working fluid can extract heat from the second process fluid of the second process fluid loop 505 for cooling the cooling load 550, thereby evaporating the working fluid prior to the working fluid returning to the compressor. Working fluid leaving the second chiller 528 can be returned to a suction of the compressor, and the working fluid can continue to be circulated in second heat transfer circuit 520.

[0045] In some embodiments, the first heat exchanger 514 of the first heat transfer circuit 510 and/or the cascade heat exchanger 524 of the second heat transfer circuit 520 can include the auxiliary or isolation heat exchanger 525. As such, the first heat exchanger 514 can be selectively configurable to reject heat to a process fluid for heating a heating load 540, while the auxiliary or isolation heat exchanger can be configurable to reject heat to a cooling fluid, e.g., from a cooling device 560, for example, cooling water in a cooling fluid loop from a cooling tower or other cooling source or air from a cooling fan (not shown). Similarly, the cascade heat exchanger 524 can be selectively configurable to reject heat to a coolant from the coolant loop 530, while the auxiliary or isolation heat exchanger 525 is configured to reject heat to the cooling fluid from the cooling device 560. While the supply of cooling fluid to the auxiliary or isolation heat exchanger 525 is discussed above, it is understood that such disclosure is not intended to be limiting. For example, it is understood that the cascade heat exchanger 524 (or the first heat exchanger 514) can instead receive the cooling fluid from the cooling device 560, while the auxiliary or isolation heat exchanger receives the other fluids.

[0046] The coolant loop 530 can include a coolant and one or more of valve(s), pump(s), filters, strainers, or the like, for controlling fluid flow between the first chiller 518

of the first heat transfer circuit 510 and the cascade heat exchanger 524 of the second heat transfer circuit 520. The coolant can be, but not limited to, ethylene glycol, propylene glycol, water, a brine solution, or the like. The one or more valves can include a three-way feed valve, e.g., two position valve, or a four-way feed valve, e.g., three position valve, to allow the selectable connection of fluid to be cooled by the first chiller 518, e.g., connection to either the coolant in the coolant loop 530 or the second process fluid for cooling the cooling load 550, as will be discussed further below.

[0047] The controller can be a controller that is programmed, designed, or otherwise configured to control one or more components of the HVACR system 500 and/or is a building automation system (BAS) controller for a computerized network of electronic devices that can be configured to control one or more systems (e.g., mechanical, electrical, lighting, security, HVACR, or the like). The controller can include one or more processors and one or more non-volatile storage memories having instructions, which when executed by the one or more processors, carry out control operations, as discussed herein. In some embodiments, the controller can include programmability to enable receiving and/or receiving a signal to heat or cool, e.g., from the BAS controller. For example, a building load can be determined based on seasonality, e.g., winter or summer, such that when there is no heating demand, e.g., in the summer, the first heat transfer circuit can be selectively operated in a cooling mode, whereas, when there is heating demand, e.g., in the winter, the first heat transfer circuit can be selectively operated in a heating mode, in which the controller is configured to selectively provide one or more of the coolant, the second process fluid from the coolant load, or cooling fluid from the cooling device 560 to one or more of the heat exchangers.

[0048] As such, the HVACR system 500 can be optimized for use for either heating or cooling. In an embodiment, the controller can receive a control request to operate the HVACR system 500 in a heating mode, e.g., from the BAS controller when heating is required, such as during winter season. As such, the controller can be configured to operate the HVACR system 500 in a cascaded operation, as follows. The controller instructs the coolant loop 530 to supply coolant that is in thermal communication with the first chiller 518 and the cascade heat exchanger 524, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) 536 provided between the first chiller 518 and the cascade heat exchanger 524, and to heat a process fluid from the heating load 540, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the first heat exchanger 514 and the heating load 540. In some embodiments, the controller can instruct the coolant loop 530 and/or the second process fluid loop 505 to close valves (and/or stop pump(s)) to isolate or stop supplying any process fluid flow from the cooling load 550 to the first

chiller 518. In some embodiments, the controller can also instruct the cooling device 560 to stop the flow of any cooling fluid to the auxiliary or isolation heat exchanger 524 and the first heat exchanger 514, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the cooling fluid.

[0049] As such, in cascaded operation, the compressor of the second heat transfer circuit 520 compresses the working fluid such that the heat generated during the compression of the working fluid can be rejected in the cascade heat exchanger 524 to coolant flowing in the coolant loop 530. The coolant in the coolant loop 530 is then used to thermally communicate thermal energy from the cascade heat exchanger 524 to the first chiller 518 of the first heat transfer circuit 510 to provide thermal lift to heat the working fluid in the first heat transfer circuit 510. Thus, the working fluid compressed by compressor in the first heat transfer circuit 510 is at a higher (e.g., elevated) temperature to provide heating or thermal energy, via the first heat exchanger 514, to the process fluid of the first process fluid loop 502 for heating the heating load 540, which can be used for heating operations, e.g., heating to condition a space or building.

[0050] In another embodiment, the controller can receive a control request to operate the HVACR system 500 in a cooling mode, e.g., from the BAS controller when the heating demand of the building is below a threshold value, such as during the summer season. As such, the controller can be configured to operate the HVACR system 500 in parallel operation, as follows. The controller instructs the second process fluid loop 505 to supply the second process fluid from the cooling load 550 to the first chiller 518, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the first chiller 518 and the cooling load 550, and to provide cooling fluid from the cooling device 560 to the auxiliary or isolation heat exchanger 525 and to the first heat exchanger 514 to provide cooling of the working fluid, e.g., by sending instructions to open one or more valve(s) and/or to operate one or more pumps between the cooling device 560 and the first heat exchanger 514 and/or the auxiliary or isolation heat exchanger 525. In some embodiments, the controller can instruct the coolant loop 530 to close valves (and/or stop pump(s) 536) to isolate or stop supplying any coolant flow from the coolant loop 530 between the first chiller 518 and the cascade heat exchanger 524. In some embodiments, the controller can also instruct the heating load 540 to stop the flow of any process fluid in the first fluid process loop 502 to the first heat exchanger 514, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the process fluid for heating the heating load 540.

[0051] As such, in parallel operation, the compressor of the first heat transfer circuit 510 and the compressor of the second heat transfer circuit 520 compress the working fluid such that the heat generated during the com-

pression of the working fluid can be rejected in the first heat exchanger 514 and the auxiliary or isolation exchanger 525, respectively, by the cooling fluid from the cooling device 560, for example, rejecting heat to the cooling fluid which increases the temperature of the cooling fluid from 85°F to 95°F. After expansion of the working fluid by the expanders, the first chiller 518 and the second chiller 528 are both configured to extract heat from the process fluid for providing cooling to the cooling load 550, e.g., extracts heat from the second process fluid of the second process fluid loop 505, e.g., lowers the temperature of the second process fluid from 52°F to 42°F.

[0052] Thus, the HVACR system 500 is configured to improve the utilization and operability of the HVACR system 500, which was not previously obtainable by the prior HVACR systems, by being able to utilize both the first heat transfer circuit 510 and the second heat transfer circuit 520 for both a heating mode to heat a process fluid for a heating load (in a cascade hydronic series arrangement) and a cooling mode to cool a process fluid for a cooling load in parallel operation (in a hydronic parallel arrangement) that provides additional cooling capacity. As such, the HVACR system 500 can be used to provide high lift to heat a process fluid for a heating load and provide additional cooling capacity, e.g., capacity to cool by the compressor(s), during periods of high cooling demand that was not previously attainable by prior HVACR systems, in which the prior HVACR systems had one or more stages or circuits that are idle during different times, e.g., different seasons.

[0053] FIG. 6 is a flowchart for a method 600 for heating and/or cooling a system, for example, the heating and cooling system 100 of FIG. 1 or the HVACR system 200 of FIG. 2 or the HVACR system 500 of FIG. 5. The system includes a first heat transfer circuit (e.g., 110, 210, 510), in which the first heat transfer circuit includes a first compressor (e.g., 112), a first heat exchanger (e.g., 114, 214, 514), and a second heat exchanger (e.g., 118, 218, 518); a second heat transfer circuit (e.g., 120, 220, 520), in which the second heat transfer circuit includes a second compressor (e.g., 122), a third heat exchanger (e.g., 124, 224, 524), and a fourth heat exchanger (e.g., 128, 228, 528); a coolant loop (e.g., 130, 230, 530) including a coolant; and a controller (e.g., 170), according to an embodiment.

[0054] The method 600 can include one or more operations, actions, or functions depicted by one or more blocks 610, 620, 630, and 640. Although illustrated as discrete blocks, various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. In an embodiment, the method 600 can be performed by the controller 170 of FIG. 1 or the BAS controller, or any other suitable control systems or controllers. The method 600 may optionally begin at block 610 for selectively operating the system in either one of a cascaded operation or a parallel operation.

[0055] At block 610, "Receive a signal for heating a

heating load or supplemental cooling a cooling load", the controller is programmed, designed, or otherwise configured to control one or more components of the heating and cooling system (or HVACR system) and/or is a building automation system (BAS) controller for a computerized network of electronic devices that can be configured to control one or more systems (e.g., mechanical, electrical, lighting, security, HVACR, or the like). The controller can include one or more processors and one or more non-volatile storage memories having instructions, which when executed by the one or more processors, carry out control operations, as discussed herein. In some embodiments, the controller can include programmability to enable receiving and/or receiving a signal to heat or cool, e.g., from the BAS controller. For example, a building load can be determined based on seasonality, e.g., winter or summer, such that when there is no heating demand, e.g., in the summer, the first heat transfer circuit can be selectively operated in a cooling mode, whereas, when there is heating demand, e.g., in the winter, the first heat transfer circuit can be selectively operated in a heating mode, in which the controller is configured to selectively provide one or more of the coolant, the second process fluid from the coolant load, or cooling fluid from the cooling device to one or more of the heat exchangers. As such, the heating and cooling system (or HVACR system) can be optimized for use in either heating or cooling. The method 600 can proceed to 620.

[0056] At 620, "Selectively operate the system to heat the heating load and/or cool the cooling load," the controller is configured to receive a control request to selectively operate the heating and cooling system in one of a "heating mode" and a "cooling mode," in which the first heat transfer circuit is operable in either a cascaded operation or a parallel operation to enable utilization of the first heat transfer circuit for all seasons. The method 600 can then proceed to either 630 or 640.

[0057] At 630, "Operate the system in a heating mode," in an embodiment, when the system is operated in a heating mode, e.g., when heating is required and demand is high for heating, such as during winter season, the controller can be configured to receive the "heating mode" signal, e.g., from the BAS controller, and operate the heating and cooling system in a cascaded operation, as follows. The controller instructs the coolant loop to supply coolant that is in thermal communication with the second heat exchanger and the third heat exchanger, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the second heat exchanger and the third heat exchanger, and to heat a process fluid from the heating load, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the first heat exchanger and the heating load. That is, the controller is configured to selectively control the flow of the coolant through the coolant, such as to provide either the coolant to the second heat exchanger of the first heat transfer circuit (or the second process fluid

to the second heat exchanger in the cooling mode, as discussed below). In some embodiments, the controller can instruct the coolant loop to close valves (and/or stop pump(s)) to isolate or stop supplying any process fluid flow from the cooling load to the second heat exchanger. In some embodiments, the controller can also instruct the cooling device to stop the flow of any cooling fluid to the third heat exchanger and the first heat exchanger, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the cooling fluid. The method 600 can proceed to 630.

[0058] As such, in cascaded operation, the compressor of the second heat transfer circuit compresses the working fluid such that the heat generated during the compression of the working fluid can be rejected in the third heat exchanger, e.g., condenser of the second heat transfer circuit, to coolant flowing in the coolant loop. The coolant in the coolant loop is then used to thermally communicate thermal energy from the third heat exchanger to the second heat exchanger of the first heat transfer circuit to provide thermal lift to heat the working fluid in the first heat transfer circuit. Thus, the working fluid compressed by compressor in the first heat transfer circuit is at a higher (e.g., elevated) temperature to provide heating or thermal energy, e.g., reject heat, via the first heat exchanger, to the process fluid of the heating load, which can be used for heating operations, e.g., heating process flows and/or heating to condition a space or building.

[0059] At 640, "Operate the system in a cooling mode," in an embodiment when the system is operated in a cooling mode, e.g., from the BAS controller when the heating demand of the building is below a threshold value, such as during the summer season, the controller can be configured to receive the "cooling mode" signal and operate the heating and cooling system in a parallel operation, as follows. The controller instructs the coolant loop to selectively supply the second process fluid from the cooling load to the second heat exchanger, e.g., by sending instructions to open one or more of valve(s) and/or to operate one or more pump(s) provided between the second heat exchanger and the cooling load, and to provide cooling fluid from the cooling device to the third heat exchanger and to the first heat exchanger to provide cooling of the working fluid, e.g., by sending instructions to open one or more valve(s) and/or to operate one or more pumps between the cooling device and the first heat exchanger and/or the third heat exchanger, e.g., such that the first heat exchanger and the third heat exchanger are condensers for their respective heat transfer circuits. In some embodiments, the controller can instruct the coolant loop to close valves (and/or stop pump(s)) to isolate or stop supplying any coolant flow from the coolant loop between the second heat exchanger and the third heat exchanger. In some embodiments, the controller can also instruct the heating load to stop the flow of any process fluid to the first heat exchanger, e.g., by sending instructions to close one or more valves and/or stopping operation of one or more pumps supplying the process

fluid from the heating load.

[0060] As such, in parallel operation, the compressor of the first heat transfer circuit and the compressor of the second heat transfer circuit compress the working fluid such that the heat generated during the compression of the working fluid can be rejected in the first heat exchanger and the third heat exchanger, respectively, to the cooling fluid from the cooling device. After expansion of the working fluid by the expander(s), the second heat exchanger and the fourth heat exchanger are both configured to extract heat from the process fluid from the cooling load, thereby evaporating the working fluid prior to the working fluid returning to the respective compressors.

[0061] Thus, the heating and cooling system is configured to improve the utilization and operability of the heating and cooling system, which was not obtainable by the prior heating and cooling systems, by being able to utilize both the first heat transfer circuit and the second heat transfer circuit for both a heating mode to heat a process fluid for a heating load in cascaded operation and a cooling mode to cool a process fluid for a cooling load in parallel operation. As such, the heating and cooling system can be used to provide high lift to heat a process fluid for a heating load and provide additional cooling capacity, e.g., capacity to cool by the compressor(s), during periods of high cooling demand that was not previously attainable by prior heating and cooling systems, in which the prior heating and cooling systems had one or more stages or circuits that are idle during various times of the year, e.g., different seasons.

[0062] Aspects: It is appreciated that any one of aspects 1-9, any one of aspects 10-16, and any one of aspects 17-19 can be combined with each other.

[0063] Aspect 1. A heating and cooling system comprising: a first heat transfer circuit, wherein the first heat transfer circuit comprises a first compressor, a first heat exchanger, and a second heat exchanger; a second heat transfer circuit, wherein the second heat transfer circuit comprises a second compressor, a third heat exchanger, and a fourth heat exchanger; a coolant loop including a coolant, the coolant loop configured to thermally communicate thermal energy between the second heat exchanger of the first heat transfer circuit and the third heat exchanger of the second heat transfer circuit; and a controller, wherein the controller is configured to selectively operate the heating and cooling system in: a heating mode, wherein the heating and cooling system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat a first process fluid via heat transfer with the first heat exchanger, wherein the coolant loop is configured to thermally communicate the thermal energy between the third heat exchanger of the second heat transfer circuit and the second heat exchanger of the first heat transfer circuit, and a cooling mode, wherein the heating and cooling system is configured to operate the first heat transfer circuit and the second heat transfer circuit in

parallel operation to both provide cooling to a second process fluid via heat transfer with the fourth heat exchanger and the second heat exchanger.

[0064] Aspect 2. The heating and cooling system of Aspect 1, wherein the third heat exchanger of the second heat transfer circuit is configured to selectively receive cooling fluid in the cooling mode or the coolant from the coolant loop in the heating mode.

[0065] Aspect 3. The heating and cooling system of any one of Aspects 1-2, wherein the first heat exchanger of the first heat transfer circuit is configured to selectively receive cooling fluid in the cooling mode or the first process fluid in the heating mode.

[0066] Aspect 4. The heating and cooling system of any one of Aspects 1-3, wherein the first heat exchanger of the first heat transfer circuit and/or the third heat exchanger of the second heat transfer circuit is a dual-bundled heat exchanger.

[0067] Aspect 5. The heating and cooling system of any of Aspects 1-3, wherein the first heat exchanger of the first heat transfer circuit and/or the third heat exchanger of the second heat transfer circuit includes an auxiliary heat exchanger.

[0068] Aspect 6. The heating and cooling system of any one of Aspects 1-5, wherein the coolant loop includes one or more valves for controlling a flow of the coolant through the coolant loop, and the controller is configured to operate the one or more valves to selectively provide either the coolant to the second heat exchanger in the heating mode or the second process fluid to the second heat exchanger in the cooling mode.

[0069] Aspect 7. The heating and cooling system of any one of Aspects 1-6, wherein the heating and cooling system is a hydronic system, and the first process fluid is heating water and the second process fluid is chilled water.

[0070] Aspect 8. The heating and cooling system of any one of Aspects 1-7, further comprising a cooling fluid loop including one or more valves, wherein the controller is configured to operate the one or more valves to supply cooling fluid to the first heat exchanger of the first heat transfer circuit and the third heat exchanger of the second heat transfer circuit in the cooling mode.

[0071] Aspect 9. The heating and cooling system of any one of Aspects 1-8, wherein the coolant is at least one of: ethylene glycol, propylene glycol, water, and a brine solution.

[0072] Aspect 10. A heating, ventilation, air conditioning, and refrigeration (HVACR) system comprising: a hydronic system comprising a first process fluid and a second process fluid for conditioning one or more spaces; a first heat transfer circuit, wherein the first heat transfer circuit comprises a first compressor, a first heat exchanger, and a first chiller, wherein the first heat exchanger is configured to selectively exchange heat with the first process fluid, wherein the first process fluid further exchanges heat with a heating load in the one or more spaces, or exchanges heat with cooling fluid; a

second heat transfer circuit, wherein the second heat transfer circuit comprises a second compressor, a cascade heat exchanger, and a second chiller; wherein the second chiller is configured to exchange heat between the second process fluid, wherein the second process fluid further exchanges heat with a cooling load; a coolant loop including a coolant, the coolant loop configured to thermally communicate thermal energy between the first chiller of the first heat transfer circuit and the cascade heat exchanger of second heat transfer circuit; and a controller, wherein the controller is configured to selectively operate the HVACR system in: a heating mode, wherein the HVACR system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat the first process fluid via heat transfer with the first heat exchanger, wherein the coolant loop is configured to thermally communicate the thermal energy between the cascade heat exchanger of the second heat transfer circuit and the first chiller of the first heat transfer circuit, and a cooling mode, wherein the HVACR system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a parallel operation to provide cooling to the second process fluid via heat transfer with the first chiller and the second chiller, wherein the first heat exchanger is configured to exchange heat with the cooling fluid.

[0073] Aspect 11. The HVACR system of Aspect 10, wherein the cascade heat exchanger of the second heat transfer circuit is configured to selectively receive the cooling fluid or the coolant from the coolant loop.

[0074] Aspect 12. The HVACR system of any one of Aspects 10-11, wherein the first heat exchanger of the first heat transfer circuit and/or the cascade heat exchanger of the second heat transfer circuit is a dual-bundled heat exchanger.

[0075] Aspect 13. The HVACR system of any one of Aspects 10-11, wherein the first heat exchanger of the first heat transfer circuit and/or the cascade heat exchanger of the second heat transfer circuit includes an auxiliary heat exchanger.

[0076] Aspect 14. The HVACR system of any one of Aspects 10-13, wherein the coolant is at least one of: ethylene glycol, propylene glycol, water, and a brine solution.

[0077] Aspect 15. The HVACR system of any one of Aspects 10-14, wherein the cooling fluid is provided via a cooling fluid loop including one or more valves, wherein the controller is configured to operate the one or more valves to supply the cooling fluid to the first heat exchanger of the first heat transfer circuit and the cascade heat exchanger of the second heat transfer circuit in the cooling mode.

[0078] Aspect 16. The HVACR system of any one of Aspects 10-15, wherein the coolant loop includes one or more valves for controlling a flow of the coolant through the coolant loop, and the controller is configured to operate the one or more valves to selectively provide either the coolant to the first chiller in the heating mode or the

second process fluid to the first chiller in the cooling mode.

[0079] Aspect 17. A method for heating and/or cooling a system, the system comprising a first heat transfer circuit, wherein the first heat transfer circuit comprises a first compressor, a first heat exchanger, and a second heat exchanger; a second heat transfer circuit, wherein the second heat transfer circuit comprises a second compressor, a third heat exchanger, and a fourth heat exchanger; a coolant loop including a coolant; and a controller, the method comprising selectively operating the system in either one of the following modes: operating the system in a heating mode by operating the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat a first process fluid via heat transfer with the first heat exchanger, wherein the operating the system in the heating mode includes thermally communicating, via the coolant loop, thermal energy from the third heat exchanger of the second heat transfer circuit and the second heat exchanger of the first heat transfer circuit; or operating the system in a cooling mode by operating the first heat transfer circuit and the second heat transfer circuit in parallel operation to provide cooling to a second process fluid, wherein the operating the system in the cooling mode includes providing the second process fluid to the fourth heat exchanger and the second heat exchanger.

[0080] Aspect 18. The method of Aspect 17, further comprising selectively controlling flow of the coolant through the coolant loop to provide either the coolant to the second heat exchanger of the first heat transfer circuit in the heating mode or the second process fluid to the second heat exchanger in the cooling mode.

[0081] Aspect 19. The method of any one of Aspects 17-18, further comprising circulating cooling fluid from a cooling fluid loop to selectively supply the cooling fluid to the first heat exchanger of the first heat transfer circuit and the third heat exchanger of the second heat transfer circuit in the cooling mode.

[0082] The terminology used in this specification is intended to describe particular embodiments and is not intended to be limiting. The terms "a," "an," and "the" include the plural forms as well, unless clearly indicated otherwise. The terms "comprises" and/or "comprising," when used in this specification, specify the presence of the stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, and/or components.

[0083] With regard to the preceding description, it is to be understood that changes may be made in detail, especially in matters of the construction materials employed and the shape, size, and arrangement of parts without departing from the scope of the present disclosure. This specification and the embodiments described are exemplary only, with the true scope and spirit of the disclosure being indicated by the claims that follow.

Claims

1. A heating and cooling system (100) comprising:

a first heat transfer circuit (110, 210, 510),
wherein the first heat transfer circuit comprises
a first compressor (112), a first heat exchanger
(114, 214, 514), and a second heat exchanger
(118, 218, 518);
a second heat transfer circuit (120, 220, 520),
wherein the second heat transfer circuit com-
prises a second compressor (122), a third heat
exchanger (124, 224, 524), and a fourth heat
exchanger (128, 228, 528);
a coolant loop (130, 230, 530) including a cool-
ant, the coolant loop configured to thermally
communicate thermal energy between the sec-
ond heat exchanger of the first heat transfer
circuit and the third heat exchanger of the sec-
ond heat transfer circuit; and
a controller (170), wherein the controller is con-
figured to selectively operate the heating and
cooling system in:

a heating mode, wherein the heating and
cooling system is configured to operate the
first heat transfer circuit and the second
heat transfer circuit in a cascaded operation
to heat a first process fluid via heat transfer
with the first heat exchanger, wherein the
coolant loop is configured to thermally com-
municate the thermal energy between the
third heat exchanger of the second heat
transfer circuit and the second heat exchan-
ger of the first heat transfer circuit, and
a cooling mode, wherein the heating and
cooling system is configured to operate the
first heat transfer circuit and the second
heat transfer circuit in parallel operation to
both provide cooling to a second process
fluid via heat transfer with the fourth heat
exchanger and the second heat exchanger.

2. The heating and cooling system of claim 1, wherein
the third heat exchanger of the second heat transfer
circuit is configured to selectively receive cooling
fluid in the cooling mode or the coolant from the
coolant loop in the heating mode.

3. The heating and cooling system of any one of claims
1-2, wherein the first heat exchanger of the first heat
transfer circuit is configured to selectively receive
cooling fluid in the cooling mode or the first process
fluid in the heating mode, or

wherein the first heat exchanger of the first heat
transfer circuit and/or the third heat exchanger of
the second heat transfer circuit is a dual-bundled

heat exchanger, or
wherein the first heat exchanger of the first heat
transfer circuit and/or the third heat exchanger of
the second heat transfer circuit includes an aux-
iliary heat exchanger.

4. The heating and cooling system of any one of claims
1-3, wherein the coolant loop includes one or more
valves for controlling a flow of the coolant through the
coolant loop, and the controller is configured to op-
erate the one or more valves to selectively provide
either the coolant to the second heat exchanger in
the heating mode or the second process fluid to the
second heat exchanger in the cooling mode.

5. The heating and cooling system of any one of claims
1-4, wherein the heating and cooling system is a
hydronic system, and the first process fluid is heating
water and the second process fluid is chilled water.

6. The heating and cooling system of any one of claims
1-5, further comprising a cooling fluid loop including
one or more valves, wherein the controller is config-
ured to operate the one or more valves to supply
cooling fluid to the first heat exchanger of the first
heat transfer circuit and the third heat exchanger of
the second heat transfer circuit in the cooling mode.

7. The heating and cooling system of any one of claims
1-6, wherein the coolant is at least one of: ethylene
glycol, propylene glycol, water, and a brine solution.

8. A heating, ventilation, air conditioning, and refrigera-
tion (HVACR) system (200, 500) comprising:

a hydronic system comprising a first process
fluid and a second process fluid for conditioning
one or more spaces;

a first heat transfer circuit (110, 210, 510),
wherein the first heat transfer circuit comprises
a first compressor (112), a first heat exchanger
(114, 214, 514), and a first chiller (218, 518),
wherein the first heat exchanger is configured to
selectively exchange heat with the first process
fluid, wherein the first process fluid further ex-
changes heat with a heating load (240) in the
one or more spaces, or exchanges heat with
cooling fluid;

a second heat transfer circuit (120, 220, 520),
wherein the second heat transfer circuit com-
prises a second compressor (122), a cascade
heat exchanger (224, 524), and a second chiller
(228, 528);

wherein the second chiller is configured to ex-
change heat between the second process fluid,
wherein the second process fluid further ex-
changes heat with a cooling load (250);

a coolant loop (130, 230, 530) including a cool-

ant, the coolant loop configured to thermally communicate thermal energy between the first chiller of the first heat transfer circuit and the cascade heat exchanger of second heat transfer circuit; and

a controller (170), wherein the controller is configured to selectively operate the HVACR system in:

a heating mode, wherein the HVACR system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat the first process fluid via heat transfer with the first heat exchanger, wherein the coolant loop is configured to thermally communicate the thermal energy between the cascade heat exchanger of the second heat transfer circuit and the first chiller of the first heat transfer circuit, and

a cooling mode, wherein the HVACR system is configured to operate the first heat transfer circuit and the second heat transfer circuit in a parallel operation to provide cooling to the second process fluid via heat transfer with the first chiller and the second chiller, wherein the first heat exchanger is configured to exchange heat with the cooling fluid.

9. The HVACR system of claim 8, wherein the cascade heat exchanger of the second heat transfer circuit is configured to selectively receive the cooling fluid or the coolant from the coolant loop.

10. The HVACR system of any one of claims 8-9, wherein the first heat exchanger of the first heat transfer circuit and/or the cascade heat exchanger of the second heat transfer circuit is a dual-bundled heat exchanger, or wherein the first heat exchanger of the first heat transfer circuit and/or the cascade heat exchanger of the second heat transfer circuit includes an auxiliary heat exchanger.

11. The HVACR system of any one of claims 8-10, wherein the coolant is at least one of: ethylene glycol, propylene glycol, water, and a brine solution.

12. The HVACR system of any one of claims 8-11, wherein the cooling fluid is provided via a cooling fluid loop including one or more valves, wherein the controller is configured to operate the one or more valves to supply the cooling fluid to the first heat exchanger of the first heat transfer circuit and the cascade heat exchanger of the second heat transfer circuit in the cooling mode.

13. The HVACR system of any one of claims 9-12,

wherein the coolant loop includes one or more valves for controlling a flow of the coolant through the coolant loop, and the controller is configured to operate the one or more valves to selectively provide either the coolant to the first chiller in the heating mode or the second process fluid to the first chiller in the cooling mode.

14. A method for heating and/or cooling a system, the system comprising a first heat transfer circuit, wherein the first heat transfer circuit comprises a first compressor, a first heat exchanger, and a second heat exchanger; a second heat transfer circuit, wherein the second heat transfer circuit comprises a second compressor, a third heat exchanger, and a fourth heat exchanger; a coolant loop including a coolant; and a controller, the method comprising selectively operating the system in either one of the following modes:

operating the system in a heating mode by operating the first heat transfer circuit and the second heat transfer circuit in a cascaded operation to heat a first process fluid via heat transfer with the first heat exchanger, wherein the operating the system in the heating mode includes thermally communicating, via the coolant loop, thermal energy from the third heat exchanger of the second heat transfer circuit and the second heat exchanger of the first heat transfer circuit; or

operating the system in a cooling mode by operating the first heat transfer circuit and the second heat transfer circuit in parallel operation to provide cooling to a second process fluid, wherein the operating the system in the cooling mode includes providing the second process fluid to the fourth heat exchanger and the second heat exchanger.

15. The method of claim 14, further comprising selectively controlling flow of the coolant through the coolant loop to provide either the coolant to the second heat exchanger of the first heat transfer circuit in the heating mode or the second process fluid to the second heat exchanger in the cooling mode.

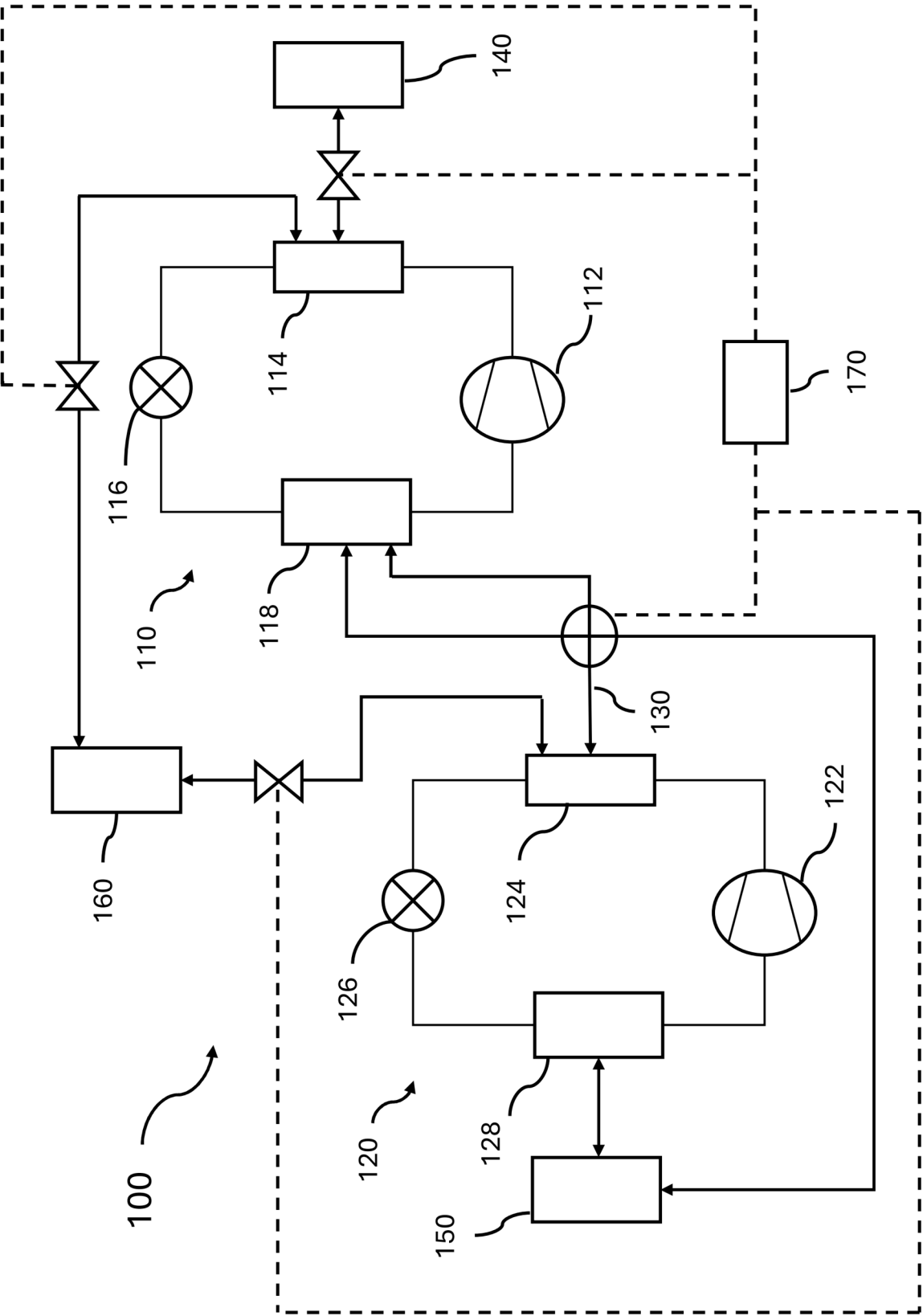


FIG. 1

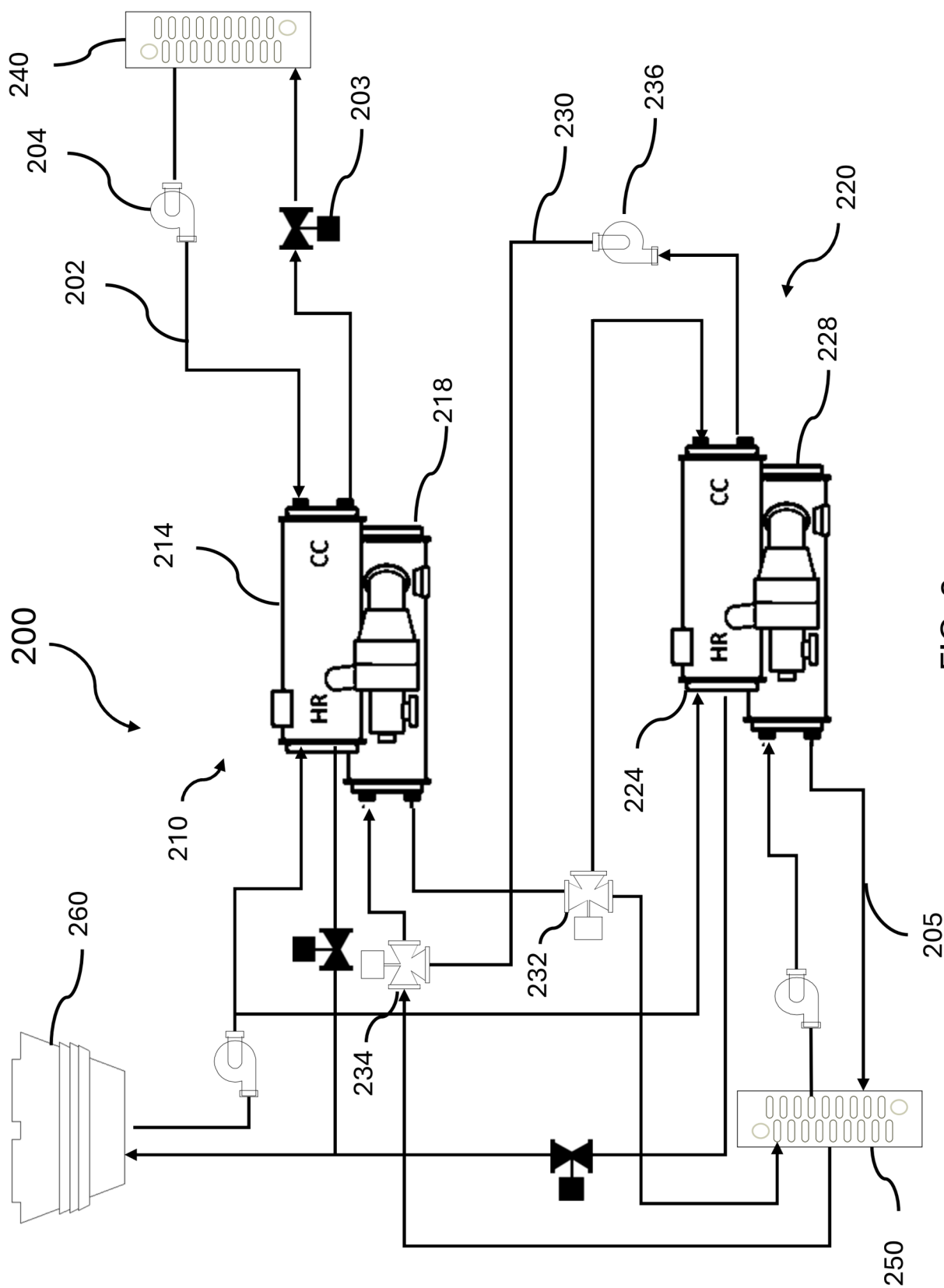


FIG. 2

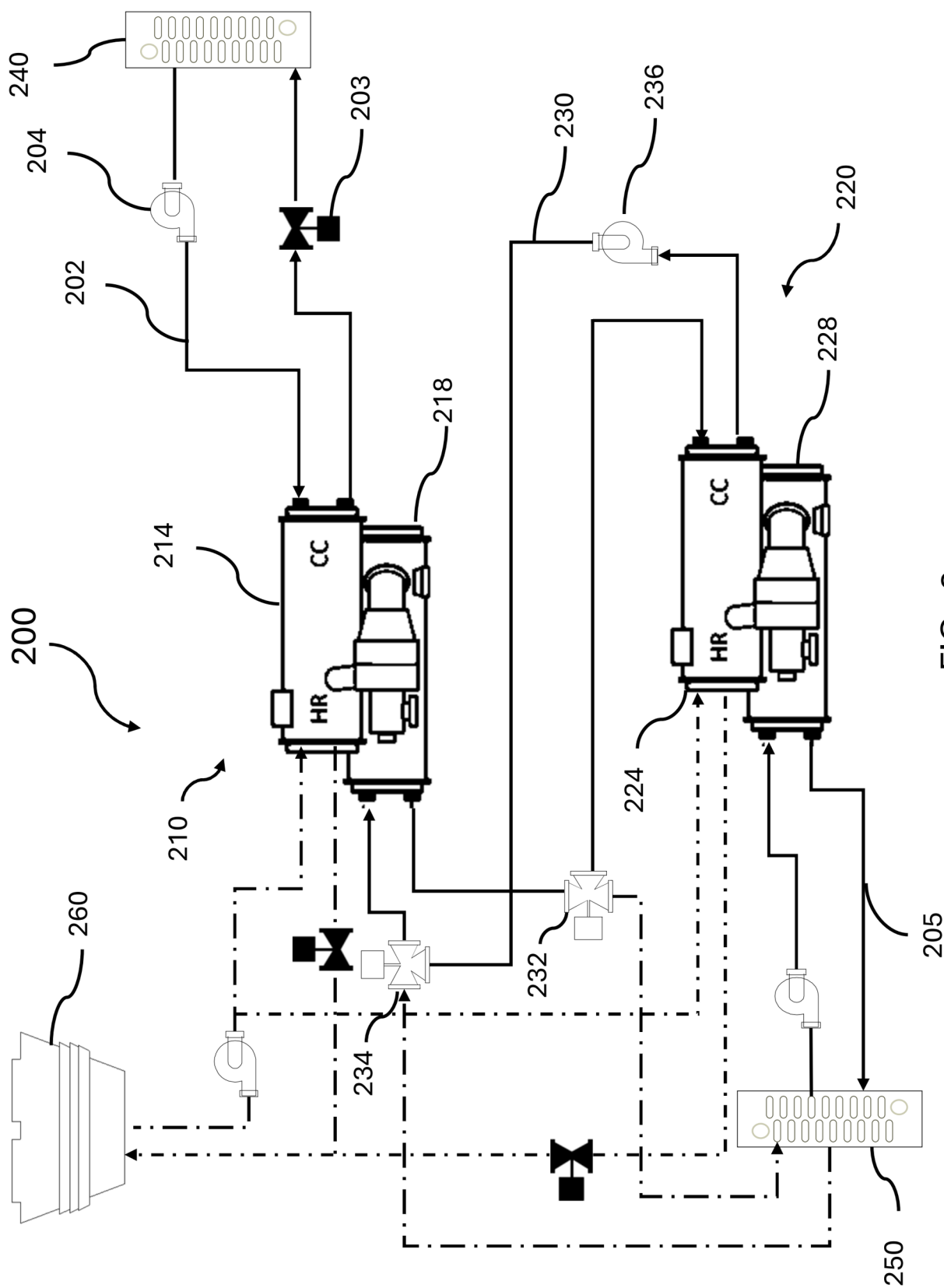


FIG. 3

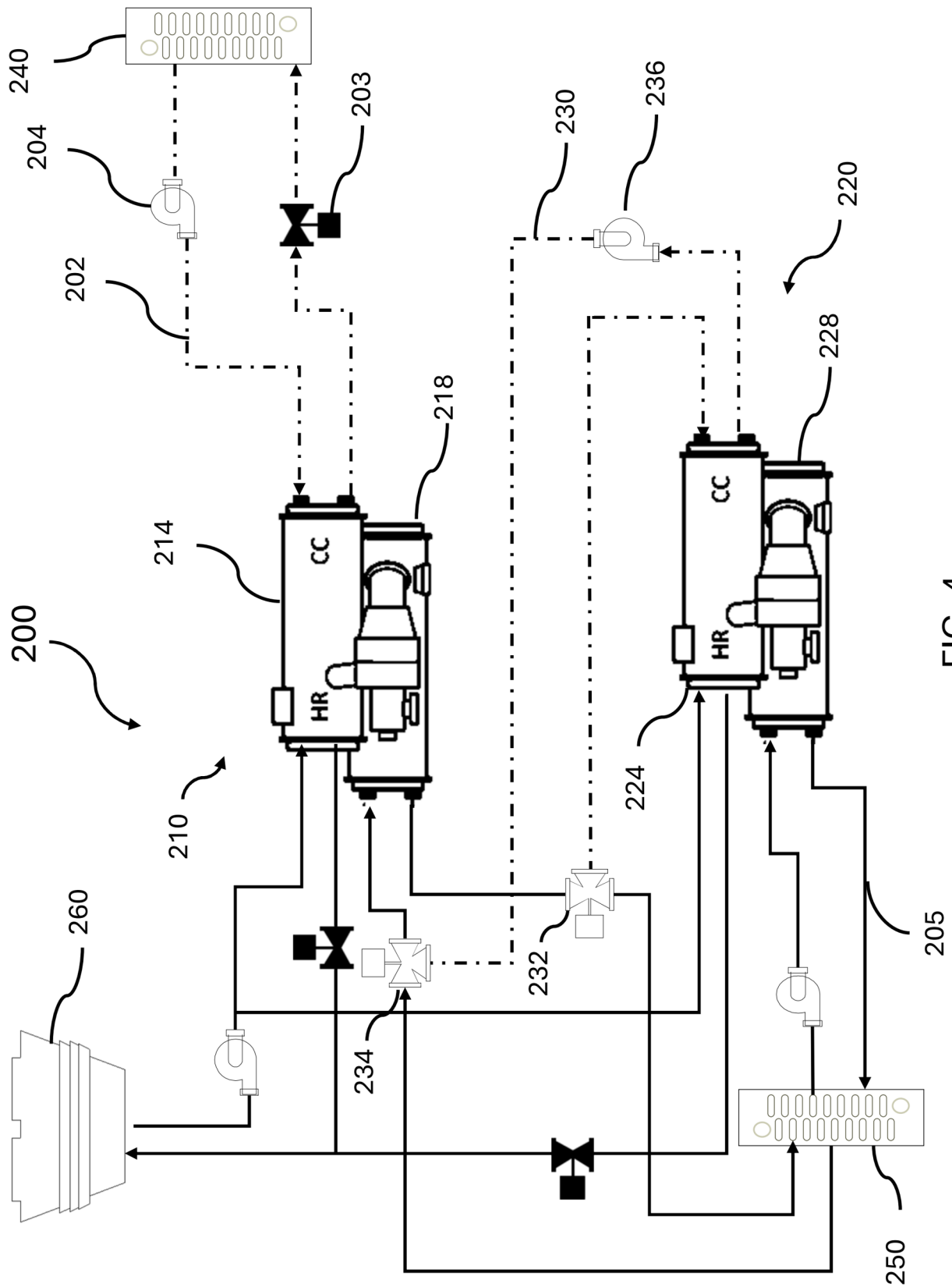


FIG. 4

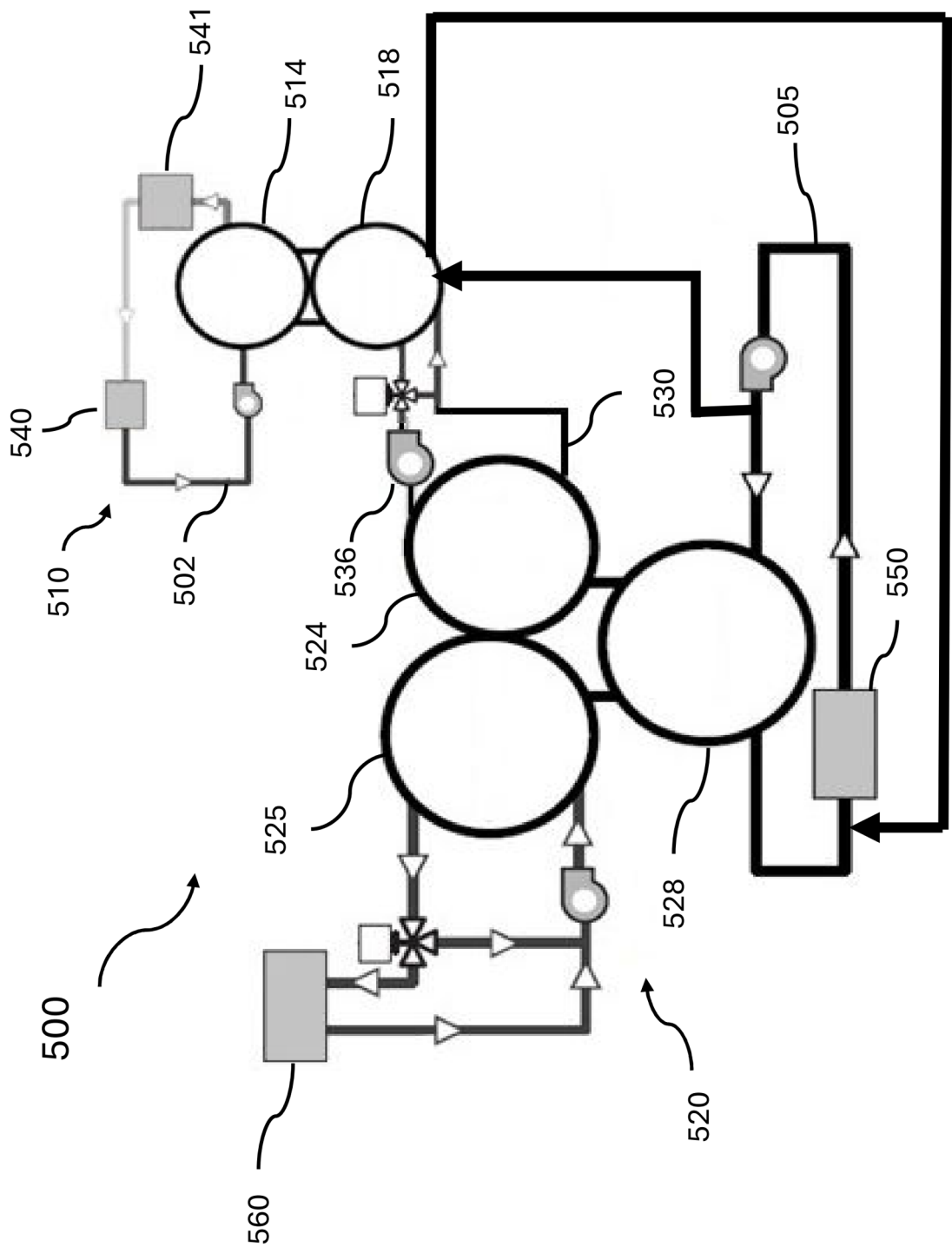


FIG. 5

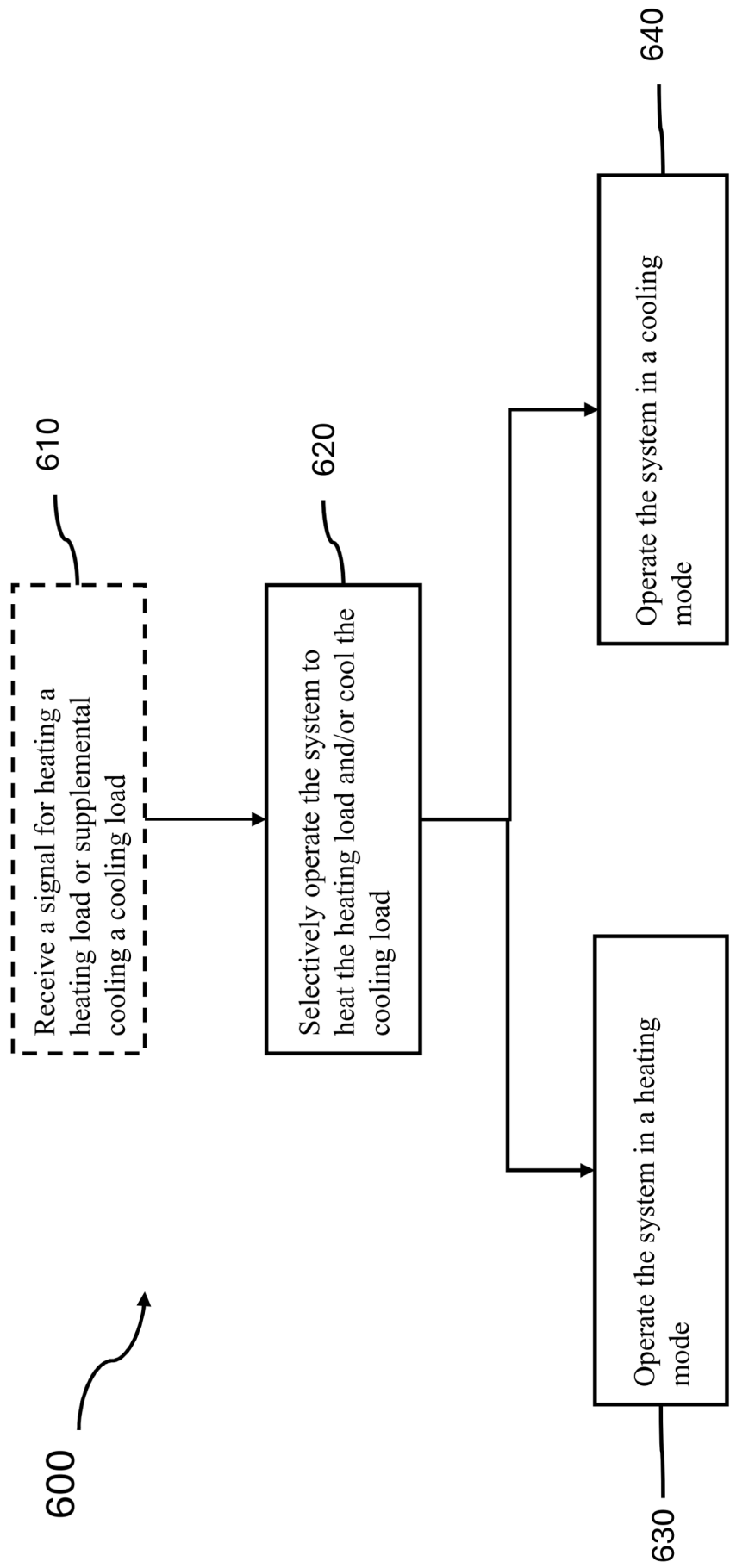


FIG. 6



EUROPEAN SEARCH REPORT

Application Number

EP 25 21 5093

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 12 March 2026	Examiner Lucic, Anita
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