



(11) **EP 4 741 741 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.05.2026 Bulletin 2026/20

(51) International Patent Classification (IPC):
F25B 49/02 ^(2006.01)

(21) Application number: **25215094.1**

(52) Cooperative Patent Classification (CPC):
F25B 49/02; F25B 25/005; F24F 2221/54;
F25B 2339/047; F25B 2400/06

(22) Date of filing: **11.11.2025**

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

(72) Inventors:
• **CLINE, Lee R**
Davidson, North Carolina, 28036 (US)
• **KEYS, Daryl**
Davidson, North Carolina, 28036 (US)

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

(30) Priority: **11.11.2024 US 202463718978 P**

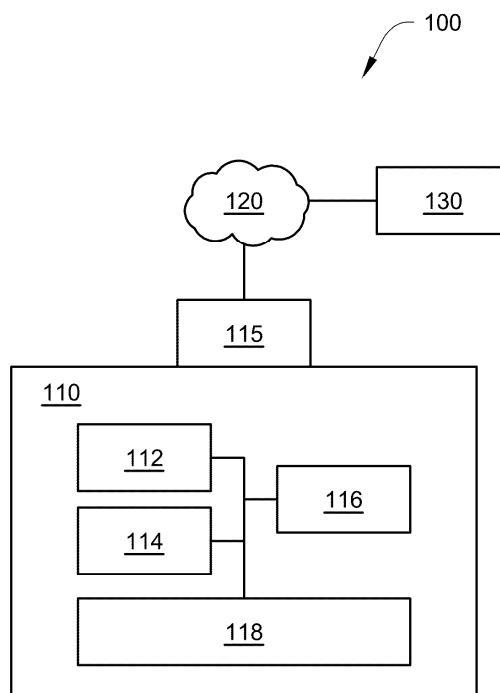
(71) Applicant: **Trane International Inc.**
Davidson, NC 28036 (US)

(54) **CASCADE HEATING/COOLING SYSTEM WITH INTERMEDIATE LOOP HEAT EXCHANGE**

(57) A heating, ventilation, air conditioning, and re-
frigeration (HVACR) system includes a first heat transfer
circuit; a second heat transfer circuit; a fluid loop between
the first heat transfer circuit and the second heat transfer
circuit; a heat exchanger connecting to the fluid loop; and

a controller. The controller is configured to determine an
operation parameter of the system; and control the heat
exchanger to remove heat from the fluid loop when the
operation parameter is above a first threshold.

Fig. 1



EP 4 741 741 A1

Description

FIELD

[0001] The embodiments described herein pertain generally to systems and methods for heat energy control of a heating, ventilation, air conditioning, and refrigeration (HVACR) system. More specifically, the embodiments described herein pertain to maintaining desired temperature in the intermediate loop of a cascade heating and/or cooling HVACR system in different modes of system operation.

BACKGROUND

[0002] A heating, ventilation, air conditioning, and refrigeration (HVACR) system may include one or more heat transfer circuits. A heat transfer circuit may include one or more compressors, a condenser, an evaporator, fans, filters, dampers, and various other equipment. The one or more compressors, the condenser, the expansion device, and the evaporator are fluidly connected. The heat transfer circuit can be a heat pump, a chiller, or the like.

SUMMARY

[0003] Features in the embodiments disclosed herein may enable and/or expand the application of an HVACR system including cascade heat transfer circuits such as vapor-compression chiller units and/or heat pump units. Features in the embodiments disclosed herein may also allow for reliable and/or long-term system operation when the operating capacities of the primary unit and the secondary unit of the cascade system are not synchronized. Features in the embodiments disclosed herein may aid in different system operation modes such as system start-up, stable operation, and intentional capacity mismatch (e.g., cooling-dominant system operation).

[0004] Features in the embodiments disclosed herein may maintain a desired temperature in the intermediate loop of a cascade heating and/or cooling system in different modes of system operation. The modes include, but not limited to, system startup, unit(s) startup, individual unit capacity changes (e.g., loading, unloading, or the like), intentional cooling dominant operation, intentional heating dominant operation, unit(s) shutdown, and/or system shutdown. Features in the embodiments disclosed herein may prevent unacceptable temperature transients from occurring (during one or more of the operation modes) which may negatively impact system operation (e.g., supply of heating or cooling), causing unstable system and/unit(s) operation and impact unit(s) reliability, short or long term.

[0005] In an example embodiment, a heating, ventilation, air conditioning, and refrigeration (HVACR) system is provided. The system includes a first heat transfer circuit; a second heat transfer circuit; a fluid loop between

the first heat transfer circuit and the second heat transfer circuit; a heat exchanger connecting to the fluid loop; and a controller. The controller is configured to determine an operation parameter of the system; and control the heat exchanger to remove heat from the fluid loop when the operation parameter is above a first threshold.

[0006] In an example embodiment, a method of operating a heating, ventilation, air conditioning, and refrigeration (HVACR) system is provided. The system includes a first heat transfer circuit; a second heat transfer circuit; a fluid loop between the first heat transfer circuit and the second heat transfer circuit; a heat exchanger connecting to the fluid loop; and a controller. The method includes determining an operation parameter of the system; and controlling the heat exchanger to remove heat from the fluid loop when the operation parameter is above a first threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The accompanying drawings illustrate various embodiments of systems, methods, and embodiments of various other aspects of the disclosure. Any person with ordinary skills in the art will appreciate that the illustrated element boundaries (e.g. boxes, groups of boxes, or other shapes) in the figures represent one example of the boundaries. It may be that in some examples one element may be designed as multiple elements or that multiple elements may be designed as one element. In some examples, an element shown as an internal component of one element may be implemented as an external component in another, and vice versa. Non-limiting and non-exhaustive descriptions are described with reference to the following drawings. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating principles. In the detailed description that follows, embodiments are described as illustrations only since various changes and modifications may become apparent to those skilled in the art from the following detailed description.

FIG. 1 illustrates a schematic diagram of a controller subsystem, arranged in accordance with at least some embodiments described herein.

FIG. 2A illustrates a schematic diagram of a cascade HVACR system, arranged in accordance with at least some embodiments described herein.

FIG. 2B illustrates a schematic diagram of a cascade HVACR system, arranged in accordance with at least some embodiments described herein.

FIG. 2C illustrates a schematic diagram of a cascade HVACR system, arranged in accordance with at least some embodiments described herein.

FIG. 3 is a flow chart illustrating an example proces-

sing flow for operating a cascade HVACR system, arranged in accordance with at least some embodiments described herein.

DETAILED DESCRIPTION

[0008] In the following detailed description, particular embodiments of the present disclosure are described herein with reference to the accompanying drawings, which form a part of the description. In this description, as well as in the drawings, like-referenced numbers represent elements that may perform the same, similar, or equivalent functions, unless context dictates otherwise. Furthermore, unless otherwise noted, the description of each successive drawing may reference features from one or more of the previous drawings to provide clearer context and a more substantive explanation of the current example embodiment. Still, the example embodiments described in the detailed description, drawings, and claims are not intended to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the drawings, may be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0009] 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.

[0010] 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.

[0011] 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".

[0012] As referenced herein, "directly" upstream or "directly" downstream may refer to that no other components of a fluid circuit, other than fluid lines/connection-pipes for conveying the fluid are provided between such directly related elements. As referenced herein, "up-

stream" and "downstream" may refer to the direction of flow of the fluid or a component thereof through the fluid circuit.

[0013] FIG. 1 illustrates a schematic diagram of a controller subsystem 100, arranged in accordance with at least some embodiments described herein. In an example embodiment, the controller subsystem 100 can be a part of the HVACR system and/or a part of the unit (e.g., a vapor-compression unit).

[0014] It is to be understood that an HVACR system may include one or more heat transfer circuits. Each heat transfer circuit can be a vapor-compression unit such as a heat pump, a chiller, or the like. The vapor-compression units (i.e., the heat transfer circuits) can form a cascade HVACR system including at least a primary unit and a secondary unit. Each heat transfer circuit may include one or more compressors, a condenser, an evaporator, fans, filters, dampers, and various other equipment. The one or more compressors, the condenser, the expansion device, and the evaporator are fluidly connected.

[0015] In an example embodiment, the HVACR system may include plants, chillers, air handlers, furnaces, and/or boilers with multiple data sensors producing a continuous stream of data, variable air volume (VAV) boxes and dampers, temperature or humidity sensors monitoring a space, etc. In an embodiment, the HVACR system may include a panel, a sensor, a controller, a microprocessor-controlled device, a converter, a thermostat, a furnace, a heating system, a chiller, a cooling system, an air conditioner, an air filter, an air purifier, a fire and life safety system, a security system, an alarm system, an occupancy sensor, an electrical system monitor and controller, a lighting system monitor and controller, a ventilation system monitor and controller, a temperature sensor, a smoke sensor, a light sensor, a motion sensor, a humidity sensor, a pump, an air handler, fluid and air moving and handling equipment, a terminal device, life science and pharmacological control equipment and monitoring systems, a positive pressure clean room, a negative pressure clean room, industrial automation and control equipment and systems, a programmable logic controller, etc.

[0016] In an example embodiment, the controller subsystem 100 includes a controller 110. The controller 110 can be the HVACR system controller and/or the unit (e.g., vapor-compression unit) controller. The controller 110 can include a processor 112 in operative communication with a memory 114, a user interface 116, and data storage 118. The memory 114 can include random-access memory (RAM) which can be used, for example, for storage of transient data, computed and intermediate results, input/output (I/O) buffering, graphical user interface (GUI) buffering, program execution, and any other suitable purposes. Data storage 118 can include non-volatile storage such as a flash drive, read-only memory (ROM), electrically erasable programmable ROM (EEPROM), magnetic hard disk, solid state disk (SSD), hybrid drives (combination hard disk/SSD) which can

be used for storage of data which persists through power cycling.

[0017] In an example embodiment, user interface 116 can include a number of elements which may facilitate user input and the display of output to the user, and may include one or more buttons, switches, light-emitting diode (LED) indicators, a character display such as a liquid crystal display (LCD) or a vacuum fluorescent display (VFD), a graphic display such as a thin film transistor (TFT) display, a touchscreen display, and the like.

[0018] In an example embodiment, the controller 110 can also include a data network interface 115 for communicating data (wirelessly or in wired communication) to one or more user devices and/or one or more components of the HVACR system over a data network 120, such as a private LAN and/or the public Internet. User devices may include a mobile telephone, smart phone, tablet device, smart watch, pager, server, notebook computer, and/or a desktop computer, and the like. An optional server 130 can be communicatively coupled to the controller 110 via the data network 120 and stores information for a plurality of devices, including information relating to specific products, product versions, firmware versions, and/or software versions.

[0019] FIGS. 2A, 2B, and 2C illustrate schematic diagrams of cascade HVACR systems (201, 202, 203), arranged in accordance with at least some embodiments described herein. Each of the HVACR systems (201, 202, 203) can be a cascade (heating and/or cooling) system including a first (or primary) heat transfer circuit 210 and a second (or secondary) heat transfer circuit 220. Each heat transfer circuit can be a unit (e.g., a vapor-compression unit) such as a heat pump, a chiller, or the like. It is to be understood that the HVACR systems can include fluid lines/connections/pipes for conveying the fluid. The HVACR systems can also include flow control device(s) such as a valve (e.g., a solenoid valve, a ball valve, a three-way valve, a butterfly valve, a check-valve, or the like), a damper, a pump, or the like, to allow, regulate, and/or modulate the fluid flow (e.g., the flow rate, the amount of flow, or the like) flowing through the flow control device, or to block the fluid flow from passing through the flow control device. The primary unit 210 and/or the secondary unit 220 can be water source units.

[0020] In an example embodiment, each heat transfer circuit (unit) can include a compressor, a condenser, an optional expander, an evaporator, and a controller (e.g., 110 of FIG. 1) configured to control the operations of other components of the heat transfer circuit. The heat transfer circuit can generally be applied in a variety of systems used to control an environmental condition (e.g., temperature, humidity, air quality, or the like) in a conditioned space. The conditioned space can be a space within an office building, a commercial building, a factory, a laboratory, a data center, a residential building, or the like. In an example embodiment, the heat transfer circuit can be configured to be a cooling system (e.g., an air conditioning system) capable of operating in a cooling mode. In

another example embodiment, the heat transfer circuit can be configured to be a heat pump that can operate in a heating/defrost mode. It is appreciated that the heat transfer circuit can be configured to operate in a cooling mode and/or a heating/defrosting mode. In an example embodiment, the heat transfer circuit can heat or cool a process fluid (e.g., air, water and/or glycol, or the like). A working fluid (e.g., one or more refrigerants) can flow through the heat transfer circuit and be utilized to heat or cool the process fluid. In the heat transfer circuit, the compressor, the condenser, the expander, and the evaporator can be fluidly connected. An "expander" as described herein may also be referred to as an expansion device. The expander can be an expansion valve, expansion plate, expansion vessel, orifice, or the like, or other such types of expansion mechanisms. It should be appreciated that the expander may be any suitable type of expander used in the field for expanding a working fluid to cause the working fluid to decrease in pressure and temperature. The heat transfer circuit can be configured to include more or less components, such as, but not limited to, an economizer heat exchanger, one or more flow control devices (e.g., a valve, a pump, etc.), a lubricant separator, a receiver tank, a dryer, a suction-liquid heat exchanger, one or more sensors, or the like.

[0021] It is to be understood that the heat transfer circuit can operate according to generally known principles. The heat transfer circuit can be configured to heat and/or cool a liquid process fluid. The liquid process fluid can be a heat transfer fluid or medium (e.g., a liquid such as, but not limited to, water or the like). The heat transfer circuit may be generally representative of a liquid chiller system. The heat transfer circuit can alternatively be configured to heat and/or cool a gaseous process fluid (e.g., a heat transfer medium or fluid (e.g., a gas such as, but not limited to, air or the like), in which case the heat transfer circuit may be generally representative of an air conditioner and/or heat pump.

[0022] In an example embodiment, the heat transfer circuit can operate as a vapor-compression circuit such that the compressor compresses a working fluid (e.g., a heat transfer fluid such as, but not limited to, refrigerant or the like) from a relatively lower pressure gas to a relatively higher-pressure gas. The relatively higher-pressure gas is at a relatively higher temperature, being discharged from the compressor and flowing through the condenser. In accordance with generally known principles, the working fluid flows through the condenser and rejects heat to the process fluid (e.g., water, air, etc.), thereby cooling the working fluid. The cooled working fluid, which is now in a liquid form, flows to the expander that can reduce the pressure of the working fluid. As a result, a portion of the working fluid is converted to a gaseous form. The working fluid, which is now in a mixed liquid and gaseous form flows to the evaporator. The working fluid flows through the evaporator and removes heat from the process fluid (e.g., a heat transfer medium such as, but not limited to, water, a solution, air, etc.), heating the working fluid, and

converting it to a gaseous form. The gaseous working fluid then returns to the compressor. The above-described process continues while the heat transfer circuit is operating, for example, in a cooling mode (e.g., while the compressor is enabled).

[0023] As shown in FIG. 2A, the HVACR system 201 is a cascade system including the heat transfer circuit (the primary unit) 210 and the heat transfer circuit (the secondary unit) 220. An optional cooled loop can be a source of heat energy to the cascade system 201. In an example embodiment, the cooled loop can be a chilled water-cooling loop, or some form of geothermal heat source such as surface water (ocean, lake, stream, or the like) or geothermal well system (e.g., vertical bore, horizontal trench, or the like).

[0024] In an example embodiment, in the cooled loop, a fluid flow (e.g., water) 242 having a first temperature (e.g., at or about 50°F) can be mixed with a fluid flow 246 having a second temperature (e.g., at or about 38°F, which is lower than the first temperature) to form a fluid flow 244 having a third temperature (e.g., at or about 43°F, which is between the first temperature and the second temperature). The fluid flow 244 can flow, e.g., via a pump 240, into the primary unit 210 through its first inlet 211 at the cooled loop side. The primary unit 210 can remove heat energy from the fluid flow 244 such that the fluid flow 244 becomes the fluid flow 247. The fluid flow 247 having the second temperature flows out of the primary unit 210 through its first outlet 212 at the cooled loop side, e.g., via a flow control device (e.g., a valve) 215. The fluid flow 247 can pass through the flow control device (e.g., a valve) 205 as fluid flow 248. In an example embodiment, a portion of the fluid flow 247 can also pass through the flow control device 205 as fluid flow 246, when the flow control device 205 is controlled by e.g. a system controller (e.g., e.g., 110 of FIG. 1).

[0025] In an example embodiment, the primary (low temperature) unit 210 can elevate a cooled loop temperature to a higher temperature (in the intermediate loop) by removing heat energy (e.g., in British thermal unit) from the cooled loop and/or adding heat energy to the intermediate loop. The intermediate loop can be a fluid loop such as a hydronic loop. The primary unit 210 may include, but not limited to, water-to-water heat pump(s) and/or air-to-water heat pump(s). The primary unit 210 may use any suitable type of compressor technology. The primary unit 210 at the cooled loop side may include an evaporator to remove heat energy from the cooled loop, and the primary unit 210 at the intermediate loop side may include a condenser to add heat energy to the intermediate loop.

[0026] In an example embodiment, the secondary (high temperature) unit 220 can remove heat energy from the intermediate loop and elevate the temperature of the intermediate loop to a higher temperature in a heated loop by adding heat energy to the heated loop. The secondary unit 220 can be, but not limited to, water-to-water heat pump(s). The secondary unit 220 may use any

suitable type of compressor technology. The secondary unit 220 at the intermediate loop side may include an evaporator to remove heat energy from the intermediate loop, and the primary unit 220 at the heated loop side may include a condenser to add heat energy to the heated loop.

[0027] In an example embodiment, the intermediate loop can be a closed loop (between the primary unit 210 and the secondary unit 220) that couples the primary unit 210 and the secondary unit 220. In the intermediate loop, a fluid flow (e.g., water) 292 having a fourth temperature (e.g., at or about 95°F) can flow out of the second outlet 214 of the primary unit 210, e.g., via a pump 250, into the secondary unit 220 via its first inlet 221. The secondary unit 220 can remove heat energy from the fluid flow 292 such that the fluid flow 292 becomes the fluid flow 282. The fluid flow 282 having the fifth temperature (e.g., at or about 85°F, which is lower than the fourth temperature) flows out of the secondary unit 220 through its first outlet 222 at the intermediate loop side, e.g., via a flow control device (e.g., a valve) 265.

[0028] In an example embodiment, when the primary unit 210 and the secondary unit 220 are in balance (i.e., in sync), the fluid flow 282 can flow through a flow control device (e.g., a valve) 235 and become fluid flow 284. The fluid flow 284 can flow into a receiver (e.g., a buffer tank) 270 via its inlet 271, and flow out of the receiver 270 via its outlet 272. The fluid flow 284 can then flow, via a flow control device 225, into the primary unit 210 through its second inlet 213 at the intermediate loop side. The primary unit 210 can add heat energy to the fluid flow 284 such that the fluid flow 284 becomes fluid flow 292 flowing out of its second outlet 214 at the intermediate loop side. It is to be understood that when the amount of cooling load for the primary (low temperature) unit 210 and the amount of heating load for the secondary (high temperature unit 220) are in balance, cascading units (the primary unit 210 and the secondary unit 220) on the intermediate loop side (e.g., the hydronic side) are configured to take the fluid leaving the condenser of the low temperature unit 210 and push it into the evaporator of the high temperature unit 220 to further boost the temperature.

[0029] In an example embodiment, in the heated loop, a fluid flow (e.g., water) 262 having a sixth temperature (e.g., at or about 135°F) can flow, via a pump 260, into the secondary unit 220 through its second inlet 223 at the heated loop side. The secondary unit 220 can add heat energy to the fluid flow 262 such that the fluid flow 262 becomes fluid flow 264 (having a seventh temperature, e.g., at or about 155°F, which is greater than the sixth temperature) flowing out of its second outlet 224 at the heated loop side, e.g., via a flow control device (e.g., a valve) 255. It is to be understood that the heated loop can be the main sink of heat energy from the cascade system. The heated loop can be a building or process heating water loop.

[0030] It is to be understood that in typical cascade system operations, the capacity of the cooled loop and

the heated loop may not be in balance or in sync. That is, the heat output of the primary unit 210's condenser may not naturally and dynamically meet the heat input requirements of the secondary unit 220's evaporator. This deviation (of 210's heat output and 220's heat input) may cause the temperature in the intermediate loop to vary. It is to be understood that it may be possible to control the primary unit 210's and the secondary unit 220's capacities to keep the intermediate loop's temperature in an acceptable/desired range under some operating conditions. However, it may be difficult or impossible to guarantee this (i.e., the intermediate loop's temperature being in an acceptable/desired range) under various dynamic conditions the cascade system is subject to such as preventing unacceptable temperature transients from occurring (during one or more of the operation modes). Variation of the intermediate loop temperature out of the acceptable/desired design range may result in malfunction of the system and/or units.

[0031] In an example embodiment, when the primary unit 210 and the secondary unit 220 are not in balance (i.e., not in sync), the fluid flow 282 can flow through the flow control device 235 and become fluid flow 286. That is, instead of the fluid flow 282 flowing through the flow control device 235 and becoming fluid flow 284, the flow control device 235 is controlled (e.g., by a controller) to direct the fluid flow 282 (or the fluid flow 292) into a heat exchanger 230 via its first inlet 233. The heat exchanger 230 is coupled to, connected to, or disposed in the intermediate loop (e.g., the heat exchanger 230 connecting to either the fluid flow 282 or to the fluid flow 292). The heat exchanger 230 can either remove heat energy from the fluid flow 286 of the intermediate loop, or add heat energy to the fluid flow 286, based on an operation parameter so that the fluid flow 286 may flow out of the heat exchanger 230 via its first outlet 234 and becomes fluid flow 288 and then becomes fluid flow 284 flowing into the receiver 270.

[0032] In an example embodiment, the operation parameter can be a temperature of the intermediate loop (e.g., leaving and/or entering water temperature of the secondary unit 220, leaving and/or entering water temperature of the primary unit 210, a combination thereof, etc.). The operation parameter can be determined (e.g., by a controller) via sensed measurements of sensor(s) (e.g., temperature sensor(s), etc.).

[0033] In an example embodiment, a fluid flow (away from the intermediate loop side) can flow into the heat exchanger 230 via its second inlet (232 or 231), and the heat exchanger 230 can either remove heat energy from such fluid flow, or add heat energy to such fluid flow, and the fluid flow can flow out of the heat exchanger 230 via its second outlet (231 or 232). A flow control device 245 can be controlled (e.g., by a controller) to adjust, regulate, modulate, or control the flow rate and/or the amount of flow of the fluid flow (away from the intermediate loop side) based on the determined operation parameter so that the operation parameter can be changed back to be in the acceptable/desired range.

[0034] It is to be understood that the heat exchanger 230 can be e.g., an isolation heat exchanger, applied in the intermediate loop of the cascade heating/cooling system, to enable heat exchange between the intermediate loop and another heat sink and/or heat source (not shown, at the side away from the intermediate loop side). Such heat sink and/or heat source can be transient heat sink/source such as a cooling tower circuit, a geothermal, a chilled water circuit, or the like. It is to be understood that the secondary (high temperature) unit 220 may need to reject more heat energy that is produced by the primary (low temperature) unit 210, due to heat produced via the compression. It is to be understood that the primary unit 210 and the secondary unit 220 may almost never be in balance so the intermediate loop temperature may vary. By adding the heat exchanger 230 in the intermediate loop, heat energy can either be added to or removed from the intermediate loop in order to ensure that the temperature of the intermediate loop is within operational parameters.

[0035] In an example embodiment, the cooling capacity of the primary unit 210 can be at or about 1000 tons. That is, the primary unit 210 can make at or about 1000 cooling tons, and the energy rejected into its condenser loop can be at or about 1300 tons due to the heat of compression. If the capacity of the secondary unit 220 is limited to at or about 1000 tons (e.g., on its evaporator capacity), then the additional at or about 300 tons may need to be rejected out of the intermediate loop via the heat exchanger 230. That is, the capacity of the heat exchanger 230 can be at or about 300 tons. It is also to be understood that (the capacity of) the heat exchanger 230 and/or the heat sink and/or heat source can be sized based on the system requirements. For example, they can be sized based on the minimum load of the primary unit 210 if they are only needed for system start up and transient load modulation. If there is a requirement for the primary unit 210 to be able to provide a full cooling capacity under any (or no) heating load, then they can be sized based on the full cooling capacity of the primary unit 210. The heat sink and/or heat source connected to the isolation heat exchanger 230 can provide for the heat removal from and/or heat addition to the intermediate loop via the operation of the heat exchanger 230. In an example embodiment, types of heat sinks and/or heat sources include, but not limited to, evaporative cooling towers dedicated to the intermediate loop operation and/or applied for dedicated unit (210, 220) operation. It is further to be understood that dry coolers or evaporative fluid coolers can be applied rather than separate isolation heat exchanger(s) 230 and evaporative cooling tower(s) as equivalent equipment. The cooling tower can be configured to add heat energy to the atmosphere, by controlling e.g., fan speed or water flow into the cooling tower.

[0036] In an example embodiment, the heat exchanger 230 can be a water-to-water heat exchanger (i.e., a water-water heat exchanger), a water-to-air heat exchanger, or the like. For water-water heat exchangers, the

intermediate loop temperature can be controlled (e.g., by a controller, via the flow control device 245) by controlling the flow (e.g., the amount of flow, the flow rate, etc.) flowing through the water-water heat exchanger. For example, as the flow is controlled to be reduced, the capacity rejected (and/or added) by the heat exchanger 230 may be reduced. Conversely, as the flow is controlled to be increased, the capacity may be increased. The water-water heat exchanger can be in series with a number of heat sources (and/or heat sinks) such as geo-thermal, condenser loop, chilled water circuit, hot water circuit, wastewater, body of water, and/or any viable fluid stream that has a temperature differential with the intermediate loop.

[0037] In an example embodiment, the flow (of the heat exchanger 230) can be controlled in different ways. For example, a variable speed pump can be utilized to regulate the flow, a modulating valve (e.g., the flow control device 245) can be used to regulate the flow, etc. The pump(s)/valve(s) can be on either side of the heat exchanger 230, and they may be feedback controlled to a desired intermediate loop temperature.

[0038] In an example embodiment, the heat exchanger (e.g., 230A of FIG. 2C) can be an air-water heat exchanger. In such configuration, the energy may be exchanged with the ambient air, and the heat exchanger (e.g., 230A of FIG. 2C) can be a cooling tower, a dry fluid cooler, or the like. It is to be understood that with these types of heat exchangers (e.g., 230A of FIG. 2C), the capacity can be adjusted by either regulating the air flow through the heat exchanger, or the fluid flow through the heat exchanger. For regulating the airflow, variable speed fans can be utilized. In an example embodiment, fan staging can be used for varying airflow as well. Louvers may also be used to restrict airflow. It is to be understood that for the water flow (e.g., for the heat exchanger 230), variable speed pumps and/or modulating valves can be utilized. These arrangements may also utilize the intermediate loop temperature for control.

[0039] It is to be understood that in FIG. 2B, the structure and function of the HVACR system 202 is the same as those of the HVACR system 201 of FIG. 2A except that in FIG. 2B, (1) there are two primary units (210 and 210A) arranged in parallel, (2) there are two secondary units (220 and 220A) arranged in parallel, and (3) in the heated loop, the flow control devices are disposed upstream of the inlets of the secondary units (220 and 220A) at the heated loop side (instead of downstream of the outlet of the secondary unit 220 as shown in FIG. 2A).

[0040] It is to be understood that in FIG. 2C, the structure and function of the HVACR system 203 is the same as those of the HVACR systems 201 of FIG. 2A except that in FIG. 2C, (1) there is no cooled loop, and the primary unit 210B can be an air-sourced unit, (2) the heat exchanger 230A replaces the heat exchanger 230 (and another heat source/sink); the heat exchanger 230A can be a fluid or dry cooler for heat rejection, (3) the receiver (buffer tank) is disposed downstream of the outlet of the

primary unit 210B and upstream of the pump 250, and (4) a flow control device 275 is disposed downstream of the flow control device 255 so that the fluid flow 264A can pass through the flow control device 275 as fluid flow 264, and/or a portion of the fluid flow 264A can pass through the flow control device 275 as fluid flow 266, when the flow control device 275 is controlled by e.g. a system controller (e.g., e.g., 110 of FIG. 1). The fluid flow 262 can be mixed with the fluid flow 266 to form a fluid flow 268 flowing to the secondary unit 220B via the pump 260.

[0041] In an example embodiment, the heat exchanger 230A can be a fluid cooler/dry cooler heat exchanger in intermediate loop. The heat exchanger 230A may serve the same function as the isolation heat exchanger 230 (plus a heat sink/source such as a cooling tower), which may be preferable for users who do not want an evaporative cooling tower on site.

[0042] It is to be understood that in FIGS. 2A, 2B, and 2C, the cascade systems (201, 202, 203) can have pump(s) 250 to manage fluid flow through units and/or heat exchangers, to minimize flow transients. Valves and other hydronic specialties can be used to enable hydronic system operation. The units (210, 210A, 210B, 220, 220A, 220B) can control their respective compressor capacity based on e.g., their respective condenser leaving (water) temperature. The intermediate loop heat exchanger (230, 230A) can enable unit start and help protect against heating system load transients. The (capacity of the) heat exchanger (230, 230A) can be sized based on minimum primary units' load if a full cooling capacity is not required of primary units. The heat exchanger (230, 230A) can also be sized for full primary unit cooling capacity if cooling is required at any heating load. Optional receivers such as buffer tanks 270 can be configured to moderate temperature transients caused by units' load changes, and/or to provide sufficient loop fluid volume to keep the control in a stable condition.

[0043] In an example embodiment, the controller (e.g., 110 of FIG. 1) can be configured to regulate and optimize the temperature of the intermediate loop as required by the vapor-compression units, external heating and cooling loads, and system mode of operation. The controller can be also configured to control and coordinate the staging of vapor compression units, heat exchanger(s), and heat sink and/or source operation. Features in the embodiments disclosed herein may provide the intermediate loop heat exchanger and heat sink/source and provide a method to control the temperatures in the intermediate loop when the primary and secondary units' capacities are not matched (e.g., not in balance, not in sync), either unintentionally or intentionally.

[0044] It is to be understood that "matching" of the primary and secondary unit's capacity may consider the fact that the units' compressor, motor cooling, oil cooling, and/or intermediate loop pump heat may be added to the heat energy in the system. As such, the heat energy extracted from the cooled loop will not equal the heat energy added to the heated loop. Rather, the

heat energy added to the heated loop may be the sum of the heat energy extracted from the cooled loop plus the sum of all the other heat energy produced in the cascade system. Thus, the energy that must be extracted from the cooled loop may be from at or about twenty to at or about sixty percent less than that required by the heated loop.

[0045] It is further to be understood that the operation of the intermediate loop heat exchanger (230, 230A) can be controlled (e.g., by a controller) in different operation modes when the primary and secondary unit's capacities during operation are not in balance (in sync), e.g., to add heat energy to the intermediate loop or remove heat energy from the intermediate loop.

[0046] In an example embodiment, the operation of the intermediate loop heat exchanger (230, 230A) can be controlled during system heating mode startup process. It is to be understood that starting the cascade system can be a dynamic process and maintaining the intermediate loop temperature during the process can be challenging. Controlling the operation of the heat exchanger (230, 230A) can simplify and stabilize the intermediate loop temperature during system operation and/or start up. An example startup sequence using the heat exchanger (230, 230A) can include: (1) enabling the intermediate loop, the heat exchanger (230, 230A) and heat rejection (i.e. cooling tower) components, noting that control sequence and setpoints may be required for proper system operation, (2) enabling the cooled loop flow to the primary unit (210, 210A, 210B), (3) enabling the primary unit controlling to its leaving condenser water temperature, if heating is the system's main goal, or to its leaving evaporator water temperature if cooling is the system's main goal, (4) allowing the primary unit's capacity and the intermediate loop's temperature to stabilize, (5) enabling the heated loop flow to the secondary unit (220, 220A, 220B), and (6) enabling the secondary unit controlling to its leaving condenser water temperature, if heating is the system's main goal.

[0047] It is to be understood that as the secondary unit extracts heat from the intermediate loop, the heat rejected via the heat exchanger 230 to the cooling tower can be decreased by the system controls resulting in stable system operation. As long as the heat rejected to the intermediate loop by the primary unit(s) is greater-than or equal-to the heat energy required by the secondary unit(s) to meet the heating load, the system can operate in balance.

[0048] It is to be understood that if the intermediate loop heat exchanger (230, 230A) is connected to a system that can not only remove heat energy from but also add heat energy to the intermediate loop, the intermediate loop temperature can be controlled when the primary and secondary units' capacities are out of sync, within the limits of the system heat sink/source.

[0049] In an example embodiment, the operation of the intermediate loop heat exchanger (230, 230A) can be controlled during cooling dominant operation. It is to be understood that the controlling of both the cascade sys-

tem leaving cooled water temperature and the leaving heated water temperature may be a common requirement in cascade systems, especially when the overall system is in a cool dominant load condition. Features in the embodiments disclosed herein may provide support to the cooling dominant operation to leverage primary unit(s) cooling capacity and to reduce the need for additional cooling units and therefore reduce system cost. In the cooling dominant operation, the control and/or the system operation is similar to the control and/or operation of the system heating mode startup process. It is to be understood that since the overall system loads are cooling dominant, the primary unit(s) operating capacity may exceed that required to maintain the temperature in the intermediate loop. The heat exchanger 230 and the heat rejection (i.e. the cooling tower) may extract excess heat from the intermediate loop, maintaining the intermediate loop's temperature within an acceptable temperature range.

[0050] In an example embodiment, the operation of the intermediate loop heat exchanger (230, 230A) can be controlled during the heating dominant operation (which is an inverse of the cooling dominant operation), with control of both the cascade system leaving cooled water temperature and the leaving heated water temperature being possible if a heat sink and heat source system is connected to the intermediate loop heat exchanger. The control and/or operation may enable injections of heat energy from that heat source, in addition to that from the chilled water loop load.

[0051] In an example embodiment, the operation of the intermediate loop heat exchanger (230, 230A) can be controlled during the system shutdown. It is to be understood that getting both the primary and secondary units to reduce capacity and shutdown simultaneously and maintaining the intermediate loop temperature can be very difficult. Features in the embodiments disclosed herein may eliminate the difficulty. The reverse of the startup sequence can be implemented.

[0052] It is to be understood that a large buffer tank can be included in the system (instead of the heat exchanger 230, 230A in the intermediate loop) the units' operation may be synced up enough to get it to operate. Such an embodiment may not enable cooling dominant operation.

[0053] FIG. 3 is a flow chart illustrating an example processing flow 300 for operating a cascade HVACR system, arranged in accordance with at least some embodiments described herein.

[0054] It is to be understood that the processing flow 300 disclosed herein can be conducted by one or more controllers including e.g., the controller of the HVACR system (and/or of the unit) of FIG. 1 and/or any other suitable controller, unless otherwise specified.

[0055] It is also to be understood that the processing flow 300 can include one or more operations, actions, or functions as illustrated by one or more of blocks 310, 320, 330, 340, and 350. These various operations, functions, or actions may, for example, correspond to software,

program code, or program instructions executable by a processor (e.g., a controller) that causes the functions to be performed. Although illustrated as discrete blocks, obvious modifications may be made, e.g., two or more of the blocks may be re-ordered; further blocks may be added; and various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. It is to be understood that before the processing flow 300, operations including initializations or the like may be performed. For example, system parameters may be initialized. It is to be understood that the processes, operations, or actions described in FIGS. 1, 2A, 2B, and 2C may be implemented or performed by the controller. Processing flow 300 may begin at block 310.

[0056] At block 310 (Operate cascade System), the controller may be configured to operate the cascade system (e.g., 201, 202, 203 of FIGS. 2A, 2B, and 2C). It is to be understood that the primary unit(s) and/or the secondary unit(s) can be operated and/or controlled independently relative to each other. Processing may proceed from block 310 to block 320.

[0057] At block 320 (In Sync?), the controller may be configured to determine whether the primary unit(s) and the secondary unit(s) are in balance (in sync). In an example embodiment, the controller may be configured to determine whether the primary unit(s) and the secondary unit(s) are in balance (in sync) by determining whether an operation parameter is within a desired range. The operation parameter can be a temperature of the intermediate loop (e.g., the leaving and/or entering water temperature of the primary unit at the intermediate loop side, the leaving and/or entering water temperature of the secondary unit at the intermediate loop side, a combination thereof, etc.). If the operation parameter is within a desired range (e.g., at or below a first threshold and at or above a second threshold, where the first threshold is greater than the second threshold), the cascade system is in sync, processing may proceed from block 320 back to block 310.

[0058] If the operation parameter is not within the desired range (e.g., above the first threshold or below the second threshold), the cascade system is not in sync, processing may proceed from block 320 to block 330.

[0059] At block 330 (Excessive Heat?), the controller may be configured to determine whether the intermediate loop or the system has excessive heat energy. In an example embodiment, the controller may be configured to determine whether the intermediate loop or the system has excessive heat energy by determining whether the operation parameter is above the first threshold. If the operation parameter is above the first threshold, the intermediate loop or the system has excessive heat energy, processing may proceed from block 330 to block 350.

[0060] If the operation parameter is not above the first threshold (that is, the operation parameter is instead below the second threshold), the intermediate loop or

the system needs extra heat energy, processing may proceed from block 330 to block 340.

[0061] At block 340 (Add heat to the intermediate loop), the controller may be configured to control the heat exchanger (230, 230A of FIGS. 2A-2C) of the intermediate loop and/or its associated heat sink/source and/or its associated flow control device(s), to add heat energy to the intermediate loop, to keep/adjust the operation parameter in/to the desired range (e.g., at or below the first threshold and at or above the second threshold). Processing may proceed from block 340 back to block 310.

[0062] At block 350 (Remove heat from the intermediate loop), the controller may be configured to control the heat exchanger (230, 230A of FIGS. 2A-2C) of the intermediate loop and/or its associated heat sink/source and/or its associated flow control device(s), to remove/reject/subtract heat energy from the intermediate loop, to keep/adjust the operation parameter in/to the desired range (e.g., at or below the first threshold and at or above the second threshold). Processing may proceed from block 350 back to block 310.

[0063] It is to be understood that features in the embodiments disclosed herein may allow unbalanced and/or uneven loads of the units and allow control to the capacity of the cold-water temperature and the hot-water temperature independently (e.g., allowing uneven loads and control for different water temperatures).

[0064] It is to be understood that the processes described with reference to the flowchart of FIG. 3 and/or the processes described in other figures may be implemented as computer software programs or in hardware. The computer program product may include a computer program stored in a computer readable non-volatile medium. The computer program includes program codes for performing the method shown in the flowcharts and/or GUIs. The processes and logic flows described in this document can be performed by one or more programmable processors (e.g., controller(s) of an HVACR system, controller(s) of a unit) executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., a field programmable gate array, an application specific integrated circuit, or the like.

[0065] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors (e.g., controller(s) of an HVACR system, controller(s) of a unit), and any one or more processors of any kind of digital computer. Generally, a processor will receive instructions and data from a read only memory or a random-access memory or both. The essential elements of a computer are a processor for performing instructions and one or more memory devices for storing instructions and data.

[0066] It is to be understood that different features, variations and multiple different embodiments have been shown and described with various details. What has been

described in this application at times in terms of specific embodiments is done for illustrative purposes only and without the intent to limit or suggest that what has been conceived is only one particular embodiment or specific embodiments. It is to be understood that this disclosure is not limited to any single specific embodiments or enumerated variations. Many modifications, variations and other embodiments will come to mind of those skilled in the art, and which are intended to be and are in fact covered by both this disclosure. It is indeed intended that the scope of this disclosure should be determined by a proper legal interpretation and construction of the disclosure, including equivalents, as understood by those of skill in the art relying upon the complete disclosure present at the time of filing.

Aspects:

[0067] It is appreciated that any one of aspects can be combined with each other.

[0068] Aspect 1. A heating, ventilation, air conditioning, and refrigeration (HVACR) system, the system comprising: a first heat transfer circuit; a second heat transfer circuit; a fluid loop between the first heat transfer circuit and the second heat transfer circuit; a heat exchanger connecting to the fluid loop; and a controller configured to: determine an operation parameter of the system; and control the heat exchanger to remove heat from the fluid loop when the operation parameter is above a first threshold.

[0069] Aspect 2. The HVACR system of aspect 1, wherein the controller is further configured to control the heat exchanger to add heat to the fluid loop when the operation parameter is below a second threshold.

[0070] Aspect 3. The HVACR system of aspect 1 or aspect 2, wherein the first heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the first heat transfer circuit is configured to add heat to the fluid loop.

[0071] Aspect 4. The HVACR system of any one of aspects 1-3, further comprising: a cooled loop configured to add heat to the fluid loop via the first heat transfer circuit, the cooled loop being a source of heat of the system.

[0072] Aspect 5. The HVACR system of any one of aspects 1-4, wherein the second heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the second heat transfer circuit is configured to remove heat from the fluid loop.

[0073] Aspect 6. The HVACR system of any one of aspects 1-5, further comprising: a heated loop configured to remove heat from the fluid loop via the second heat transfer circuit, the heated loop being a sink of heat of the system.

[0074] Aspect 7. The HVACR system of any one of aspects 1-6, further comprising: a flow control device, the

controller is further configured to control the flow control device to direct a fluid flow from the fluid loop to the heat exchanger when the operation parameter is above the first threshold.

[0075] Aspect 8. The HVACR system of aspect 7, wherein the controller is further configured to control the flow control device to direct the fluid flow from the fluid loop to the heat exchanger when the operation parameter is below a second threshold.

[0076] Aspect 9. The HVACR system of aspect 8, wherein the controller is further configured to control the flow control device to block the fluid flow from the fluid loop to the heat exchanger when the operation parameter is at or below the first threshold and is at or above the second threshold.

[0077] Aspect 10. The HVACR system of any one of aspects 1-9, wherein the operation parameter is a temperature of a fluid flow downstream of the first heat transfer circuit and upstream of the second heat transfer circuit.

[0078] Aspect 11. A method of operating a heating, ventilation, air conditioning, and refrigeration (HVACR) system, the system including a first heat transfer circuit; a second heat transfer circuit; a fluid loop between the first heat transfer circuit and the second heat transfer circuit; a heat exchanger connecting to the fluid loop; and a controller, the method comprising: determining an operation parameter of the system; and controlling the heat exchanger to remove heat from the fluid loop when the operation parameter is above a first threshold.

[0079] Aspect 12. The method of aspect 11, further comprising: controlling the heat exchanger to add heat to the fluid loop when the operation parameter is below a second threshold.

[0080] Aspect 13. The method of aspect 11 or aspect 12, wherein the first heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the first heat transfer circuit is configured to add heat to the fluid loop.

[0081] Aspect 14. The method of any one of aspects 11-13, wherein the system further comprises a cooled loop configured to add heat to the fluid loop via the first heat transfer circuit, the cooled loop being a source of heat of the system.

[0082] Aspect 15. The method of any one of aspects 11-14, wherein the second heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the second heat transfer circuit is configured to remove heat from the fluid loop.

[0083] Aspect 16. The method of any one of aspects 11-15, wherein the system further comprises a heated loop configured to remove heat from the fluid loop via the second heat transfer circuit, the heated loop being a sink of heat of the system.

[0084] Aspect 17. The method of any one of aspects 11-16, wherein the system further comprises a flow con-

trol device, the method further comprises controlling the flow control device to direct a fluid flow from the fluid loop to the heat exchanger when the operation parameter is above the first threshold.

[0085] Aspect 18. The method of aspect 17, further comprising: controlling the flow control device to direct the fluid flow from the fluid loop to the heat exchanger when the operation parameter is below a second threshold.

[0086] Aspect 19. The method of aspect 18, further comprising: controlling the flow control device to block the fluid flow from the fluid loop to the heat exchanger when the operation parameter is at or below the first threshold and is at or above the second threshold.

[0087] Aspect 20. The method of any one of aspects 11-19, wherein the operation parameter is a temperature of a fluid flow downstream of the first heat transfer circuit and upstream of the second heat transfer circuit.

[0088] 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.

[0089] 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, ventilation, air conditioning, and refrigeration (HVACR) system, the system comprising:

a first heat transfer circuit;
a second heat transfer circuit;
a fluid loop between the first heat transfer circuit and the second heat transfer circuit;
a heat exchanger connecting to the fluid loop;
and
a controller configured to:

determine an operation parameter of the system; and
control the heat exchanger to remove heat from the fluid loop when the operation parameter is above a first threshold.

2. The HVACR system of claim 1, wherein the controller

is further configured to control the heat exchanger to add heat to the fluid loop when the operation parameter is below a second threshold.

3. The HVACR system of claim 1 or 2, wherein the first heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the first heat transfer circuit is configured to add heat to the fluid loop.

4. The HVACR system of claim 3, further comprising: a cooled loop configured to add heat to the fluid loop via the first heat transfer circuit, the cooled loop being a source of heat of the system.

5. The HVACR system of any one of claims 1 to 4, wherein the second heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the second heat transfer circuit is configured to remove heat from the fluid loop.

6. The HVACR system of claim 5, further comprising: a heated loop configured to remove heat from the fluid loop via the second heat transfer circuit, the heated loop being a sink of heat of the system.

7. The HVACR system of any one of claims 1 to 6, further comprising:

a flow control device,
the controller is further configured to control the flow control device to direct a fluid flow from the fluid loop to the heat exchanger when the operation parameter is above the first threshold.

8. The HVACR system of claim 7, wherein the controller is further configured to control the flow control device to direct the fluid flow from the fluid loop to the heat exchanger when the operation parameter is below a second threshold.

9. The HVACR system of claim 8, wherein the controller is further configured to control the flow control device to block the fluid flow from the fluid loop to the heat exchanger when the operation parameter is at or below the first threshold and is at or above the second threshold.

10. The HVACR system of any one of claims 1 to 9, wherein the operation parameter is a temperature of a fluid flow downstream of the first heat transfer circuit and upstream of the second heat transfer circuit.

11. A method of operating a heating, ventilation, air

conditioning, and refrigeration (HVACR) system, the system including a first heat transfer circuit; a second heat transfer circuit; a fluid loop between the first heat transfer circuit and the second heat transfer circuit; a heat exchanger connecting to the fluid loop; and a controller, the method comprising:

determining an operation parameter of the system; and
controlling the heat exchanger to remove heat from the fluid loop when the operation parameter is above a first threshold.

12. The method of claim 11, further comprising:

(i) controlling the heat exchanger to add heat to the fluid loop when the operation parameter is below a second threshold, or
(ii) controlling a flow control device to direct a fluid flow from the fluid loop to the heat exchanger when the operation parameter is above the first threshold, or
(iii) controlling a flow control device to direct a fluid flow from the fluid loop to the heat exchanger when the operation parameter is above the first threshold, and controlling the flow control device to direct the fluid flow from the fluid loop to the heat exchanger when the operation parameter is below a second threshold, or
(iv) controlling a flow control device to direct a fluid flow from the fluid loop to the heat exchanger when the operation parameter is above the first threshold, controlling the flow control device to direct the fluid flow from the fluid loop to the heat exchanger when the operation parameter is below a second threshold, and controlling the flow control device to block the fluid flow from the fluid loop to the heat exchanger when the operation parameter is at or below the first threshold and is at or above the second threshold.

13. The method of claim 11 or 12, wherein (a) the first heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, and the first heat transfer circuit is configured to add heat to the fluid loop, or

wherein (b) the second heat transfer circuit includes a fluid inlet configured to receive fluid from the fluid loop and a fluid outlet for fluid flowing out to the fluid loop, the second heat transfer circuit is configured to remove heat from the fluid loop, or
wherein (c) the operation parameter is a temperature of a fluid flow downstream of the first heat transfer circuit and upstream of the second heat transfer circuit.

14. The method of claim 13, wherein under (a), the system further comprises a cooled loop configured to add heat to the fluid loop via the first heat transfer circuit, the cooled loop being a source of heat of the system.

15. The method of claim 13 or 14, wherein under (b), the system further comprises a heated loop configured to remove heat from the fluid loop via the second heat transfer circuit, the heated loop being a sink of heat of the system.

Fig. 1

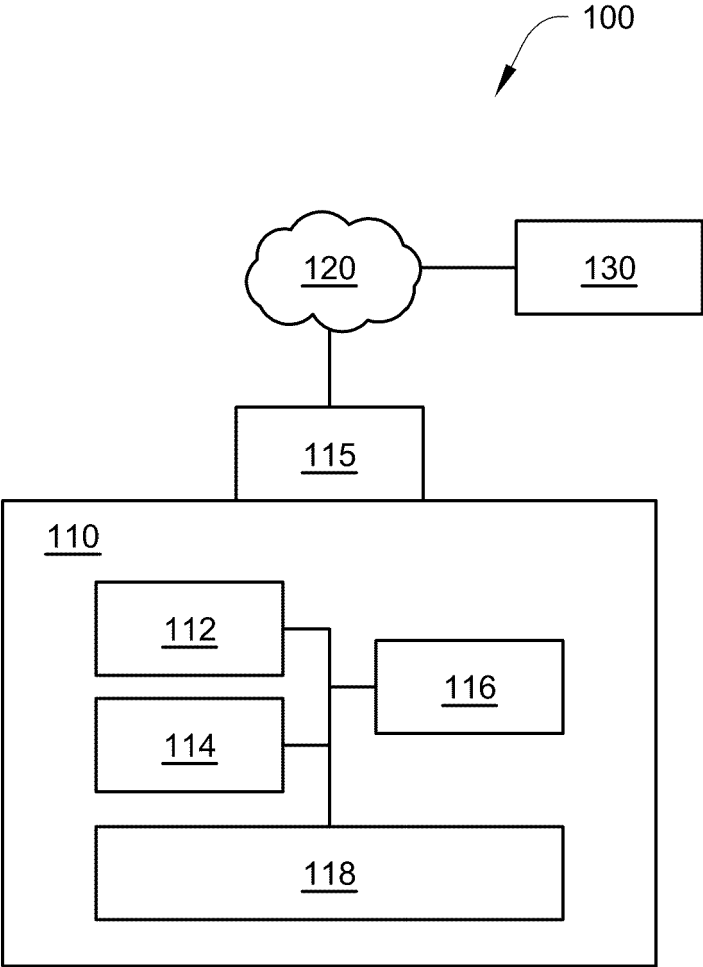


Fig. 2A

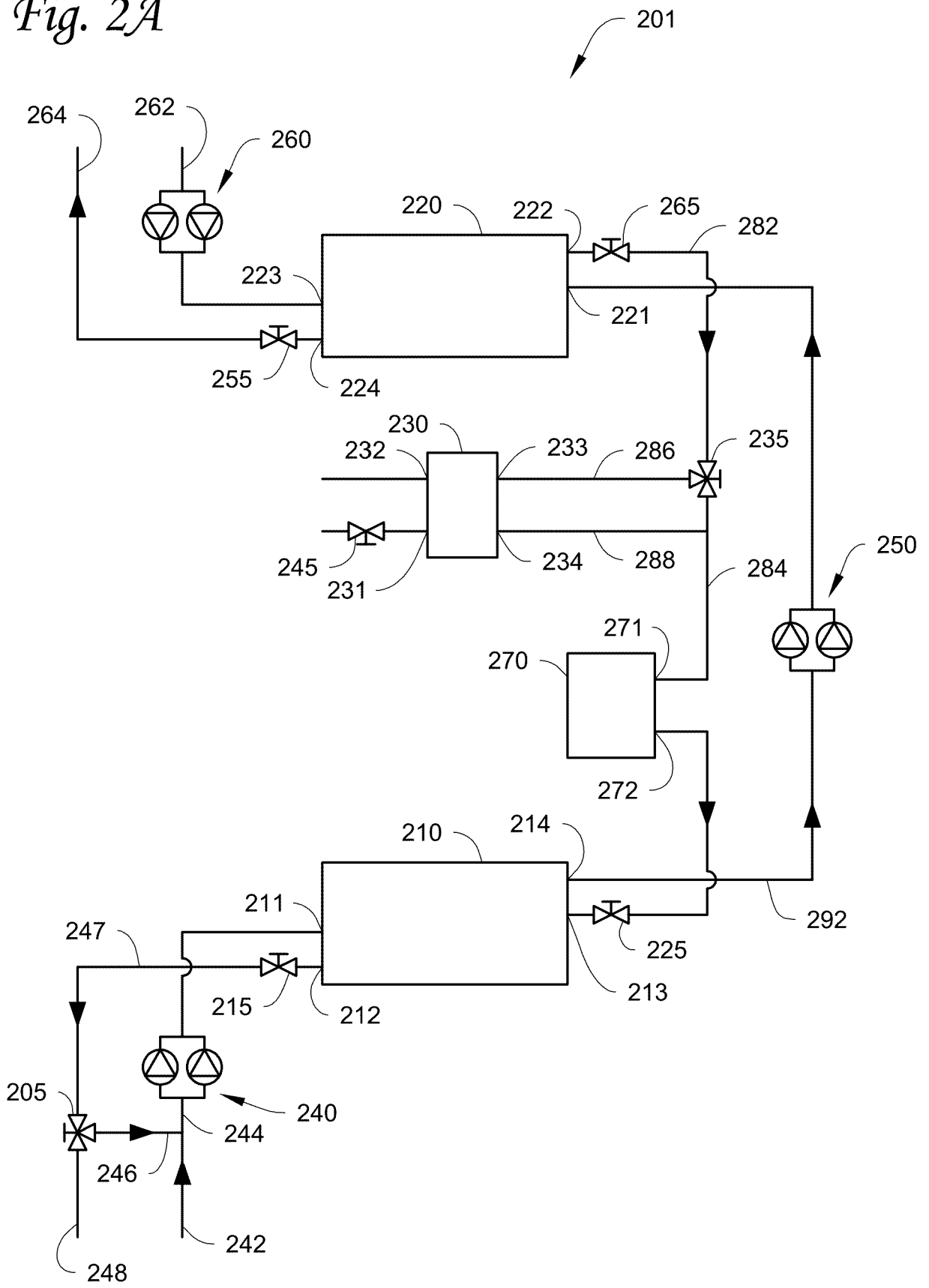


Fig. 2B

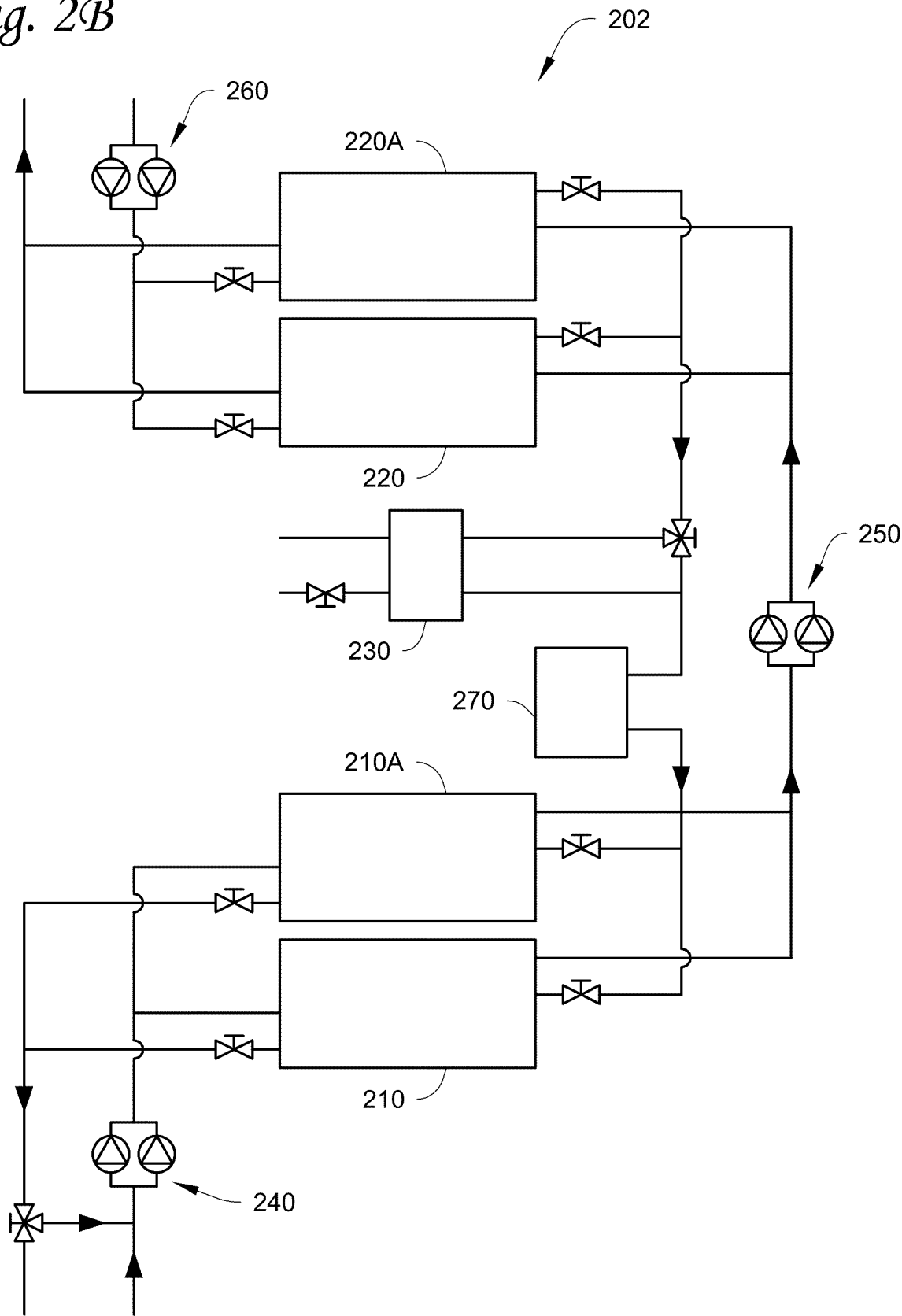


Fig. 2C

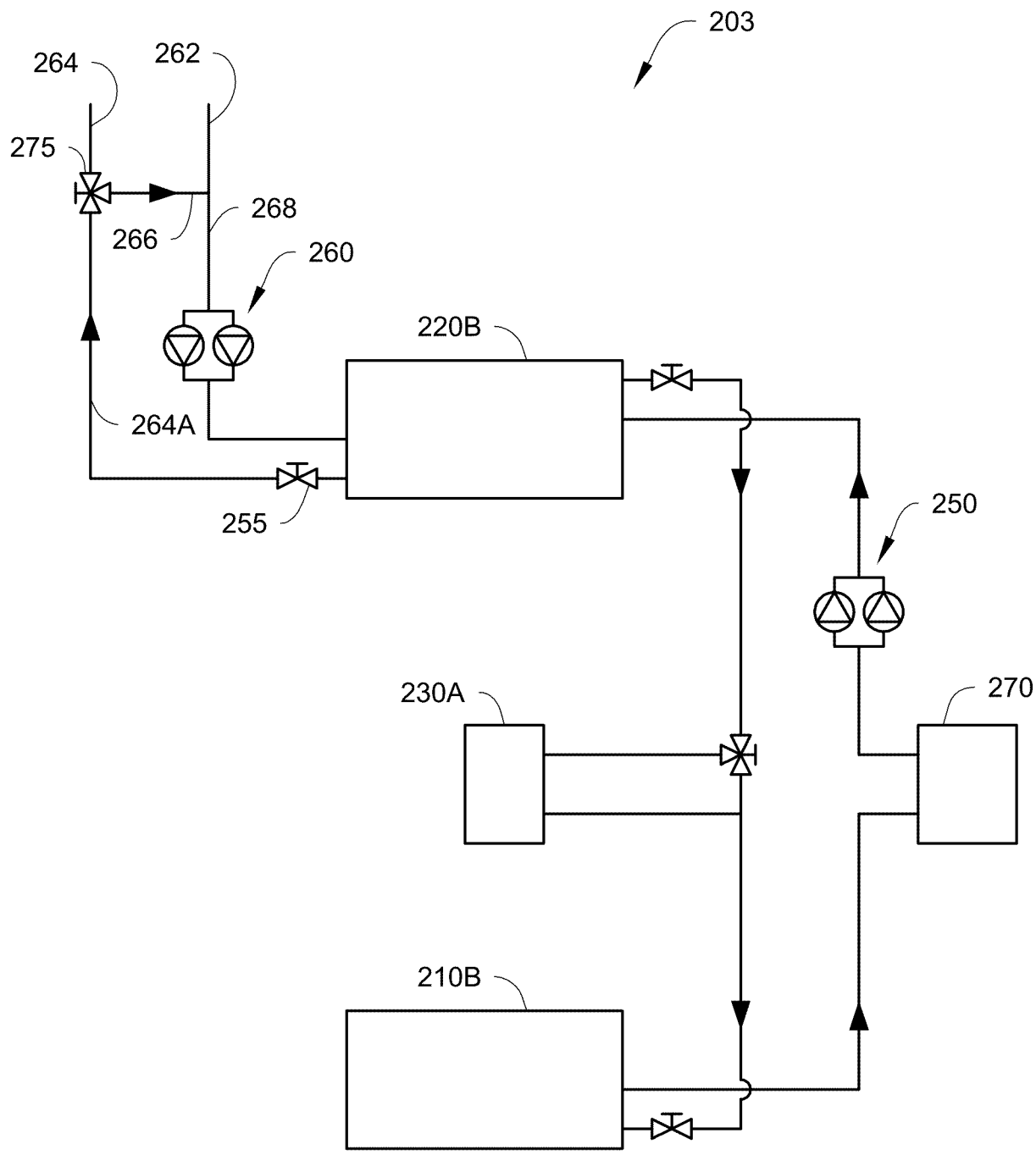
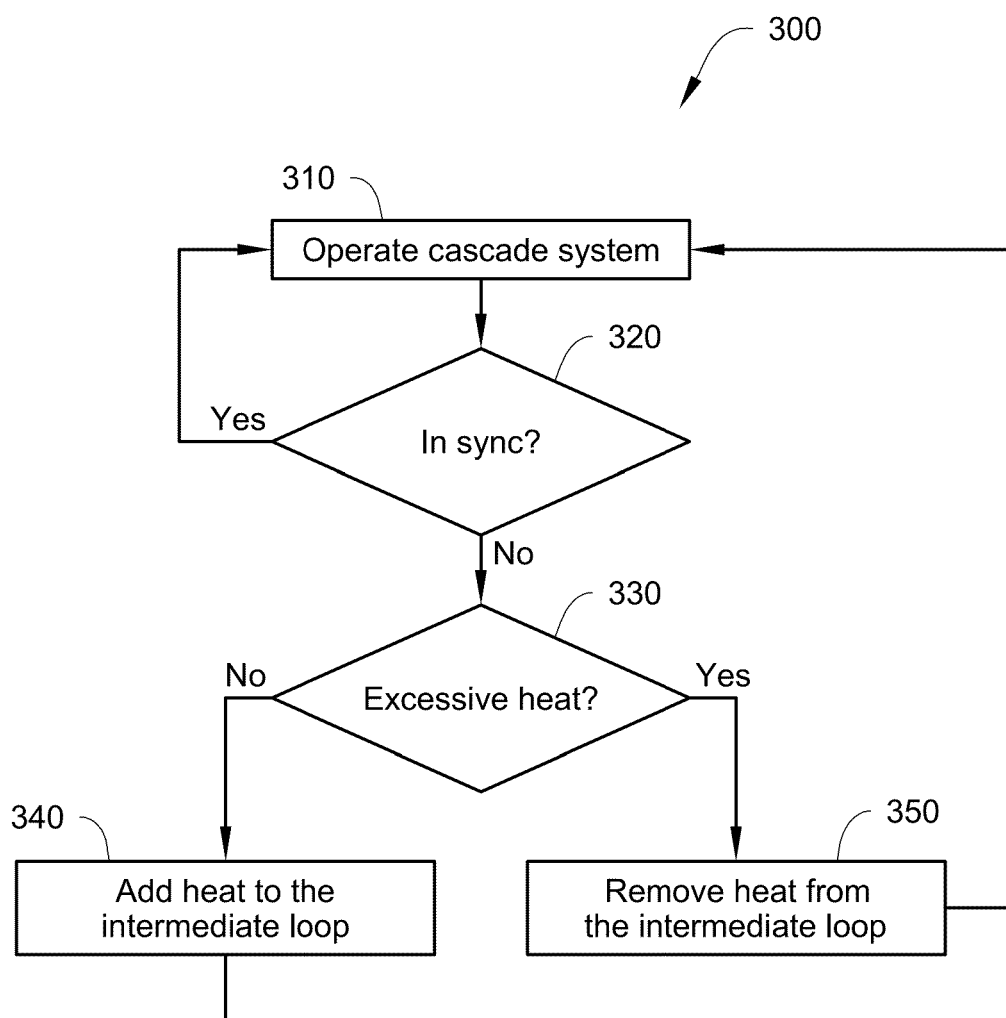


Fig. 3



EUROPEAN SEARCH REPORT

Application Number

EP 25 21 5094

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2023/128232 A1 (ZOU YANG [US] ET AL) 27 April 2023 (2023-04-27) * paragraph [0008] - paragraph [0089]; figures 1-9 *	1-15	INV. F25B49/02
X	WO 2024/069970 A1 (MITSUBISHI ELECTRIC CORP [JP]) 4 April 2024 (2024-04-04) * paragraph [0004] - paragraph [0084]; figures 1-11 *	1-15	
X	US 2007/246555 A1 (NISHIMURA TADAFUMI [JP] ET AL) 25 October 2007 (2007-10-25) * paragraph [0084] *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F24F F25B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		12 March 2026	Lucic, Anita
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P34C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 25 21 5094

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

12-03-2026

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2023128232 A1	27-04-2023	AU 2022377243 A1	18-04-2024
		EP 4423443 A1	04-09-2024
		US 2023128232 A1	27-04-2023
		US 2025109898 A1	03-04-2025
		WO 2023075972 A1	04-05-2023

WO 2024069970 A1	04-04-2024	CN 119895208 A	25-04-2025
		EP 4596995 A1	06-08-2025
		JP WO2024069970 A1	04-04-2024
		WO 2024069970 A1	04-04-2024

US 2007246555 A1	25-10-2007	AU 2005261038 A1	19-01-2006
		CN 1981166 A	13-06-2007
		EP 1775526 A1	18-04-2007
		JP 4649897 B2	16-03-2011
		JP 2006023049 A	26-01-2006
		KR 20070035068 A	29-03-2007
		US 2007246555 A1	25-10-2007
		WO 2006006515 A1	19-01-2006

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82