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(54) **HEAT EXCHANGE UNIT FOR A REFRIGERATION APPARATUS WITH A THERMAL STORAGE AND USING CO₂ AS REFRIGERANT**

(57) The present disclosure relates to a heat exchange unit 200 that is used for a refrigeration apparatus using CO₂ as refrigerant, including: at least one compressor 10, a heat-source-side heat exchanger 11, an expansion device 12, a heat exchange unit gas port 92 configured to communicate to a utilization-side heat exchanger 80A disposed outside the heat exchange unit 200, a first heat exchange unit fluid port 96 configured to communicate to the utilization-side heat exchanger 80A, a second heat exchange unit fluid port 32B communicating to the heat-source-side heat exchanger 11, and a third heat exchange unit fluid port 52B communicating to the expansion device 12, wherein the second heat exchange unit fluid port 32B and the third heat exchange unit fluid port 52 are configured to communicate to a thermal storage unit 100, a heat exchanger, particularly a plate heat exchanger, a capacity increasing unit, or a combi unit including a thermal storage unit and a capacity increasing unit, which is preferably disposed outside the heat exchange unit 200. Moreover, the disclosure relates to a refrigerant circuit 1 for a refrigeration apparatus with a thermal storage, which is using CO₂ as refrigerant. Additionally, the disclosure relates to a thermal storage unit 100 used for a refrigeration apparatus using CO₂ as refrigerant.

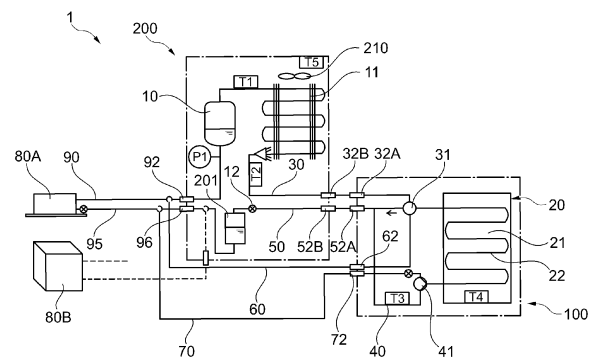


Fig. 2

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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigerant circuit for cooling and/or heating purposes. In particular, the disclosure relates to a refrigerant circuit for a refrigeration apparatus with a thermal storage particularly a thermal storage with a phase changing material (PCM). Even more particular, the disclosure relates to a refrigerant circuit for a refrigeration apparatus with a thermal storage using CO₂ as a refrigerant.

BACKGROUND

[0002] As described in EP 2 402 681 A1, conventionally, a refrigerating apparatus has been known, which includes a refrigerant circuit performing a refrigeration cycle. The refrigerating apparatus of this type has been widely used for coolers such as refrigerators and freezers for storing food etc. and air conditioners for cooling/heating an inside of a room.

[0003] Moreover, EP 2 844 924 B1 discloses an air-conditioning system comprising: a chiller system including a compressor, a condenser, an expansion device and an evaporator, a phase change material in thermal communication with the condenser, an actuator coupled to the phase change material; and a controller providing a trigger signal to the actuator to initiate changing the phase change material from a supercooled state to a solid state, wherein the phase change material includes a coolant supply line in thermal communication with the phase change material and the coolant supply line is coupled to the chiller system. The phase change material is selected so that the phase change material transitions from liquid to solid when cooling demand on the chiller system is low or non-existent. This may occur in the evening, when ambient temperatures are lower. During the day, the solid or frozen phase change material absorbs energy from the condenser, improving the efficiency of the condenser when the chiller system is running and increasing efficiency and capacity of the chiller system.

[0004] The air-conditioning system described in EP 2 844 924 B1 aims to provide a system that is capable of balancing cooling demand by using a phase change material as a heat buffer between the condenser and the ambient air temperature. During the day, the phase change material absorbs the heat from the condenser and release it to the outside air. Due to its thermal capacity and the latent heat release, the phase change material will heat up slower than air and thus result in higher energy efficiency. At night, the phase change material is cooled down faster by the fresher air temperature using the fan only.

[0005] However, active cooling of the phase change material with the fan is inefficient, therefore, said system is particularly not suitable for regions with warmer climates, where air temperatures at night remain high.

Moreover, the described system is not able to realize big improvements with regard to energy efficiency but will "flatten out" the energy consumption pattern due to the thermal response time of the phase change material. This is in particular true, since the active cooling of the phase change material also causes heating of the condenser, as the condenser is in thermal communication with the phase change material, and no control of the use of the phase change material is possible.

[0006] Additionally, fluorocarbon has been conventionally used as a refrigerant in refrigeration systems. However, following the Montreal Protocol in 1987 and the Kyoto Protocol in 1997, artificially developed substitute chlorofluorocarbons, whose ozone depletion potential is low, have become commonly used as refrigerants. Yet, in recent years, the development of technology using even more environmentally friendly substitutes, particularly using natural refrigerants such as carbon dioxide, ammonia, hydrocarbons (isobutene, propane, etc.), water and air, has progressed. These natural refrigerants are materials that have the property that, when compared with the aforementioned chlorofluorocarbons and substitute chlorofluorocarbons, their GWP (Global Warming Potential) value is extremely low.

[0007] Among these, carbon dioxide is known as a material whose ozone depletion potential is zero, whose global warming potential is also much lower in comparison to conventional refrigerants, which has no toxicity, is non-flammable, and whose efficiency in creating a high temperature is good among natural refrigerants, and from environmental/energy aspects and safety aspects, carbon dioxide is garnering attention as a refrigerant in air conditioners.

[0008] However, carbon dioxide (CO₂) performs at high outside temperatures with a lower efficiency than fluorinated refrigerants. Accordingly, on an annual base the performance of an air conditioner system using CO₂ as a refrigerant is lower compared to fluorinated refrigerants, particularly in warmer climates.

SUMMARY

[0009] In view of the above, there is the desire to provide a refrigerant circuit for a refrigeration apparatus with a thermal storage, which is using carbon dioxide (CO₂) as refrigerant, allowing the storage of thermal energy, particularly cold, for example when outside temperatures are low, preferably during the night, and use the thermal energy during peak temperatures during the day when transcritical conditions occur or during peak demand, in order to substantially prevent a decrease in cooling efficiency, which is particularly due to the use of a natural refrigerant like carbon dioxide, while ensuring a high cooling capacity and providing flexibility with regard to charging the thermal storage with cold. Additionally, if circumstances require it or allow it, the provided refrigerant circuit should also be able to store thermal energy, particularly cold, even during peak temperatures when for ex-

ample much/excess PV power (CO₂ neutral energy generation) is available.

[0010] This aim may be achieved by a heat exchange unit as defined in claim 1 and used for a refrigeration apparatus using CO₂ as refrigerant. Embodiments may be found in the dependent claims, the following description and the accompanying drawings.

[0011] According to a first aspect of present disclosure, a refrigerant circuit for a refrigeration apparatus with a thermal storage, which is using carbon dioxide (CO₂) as refrigerant, includes: at least one compressor, a heat-source-side heat exchanger, an expansion device, and a thermal storage, including a thermal storage material, particularly a phase changing material (PCM), wherein the refrigerant circuit further includes: a first fluid communication pipe (30) communicating between a fluid side of the heat-source-side heat exchanger and one side of the thermal storage, and a second fluid communication pipe communicating between the expansion device and the other side of the thermal storage.

[0012] Hence, a refrigerant circuit is provided, capable of storing thermal energy, particularly cold, when for example outside temperatures are low, and using the stored thermal energy during peak temperatures during the day when transcritical conditions occur or during peak demand, in order to substantially prevent a decrease in cooling efficiency, which is particularly due to the use of a natural refrigerant like carbon dioxide, while ensuring a high cooling capacity and providing flexibility with regard to charging the thermal storage with cold. Additionally, the provided refrigerant circuit also allows to store thermal energy, particularly cold, during peak temperatures, if other circumstances require it or make it possible, like for example excess of PV (photovoltaic) power or other CO₂ neutral generated electric power. Accordingly, the provided refrigerant circuit can not only store thermal energy when low outside temperatures allow it, but also by availability of excess renewable electricity, which in total will decrease CO₂ emissions even further, even if the refrigerant circuit is less efficient.

[0013] As regards the term "natural" concerning the "natural refrigerant", the term defines in the present disclosure refrigerants that occur naturally.

[0014] Moreover, in the present disclosure the term "fluid" concerning the "fluid communication pipe(s)" and the "fluid port(s)" is used as the fluid, particularly the CO₂, flowing there through is in a supercritical condition (supercritical fluid), which means, the fluid is at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist. Accordingly, the "fluid communication pipe(s)" and the "fluid port(s)" are common "liquid communication pipe(s)" and "liquid port(s)", only emphasizing that the fluid flowing there through is in a supercritical condition.

[0015] According to a second aspect, the refrigerant circuit further includes a first switching mechanism located/provided on the first fluid communication pipe and communicating among the heat-source-side heat ex-

changer, the thermal storage, a third fluid communication pipe, and a first gas communication pipe, wherein the third fluid communication pipe communicates to the expansion device and the first gas communication pipe communicates to a suction side of the compressor.

[0016] Moreover, the first switching mechanism may include: a first valve, which is a three-way valve, communicating among the heat-source-side heat exchanger, the expansion device and the thermal storage, and preferably a second valve, which is a three-way valve and located/provided between the first valve and the thermal storage, communicating among the first valve, the thermal storage and the first gas communication pipe.

[0017] Alternatively, the first switching mechanism may include: a first valve, which is a four-way valve, communicating among the heat-source-side heat exchanger, the thermal storage, the first gas communication pipe and the expansion device, wherein the first switching mechanism preferably further comprises a check valve that stops a backflow from the third fluid communication pipe to the first valve.

[0018] Furthermore, the refrigerant circuit may include a second switching mechanism located/provided on the second fluid communication pipe and communicating among the thermal storage, the expansion device and a fourth fluid communication pipe, wherein the fourth fluid communication pipe is communicating to a utilization-side heat exchanger.

[0019] Additionally, the second switching mechanism may be a valve, which is a three-way valve, communicating among the thermal storage, the expansion valve and the utilization-side heat exchanger, wherein preferably an expansion device is provided on the fourth fluid communication pipe, located/provided between the second switching mechanism and the utilization-side heat exchanger.

[0020] According to a third aspect, the refrigerant circuit further comprising a receiver, which is preferably located/provided on the third fluid communication pipe, preferably between the expansion device and a/the utilization-side heat exchanger, wherein the receiver (201) is configured to separate liquid refrigerant and gas refrigerant.

[0021] Moreover, the refrigerant circuit may further include an additional utilization-side heat exchanger communicating on its liquid side with the expansion device, particularly via a/the receiver, and on its gas side with the at least one compressor.

[0022] According to a fourth aspect, the refrigerant circuit further includes a subcooling heat exchanger, which is preferably located/provided between a/the utilization-side heat exchanger and the expansion device, more preferably between the utilization-side heat exchanger and a/the receiver.

[0023] The utilization-side heat exchanger may be a heat exchanger of an air-conditioner, preferably of an indoor unit, and the additional utilization-side heat exchanger may be a heat exchanger of a cooler such as a

refrigerator or a freezer.

[0024] According to a fifth aspect, the refrigerant circuit further includes a second compressor that is provided upstream of the at least one compressor, in order to build a two-stage compressor system.

[0025] According to a sixth aspect, the refrigerant circuit further includes a second and a third compressor that are provided parallel to each other and upstream of the at least one compressor, in order to build a two-stage compressor system, wherein preferably the second compressor communicates with an additional utilization-side heat exchanger or the additional utilization-side heat exchanger to build a refrigerant circuit for refrigeration and the third compressor communicates with the utilization-side heat exchanger to build a refrigerant circuit for air-conditioning.

[0026] The refrigerant circuit may further include an injection pipe communicating between a gas side of the receiver and a suction side of the at least one compressor, wherein the injection pipe is configured to inject intermediate-pressure refrigerant into the compressor.

[0027] Moreover, the injection pipe may before being connected to the suction side of the at least one compressor join with two high-pressure pipes communicating between high-pressure sides of the second and third compressors and the suction side of the at least one compressor.

[0028] The injection pipe may be provided with an expansion device, which is preferably located/provided before the connection point of the injection pipe with the high-pressure pipes.

[0029] According to a further aspect, the refrigerant circuit further includes an expansion device, particularly a storage side expansion valve (EV), located on the fourth fluid communication pipe and between the second switching mechanism and the utilization-side heat exchanger, and a controller configured to select modes of operation, wherein the modes comprise:

a normal refrigeration and/or cooling mode, a cold storage making mode and a cold storage using mode, wherein particularly:

in the normal refrigeration and/or cooling mode the first switching mechanism is set so that the first fluid communication pipe and the third fluid communication pipe are communicated, and the expansion device is closed,

in the cold storage making mode the first switching mechanism is set so that the first fluid communication pipe and the third fluid communication pipe are communicated and the first gas communication pipe and the thermal storage are communicated, the second switching mechanism is set so that the fourth fluid communication pipe and the thermal storage are communicated, and the expansion device is opened, and

in the cold storage using mode the first switching mechanism is set so that first fluid communication

pipe and the thermal storage are communicated, the second switching mechanism is set so that the second fluid communication pipe and the thermal storage are communicated, and the expansion device is closed.

[0030] Moreover, the refrigerant circuit may further include an outside temperature sensor T5, a gas cooler out temperature sensor T2, a thermal storage medium temperature sensor T4 and a discharge side pressure sensor PI, provided on the high pressure side of the at least one compressor.

[0031] Furthermore, the refrigerant circuit may further include a fan having a changeable rotation speed and supplying air to the heat-source-side heat exchanger.

[0032] According to a seventh aspect, the refrigerant circuit may further include an outside temperature sensor T5, a thermal storage medium temperature sensor T4 and a discharge side pressure sensor PI

[0033] The refrigerant circuit may further include a thermal storage unit having the thermal storage and comprising a water circuit, a refrigerant to phase change material (PCM) circuit or a refrigerant to water to phase change material (PCM) circuit, wherein the refrigerant to water to phase change material (PCM) circuit includes a heat exchanger, particularly a plate heat exchanger, and a circulating pump.

[0034] The disclosure further provides a thermal storage unit used for a refrigeration apparatus using CO₂ as refrigerant, including: a thermal storage including a thermal storage material, particularly a phase changing material (PCM), a thermal storage unit gas port configured to communicate to a utilization-side heat exchanger disposed outside the thermal storage unit, a first thermal storage unit fluid port configured to communicate to the utilization-side heat exchanger, a second thermal storage unit fluid port configured to communicate to a heat-source-side heat exchanger, disposed outside the thermal storage unit, and a third thermal storage unit fluid port configured to communicate to an expansion device disposed outside the thermal storage unit, wherein the thermal storage unit further comprises: a first switching mechanism communicating among the second thermal storage unit fluid port, the third thermal storage fluid port, the thermal storage unit gas port and one side of the thermal storage, and a second switching mechanism communicating among the first thermal storage unit fluid port, the third thermal storage unit fluid port and the other side of the thermal storage.

[0035] The thermal storage unit may further include a refrigerant heat exchange pipe disposed inside the thermal storage, particularly inside the thermal storage material, wherein the first switching mechanism communicates with one side of the refrigerant heat exchange pipe and the second switching mechanism communicates with the other end of the refrigerant heat exchange pipe.

[0036] Moreover, the first switching mechanism includes: a first valve, which is a three-way valve, commu-

nicating among the second thermal storage unit fluid port, the third thermal storage unit fluid port and the thermal storage, and preferably a second valve, which is a three-way valve and located/provided between the first valve and the thermal storage, communicating among the first valve, the thermal storage and the thermal storage unit gas port, wherein the first switching mechanism preferably further comprises a check valve that is located/provided between the first valve and the third thermal storage unit fluid port.

[0037] Alternatively, the first switching mechanism includes a first valve, which may be a four-way valve, communicating among the second thermal storage unit fluid port, the thermal storage, the thermal storage unit gas port and the third thermal storage unit fluid port, wherein the first switching mechanism further includes a check valve that stops a backflow from the third thermal storage unit fluid port to the first valve.

[0038] The second switching mechanism may be a valve, which is a three-way valve, communicating among the first thermal storage unit fluid port, the third thermal storage unit fluid port and the thermal storage, wherein preferably an expansion device is located/provided between the second switching mechanism and the first thermal storage unit fluid port.

[0039] According to a seventh aspect, the thermal storage unit further includes: a first thermal storage unit fluid communication pipe communicating between the second thermal storage unit fluid port and the one side of the thermal storage, wherein the first switching mechanism is located/provided on the first thermal storage unit fluid communication pipe, and a second thermal storage unit fluid communication pipe communicating between the third thermal storage unit fluid port and the other side of the thermal storage, wherein the second switching mechanism is located/provided on the second thermal storage unit fluid communication pipe.

[0040] The thermal storage unit may further include a third thermal storage unit fluid communication pipe communicating between the third thermal storage unit fluid port and the first switching mechanism, particularly a/the first valve, and a fourth thermal storage unit fluid communication pipe communicating between the first thermal storage unit fluid port and the second switching mechanism, wherein preferably an expansion device is located/provided on the fourth thermal storage unit fluid communication pipe.

[0041] According to an eighth aspect, a check valve is located/provided on the third thermal storage unit fluid communication pipe and stops a backflow from the third thermal storage unit fluid port to the first switching mechanism, particularly a/the first valve.

[0042] The second thermal storage unit fluid communication pipe may be connected with the third thermal storage unit fluid communication pipe between the third thermal storage unit fluid port and the check valve.

[0043] The thermal storage unit may further include a thermal storage unit gas communication pipe communi-

cating between the thermal storage unit gas port and the first switching mechanism, particularly a/the second valve.

[0044] According to a ninth aspect, the thermal storage material is a phase changing material (PCM) from the group: organic PCMs like bio-based, paraffin, carbohydrate or lipid derived, or water.

[0045] The thermal storage unit may further include a heat exchanger, particularly a plate heat exchanger, which is on one side communicating with the first switching mechanism and the second switching mechanism and on the other side with the one side of the thermal storage and the other side of the thermal storage.

[0046] Furthermore, the thermal storage unit may further include a circulating pump that is located/provided on the first thermal storage unit fluid communication pipe or the second thermal storage unit fluid communication pipe, between the heat exchanger and the thermal storage.

[0047] The thermal storage unit may further include a water circuit, a refrigerant to phase change material (PCM) circuit or a refrigerant to water to phase change material (PCM) circuit having a heat exchanger, particularly a plate heat exchanger, and a circulating pump.

[0048] The thermal storage unit is a unit that can be used for the refrigerant circuit of the disclosure. Therefore, the further features disclosed in connection with the above description of the thermal storage unit may also be applied to the refrigerant circuit of the disclosure. The same applies vice versa for the thermal storage unit.

[0049] The disclosure also provides a heat exchange unit, that is used for a refrigeration apparatus, preferably having a thermal storage, using CO₂ as refrigerant, including: at least one compressor, a heat-source-side heat exchanger, an expansion device, a heat exchange unit gas port configured to communicate to a utilization-side heat exchanger disposed outside the heat exchange unit, a first heat exchange unit fluid port configured to communicate to the utilization-side heat exchanger, a second heat exchange unit fluid port communicating to the heat-source-side heat exchanger, a third heat exchange unit fluid port communicating to the expansion device, wherein the second heat exchange unit fluid port and the third heat exchange unit fluid port are configured to communicate to a thermal storage unit, a heat exchanger, particularly a plate heat exchanger, a capacity increasing unit, or a combi unit including a thermal storage unit and a capacity increasing unit, which is preferably disposed outside the heat exchange unit.

[0050] The heat exchange unit may further include: a heat exchange unit gas communication pipe communicating between the heat exchange unit gas port and the at least one compressor, a first heat exchange unit fluid communication pipe communicating between the second heat exchange unit fluid port and the heat-source-side heat exchanger, and a second heat exchange unit fluid communication pipe communicating between the third heat exchange unit fluid port and the first heat exchange

unit fluid port.

[0051] The expansion device may be located/provided on the second heat exchange unit fluid communication pipe, preferably between the first heat exchange unit fluid port and the third heat exchange unit fluid port.

[0052] According to a tenth aspect, the heat exchange unit further includes a receiver, which is preferably located/provided on a/the second heat exchange unit fluid communication pipe, particularly between the first heat exchange unit fluid port and the expansion device, wherein the receiver is configured to separate liquid refrigerant and gas refrigerant.

[0053] The heat exchange unit may further include a fourth heat exchange unit fluid port configured to communicate between the expansion device and an additional utilization-side heat exchanger disposed outside the heat exchange unit.

[0054] Furthermore, the heat exchange unit may further include a third heat exchange unit fluid communication pipe communicating between the fourth heat exchange unit fluid port and the expansion device and is preferably connected with the second heat exchange unit fluid communication pipe between the first heat exchange unit fluid port and a/the receiver.

[0055] The heat exchange unit according to any one of the preceding claims, further comprising a subcooling heat exchanger, which is preferably located/provided between the first heat exchange unit fluid port and the expansion device, more preferably between the first heat exchange unit fluid port and a/the receiver.

[0056] According to an eleventh aspect, the utilization-side heat exchanger is a heat exchanger of an air-conditioner, preferably of an indoor unit, and the additional utilization-side heat exchanger is a heat exchanger of a cooler such as a refrigerator or a freezer, or the other way around. Furthermore, the heat exchange unit may further include a second compressor that is provided upstream of the at least one compressor, in order to build a two-stage compressor system.

[0057] The heat exchange unit may further include a second and a third compressor that are provided parallel to each other and upstream of the at least one compressor, in order to build a two-stage compressor system, wherein preferably the second compressor communicates with the additional utilization-side heat exchanger to build a refrigeration circuit and the third compressor communicates with the utilization-side heat exchanger to build an air-conditioning circuit.

[0058] Additionally, the heat exchange unit may include an injection pipe communicating between a gas side of the receiver and a suction side of the at least one compressor, wherein the injection pipe is configured to inject intermediate-pressure refrigerant into the compressor.

[0059] According to a twelfth aspect, the injection pipe before connecting to a suction side of the at least one compressor joins with two high-pressure pipes communicating between high-pressure sides of the second and

third compressors and the suction side of the at least one compressor.

[0060] The injection pipe may be provided with an expansion device, which is preferably located/provided before the connection point of the injection pipe with the high-pressure pipes.

[0061] Moreover, the capacity increasing unit may include a closed refrigerant circuit including a heat exchanger, a compressor, a heat-source-side heat exchanger cooled by a fan and an expansion device, wherein the heat exchanger exchanges heat with the heat exchange unit.

[0062] According to a further aspect, the combi unit may include a capacity increasing unit, comprising a closed refrigerant circuit including a heat exchanger, a compressor, a heat-source-side heat exchanger cooled by a fan and an expansion device, and a thermal storage unit comprising a heat exchanger, a thermal storage, including a thermal storage material, particularly a phase changing material (PCM), and a circulating pump, wherein the heat exchanger exchanges heat with the heat exchange unit.

[0063] Accordingly, the capacity increasing unit and the combi unit are units that can be integrated or combined with the provided refrigerant circuit in order to increase the refrigeration and/or cooling capacity of the refrigerant circuit, if circumstances like peak temperatures require it. Additionally, providing a capacity increasing unit allows to optimize the design or size of the basic refrigerant circuit for the average refrigeration and/or cooling demand and to cover peak demand with the capacity increasing unit. Thereby making it possible to further increase the efficiency of the refrigerant circuit.

[0064] The heat exchange unit is a unit that can be used for the refrigerant circuit of the disclosure. The heat exchange unit can also be used with or integrated into the thermal storage unit described above, or vice versa. Therefore, the further features disclosed in connection with the above description of the heat exchange unit may also be applied to the refrigerant circuit or the thermal storage unit of the disclosure. The same applies vice versa for the thermal storage unit.

[0065] Finally, the disclosure also provides a method for controlling a refrigerant circuit, particularly the above described refrigerant circuit, for a refrigerant apparatus with a thermal storage which is using CO₂ as refrigerant, the method comprising different modes of operation, wherein the modes comprise:

a normal refrigeration and/or cooling mode, a cold storage making mode and a cold storage using mode, wherein:

in the normal refrigeration and/or cooling mode a first switching mechanism is set so that a first fluid communication pipe and a third fluid communication pipe are communicated, and an expansion device is closed,

in the cold storage making mode the first switching

mechanism is set so that the first fluid communication pipe and the third fluid communication pipe are communicated and a first gas communication pipe and the thermal storage are communicated, a second switching mechanism is set so that a fourth fluid communication pipe and the thermal storage are communicated, and the expansion device is opened, and

in the cold storage using mode the first switching mechanism is set so that first fluid communication pipe and the thermal storage are communicated, the second switching mechanism is set so that the second fluid communication pipe and the thermal storage are communicated, and the expansion device is closed.

[0066] Moreover, in the method the first fluid communication pipe may communicate between a fluid side of a heat-source-side heat exchanger and one side of the thermal storage, the second fluid communication pipe may communicate between an expansion device and the other side of the thermal storage, the third fluid communication pipe may communicate to the expansion device, and/or the first gas communication pipe may communicate to a suction side of at least one compressor. The modes of operation may further include a simultaneous cold storage making and refrigeration and/or cooling mode, wherein the controller is configured to prioritize refrigeration and/or cooling over cold storage making.

[0067] Yet, the cold storage making mode may include: a cold storage making mode only and a cold storage making and a refrigeration and/or cooling mode, and the cold storage using mode comprises: a refrigerant and/or cooling and using cold storage mode.

[0068] The method for controlling a refrigerant circuit can be used for controlling the refrigerant circuit of the disclosure. The method can also be used for controlling the thermal storage unit described above, or vice versa. Therefore, the further features disclosed in connection with the above description of the method for controlling a refrigerant circuit may also be applied to the refrigerant circuit or the thermal storage unit of the disclosure. The same applies vice versa for the heat exchange unit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0069] A more complete appreciation of the present disclosure and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings.

Fig. 1 shows a conventional air-conditioning system having a supercooled phase change material (PCM);

Fig. 2 is a refrigerant circuit diagram illustrating a configuration of a refrigerant circuit of a first embod-

iment;

Fig. 3 is a refrigerant circuit diagram illustrating a configuration of a thermal storage unit of a first embodiment;

Fig. 4 is a refrigerant circuit diagram illustrating a configuration of a thermal storage unit of a second embodiment;

Fig. 5 is a refrigerant circuit diagram illustrating a configuration of a thermal storage unit of a third embodiment;

Fig. 6 is a refrigerant circuit diagram illustrating a configuration of a heat exchange unit of a first embodiment;

Fig. 7 is a refrigerant circuit diagram illustrating a configuration of a refrigeration apparatus of a first embodiment during a normal refrigeration and cooling operation;

Fig. 8 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during a refrigeration operation using the thermal storage;

Fig. 9 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during a refrigeration and cooling operation using the thermal storage;

Fig. 10 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during an only charging operation of the thermal storage;

Fig. 11 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during a refrigeration operation while charging the thermal storage;

Fig. 12 is a refrigerant circuit diagram illustrating a configuration of a refrigeration apparatus of a second embodiment having a capacity increasing unit;

Fig. 13 is a refrigerant circuit diagram illustrating a capacity increasing unit; and

Fig. 14 is a refrigerant circuit diagram illustrating a combi unit having a capacity increasing unit and a thermal storage unit.

DETAILED DESCRIPTION

[0070] Several embodiments of the present disclosure will now be explained with reference to the drawings. It will be apparent to those skilled in the field of air-conditioning from this disclosure that the following description of the embodiments is provided for illustration only and not for the purpose of limiting the disclosure as defined

by the appended claims.

[0071] Figure 1 shows a conventional air-conditioning system 100 having a supercooled phase change material (PCM). A chiller system includes a compressor 110, a first heat exchanger 112, an expansion device 114 and a second heat exchanger 116. The first heat exchanger 112 may be used as a condenser coil and may be located outside of a building or space to be conditioned. The second heat exchanger 116 may be used as an evaporator coil. As known in the art, refrigerant is subjected to a vapor compression cycle through compressor 110, condenser 112, expansion device 114 and evaporator 116. Heat is absorbed at evaporator 116 and heat is discharged at condenser 112.

[0072] The system of Fig. 1 may be a water chiller system. Evaporator 116 is in thermal communication with a heat exchanger 118 (e.g., a coil) that carries a fluid coolant, e.g., water. A supply pump 120 circulates coolant from heat exchanger 118 cooled by evaporator 116 to a supply valve 122. Supply valve 22 supplies chilled water to a local zone terminal where a fan draws air over a coil to chill a space as known in the art. A return valve 124 receives fluid returned from the local zone terminal and provides the return fluid to heat exchanger 118.

[0073] Moreover, the condenser coil 112 as shown in Fig. 1 is in thermal communication with a phase change material 126. A fan 128 draws air through the phase change material 126 to aid in cooling the phase change material 126. A controller 132 then initiates the transition of the phase change material 126 from supercooled liquid to solid. An actuator 130 is used to initiate the transition of the phase change material 126 from supercooled liquid to solid when the phase change material 126 is in a supercooled state. The actuator 130 includes a thermoelectric cooler for freezing the phase change material 126. Controller 132 receives a phase change material temperature signal from a phase change material sensor 134 and an ambient temperature signal from an ambient temperature sensor 136.

[0074] The phase change material 126 is selected so that the phase change material transitions from liquid to solid when cooling demand on the chiller system is low or non-existent. This may occur in the evening, when ambient temperatures are low. During the day, the solid or frozen phase change material 126 absorbs energy from the condenser 112 when the chiller system is running and increasing efficiency and capacity of the chiller system.

[0075] Furthermore, Fig. 2 is a refrigerant circuit 1 diagram illustrating a configuration of a refrigerant circuit of a first embodiment. The shown refrigerant circuit uses CO₂ as refrigerant and includes one compressor 10, a heat-source-side heat exchanger of an outdoor unit of a so called "Conveni-Pack", including usually coolers such as refrigerators and freezers for storing food etc. and air conditioners (indoor units) for cooling/heating an inside of a room, particularly a show room/shopping room. In the shown refrigerant circuit only one indoor unit and one

cooler are illustrated as example, but the refrigerant circuit can naturally include several coolers and air conditioners. The shown refrigerant circuit further includes a thermal storage unit 100 and a heat exchange unit 200, which will be explained later in more detail. The thermal storage unit 100 includes a thermal storage 20 including/accumulating a thermal storage material 21, which is a phase changing material (PCM). The shown refrigerant circuit further includes a first fluid communication pipe 30 that connects a fluid side of the heat-source-side heat exchanger 11 with one side of the thermal storage 20 and a second fluid communication pipe 40 that connects the expansion device 12 and the other side of the thermal storage 20.

[0076] In this regard, the term "connect" is used in the present disclosure to define that two entities, for example the "one side of the thermal storage" and the "thermal storage", are connected with each other by a connecting means such as a "liquid pipe" or a "gas pipe" in such a manner that a fluid like a refrigerant can be liquid-tight and gas-tight transferred/exchanged/flow from one entity to the other one. In other words, the connecting means provides a fluidic connection.

[0077] The refrigerant circuit 1 further includes a first switching mechanism 31, which is located on the first fluid communication pipe 30 and fluidically connects the heat-source-side heat exchanger 11, the thermal storage 20, a third fluid communication pipe 50 and a first gas communication pipe 60 with each other, wherein the third fluid communication pipe 50 is fluidically connecting to the expansion device 12 and the first gas communication pipe 60 is fluidically connecting to a suction side of the compressor 10.

[0078] The shown refrigerant circuit 1 further includes a second switching mechanism 41 located on the second fluid communication pipe 40 and fluidically connects the thermal storage 20, the expansion device 12 and a fourth fluid communication pipe 70 with each other, wherein the fourth fluid communication pipe 70 is fluidically connecting to a utilization-side heat exchanger 80A.

[0079] Fig. 2 also shows that the refrigerant circuit 1 further comprises a receiver 201, which is located on the third fluid communication pipe 50, between the expansion device 12 and the utilization-side heat exchanger 80A, wherein the receiver 201 is configured to separate the refrigerant coming from the expansion device in a subcritical state into liquid refrigerant and gas refrigerant.

[0080] The shown refrigerant circuit 1 also indicates that the refrigerant circuit 1 can further include an additional utilization-side heat exchanger 80B communicating on its liquid side with the expansion device 12 via the receiver 201 and on its gas side with the compressor 10.

[0081] As illustrated in Fig. 2, the utilization-side heat exchanger 80A can be a heat exchanger of an air-conditioner, particularly of an indoor unit, and the additional utilization-side heat exchanger 80B can be a heat exchanger of a cooler such as a refrigerator or a freezer.

[0082] Fig. 3 is a refrigerant circuit diagram illustrating

a configuration of a thermal storage unit of a first embodiment. The shown thermal storage unit 100 is part of the above described refrigerant circuit 1, wherein the switching mechanism 1 is configured according to a first alternative. The shown thermal storage unit 100 includes the thermal storage 20 including the above described thermal storage material 21, which is a phase changing material (PCM), a thermal storage unit gas port 62 communicating to the utilization-side heat exchanger 80A, disposed outside the thermal storage unit 100, a first thermal storage unit fluid port 72 communicating to the utilization-side heat exchanger 80A, a second thermal storage unit fluid port 32A communicating to the heat-source-side heat exchanger 11, disposed outside the thermal storage unit 100, and a third thermal storage unit fluid port 52A communicating to the expansion device 12 disposed outside the thermal storage unit 100.

[0083] The shown thermal storage unit 100 further includes the first switching mechanism 31 communicating among the second thermal storage unit fluid port 32A, the third thermal storage fluid port 52A, the thermal storage unit gas port 62 and one side of the thermal storage 20, and the second switching mechanism 41 communicating among the first thermal storage unit fluid port 72, the third thermal storage unit fluid port 52A and the other side of the thermal storage 20.

[0084] Moreover, the in Fig. 3 shown thermal storage unit 100 further includes a refrigerant heat exchange pipe 22 that is disposed inside the thermal storage 20, particularly inside the thermal storage material 21. The first switching mechanism 31 is fluidically connected with one side of the refrigerant heat exchange pipe 22 and the second switching mechanism 41 is fluidically connected with the other end of the refrigerant heat exchange pipe 22.

[0085] According to the shown embodiment, the first switching mechanism 31 includes: a first valve 31A, which is a three-way valve, communicating among the second thermal storage unit fluid port 32A, the third thermal storage unit fluid port 52A and the thermal storage 20, and a second valve 31B, which is a three-way valve and located between the first valve 31A and the thermal storage 20, communicating among the first valve 31A, the thermal storage 20 and the thermal storage unit gas port 62.

[0086] Between the first valve 31A and the third thermal storage unit fluid port 52A is a check valve 31A provided that stops a backflow from the third thermal storage unit fluid port 52A to the first valve 31A.

[0087] The shown second switching mechanism 41 is a valve, which is a three-way valve, fluidically connecting the first thermal storage unit fluid port 72, the third thermal storage unit fluid port 52A and the thermal storage 20 with each other, wherein an expansion device 101 is located between the second switching mechanism 41 and the first thermal storage unit fluid port 72.

[0088] The second thermal storage unit fluid communication pipe 40 is connected with the third thermal stor-

age unit fluid communication pipe 50 between the third thermal storage unit fluid port 52A and the check valve 53. A thermal storage unit gas communication pipe 60 fluidically connects the thermal storage unit gas port 62 and the first switching mechanism 31, particularly the second valve 31B, with each other.

[0089] Fig. 4 is a refrigerant circuit diagram illustrating a configuration of the thermal storage unit 100 according to a second embodiment, particularly an alternative configuration. The illustrated refrigerant circuit corresponds to the refrigerant circuit disclosed in Fig. 3 except the configuration of the first switching mechanism. In the shown alternative configuration, the first valve 31A is a four-way valve that fluidically connects the second thermal storage unit fluid port 32A, the thermal storage 20, the thermal storage unit gas port 62 and the third thermal storage unit fluid port 52A.

[0090] Fig. 5 is a refrigerant circuit diagram illustrating a configuration of a thermal storage unit 100 according to a third embodiment, particularly a third alternative. The shown alternative does not use the above described refrigerant heat exchange pipe 22, instead uses a heat exchanger 102. As shown, the heat exchanger 102 is preferably a plate heat exchanger, which is on one side communicating with the first switching mechanism 31 and the second switching mechanism 41 and on the other side with the one side of the thermal storage 20 and the other side of the thermal storage 20.

[0091] Additionally, the thermal storage unit 100 includes a circulating pump 103 that is located on the second thermal storage unit fluid communication pipe 40, between the heat exchanger 102 and the thermal storage 20. Accordingly, the thermal storage has a closed loop, particularly using water as coolant. The circulating pump 103 circulates the coolant through the thermal storage 20, thereby the coolant exchanges heat with the thermal storage material 21 of the thermal storage, and then to the heat exchanger 102, where the coolant again exchanges heat with the refrigerant of the refrigerant circuit 1. Hence, the circulating pump 103 is able to control the amount of thermal energy exchanged between the thermal storage 20, particularly the thermal storage material 21, and the refrigerant of the refrigerant circuit 1.

[0092] The in connection with Fig. 5 described embodiment can be combined with both alternatives with regard to the first switching mechanism, namely a first three-way valve or four-way valve 31A.

[0093] Fig. 6 is a refrigerant circuit diagram illustrating a configuration of a heat exchange unit 200 of a first embodiment. The shown heat exchange unit 200 includes the compressor 10, the heat-source-side heat exchanger 11 the expansion device 12, a heat exchange unit gas port 92 communicating to the utilization-side heat exchanger 80A disposed outside the heat exchange unit 200, a first heat exchange unit fluid port 96 communicating to the utilization-side heat exchanger 80A, a second heat exchange unit fluid port 32B communicating to the heat-source-side heat exchanger 11, a third heat ex-

change unit fluid port 52B communicating to the expansion device 12. The shown second heat exchange unit fluid port 32B is fluidically connected to the above described thermal storage unit 100 disposed outside the heat exchange unit 200 and the third heat exchange unit fluid port 52B is also fluidically connected to the thermal storage unit 100.

[0094] The shown heat exchange unit 200 further includes a heat exchange unit gas communication pipe 90 communicating between the heat exchange unit gas port 92 and the at least one compressor 10, a first heat exchange unit fluid communication pipe 30 communicating between the second heat exchange unit fluid port 32B and the heat-source-side heat exchanger 11, and a second heat exchange unit fluid communication pipe 50 communicating between the third heat exchange unit fluid port 52B and the first heat exchange unit fluid port 96.

[0095] The expansion device 12 is located on the second heat exchange unit fluid communication pipe 50, between the first heat exchange unit fluid port 96 and the third heat exchange unit fluid port 52B.

[0096] The shown heat exchange unit 200 further includes the above described receiver 201, which is located on the second heat exchange unit fluid communication pipe 50, between the first heat exchange unit fluid port 96 and the expansion device 12, wherein the receiver 201 is configured to separate liquid refrigerant and gas refrigerant. The heat exchange unit 200 further includes a fourth heat exchange unit fluid port 203 fluidically connecting the expansion device 12 and the additional utilization-side heat exchanger 80B disposed outside the heat exchange unit 200.

[0097] The shown heat exchange unit 200 further includes a third heat exchange unit fluid communication pipe 202 fluidically connecting the fourth heat exchange unit fluid port 203 with the expansion device 12 and is connected with the second heat exchange unit fluid communication pipe 50 between the first heat exchange unit fluid port 96 and the receiver 201.

[0098] Fig. 7 is a refrigerant circuit diagram illustrating a configuration of a refrigeration apparatus 300 of a first embodiment during a normal refrigeration and cooling operation. The shown refrigeration apparatus 300 includes the above described refrigerant circuit 1, the thermal storage unit 100 and the heat exchange unit 200, which are further detailed for explanatory purposes.

[0099] The shown heat exchange unit 200 further includes a subcooling heat exchanger 204, which is located between the first heat exchange unit fluid port 96 and the receiver 201.

[0100] The refrigeration apparatus 300 includes three coolers such as refrigerators and freezers for storing food etc. and three air conditioners (indoor units) for cooling/heating an inside of a room, particularly a show room/shopping room. The three indoor units are each provided with one utilization-side heat exchanger 380A - 380C and the three refrigerators are each provided with one additional utilization-side heat exchanger 301A -

301C.

[0101] Additionally, the shown heat exchange unit 200 further includes a second compressor 310B and a third compressor 310C that are provided parallel to each other and upstream of the above described compressor 10 of the basic configuration. In this way, the three compressors 310A - 310B build a two-stage compressor system, wherein the second compressor 310B communicates with the additional utilization-side heat exchangers 301A - 301C to build a refrigeration circuit and the third compressor 310C communicates with the utilization-side heat exchangers 380A - 380C to build an air-conditioning circuit. The three compressors 310A - 310C can be variable capacity compressors and/or fixed capacity compressors, depending on the requirements of the refrigerant apparatus. All of the three compressors 310A - 310C are hermetic scroll compressors.

[0102] The shown heat exchange unit 200 further includes an injection pipe 206 fluidically connecting a gas side of the receiver 201 with a suction side of the first compressor 10, 310A, wherein the injection pipe 206 is configured to inject intermediate-pressure refrigerant collected by the receiver 201 into the first compressor 10, 310A. As shown in Fig. 7, the injection pipe 206 joins with two high-pressure pipes 207, 208 communicating between high-pressure sides of the second compressor 310B and the third compressor 310C and the suction side of the first compressor 10, 310A, before connecting to a suction side of the first compressor 10, 310A.

[0103] Additionally, the injection pipe 206 is provided with an expansion device 207, which is preferably located before the connection point of the injection pipe 206 with the high-pressure pipes 207, 208.

DESCRIPTION OF CONTROL MODES

First Example: Normal refrigeration and cooling operation

[0104] As already mentioned above, Fig. 7 illustrates the refrigeration apparatus 300 in a normal refrigeration and cooling operation. Accordingly, all three compressors 310A - 310C are turned on, which means, the second compressor 310B draws low pressure refrigerant from the additional utilization-side heat exchangers 301A - 301C of the three coolers and the third compressor 310C draws refrigerant from the utilization-side heat exchanger 380C of one of the three indoor units. Via the high-pressure pipes 207, 208 the two compressors 310B, 310C provide intermediate-pressure refrigerant to the first compressor 310A, which further compresses the refrigerant and discharges high-pressure refrigerant which flows to the heat-source-side heat exchanger 11, which acts as a gas cooler. Such refrigerant is cooled by dissipating heat to outdoor air supplied by an outdoor fan. The high-pressure refrigerant flowing out from the heat-source-side heat exchanger 11 flows via the first fluid communication pipe 30 to the first switching mechanism

31, particularly the first valve 31A, which is a three-way valve. The three-way valve 31A is in a state, in which the first fluid communication pipe 30 is communicating with the third fluid communication pipe 50 and a flow to the second valve 31B is blocked. Hence, the high-pressure refrigerant flows directly to the expansion device 12, which is an expansion valve, without flowing through the thermal storage 20 or exchanging heat with the thermal storage 20 via the heat exchanger 102. Flowing through the expansion device 12, the pressure of the cooled high-pressure refrigerant is reduced, and the refrigerant is changed into intermediate-pressure refrigerant in a gas-liquid two-phase state (subcritical refrigerant).

[0105] Subsequently, the intermediate-pressure refrigerant flows to the receiver 201, a part of the refrigerant, particularly liquid intermediate-pressure refrigerant, flows from the receiver 201 to a first flow path 204A of the subcooling heat exchanger 204. The refrigerant flowing into the first flow path 204A is cooled by intermediate-pressure refrigerant flowing through the second flow path 204B, and the degree of subcooling of such refrigerant is increased. A part of the so subcooled liquid refrigerant flows through an expansion device 205, particularly a subcooling expansion valve, thereby reducing the pressure of the intermediate-pressure refrigerant further. The intermediate-pressure refrigerant flows into the second flow path 204B of the subcooling heat exchanger 204 and is evaporated by absorbing heat from the refrigerant flowing through the first flow path 204A of the subcooling heat exchanger 204.

[0106] The subcooled intermediate-pressure refrigerant flows so as to be branched into two main pipes providing the refrigerant to the refrigeration circuit and the air-conditioning circuit, where the refrigerant is branched again into three pipes providing the utilization-side heat exchangers 380A - 380C of the indoor units and the additional utilization-side heat exchangers 301A - 301C of the coolers with liquid refrigerant. Before entering the utilization-side heat exchangers 380A - 380C, 301A - 301C, the refrigerant flows through an expansion device, particularly an air-conditioning expansion valve or a cooler expansion valve, where the pressure of the intermediate-pressure refrigerant is reduced. Such refrigerant flows through the utilization-side heat exchangers and is evaporated by absorbing heat from example room air supplied by an air-conditioning fan of the indoor units.

[0107] The evaporated refrigerant of the utilization-side heat exchangers 380A - 380C of the indoor units is rejoined and flows via a suction pipe back to a suction side of the third compressor 310C. The evaporated refrigerant of the additional utilization-side heat exchangers 301A - 301C of the coolers is rejoined and flows via a suction pipe back to a suction side of the second compressor 310B. Thereby, the air-conditioning circuit and the refrigeration circuit are a closed loop. The evaporated refrigerant of the subcooling heat exchanger 204 is joined with intermediate-pressure refrigerant discharged from the second compressor 310B and the third compressor

310C and provided to the suction side of the first compressor 310A.

[0108] Additionally, gas intermediate-pressure refrigerant separated by the receiver 201 from the liquid intermediate-pressure refrigerant of the supercritical refrigerant, flows through an expansion device to reduce the pressure to a similar pressure as the pressure of the intermediate-pressure refrigerant discharged by the second compressor 310B and the third compressor 310C.

Second Example: Refrigeration operation using the thermal storage

[0109] Fig. 8 is a refrigerant circuit diagram illustrating the refrigeration apparatus 300 of Fig. 7 during a refrigeration operation using the thermal storage. In this operation, the first switching mechanism 31, in particular the first and second valve, and the second switching valve are set in such a way that the high-pressure refrigerant flowing out from the heat-source-side heat exchanger 11 flows via the first fluid communication pipe 30 into the first and second valve and then into the thermal storage, thereby exchanging heat with the thermal storage 20. Flowing through the thermal storage 20 the high-pressure refrigerant is cooled. After leaving the thermal storage 20 the high-pressure refrigerant flows via the second switching mechanism via the expansion device 12 back to the receiver 201. By flowing through the expansion device 12, the pressure of the cooled high-pressure refrigerant is reduced and the refrigerant is changed into intermediate-pressure refrigerant in a gas-liquid two-phase state (supercritical refrigerant).

[0110] As described above, a part of the refrigerant, particularly liquid intermediate-pressure refrigerant, flows then from the receiver 201 to the first flow path 204A of the subcooling heat exchanger 204. The refrigerant flowing into the first flow path 204A is cooled by intermediate-pressure refrigerant flowing through the second flow path 204B, and the degree of subcooling of such refrigerant is increased. A part of the so subcooled liquid refrigerant flows through the expansion device 205 thereby reducing the pressure of the intermediate-pressure refrigerant further. The intermediate-pressure refrigerant flows into the second flow path 204B of the subcooling heat exchanger 204 and is evaporated by absorbing heat from the refrigerant flowing through the first flow path 204A of the subcooling heat exchanger 204.

[0111] The subcooled intermediate-pressure refrigerant flows then so as to provide the refrigerant only to the refrigeration circuit and not to the air-conditioning circuit, where the refrigerant is branched again into three pipes providing the additional utilization-side heat exchangers 301A - 301C of the coolers with liquid refrigerant. Before entering the additional utilization-side heat exchangers 301A - 301C, the refrigerant flows through the cooler expansion valve, where the pressure of the intermediate-pressure refrigerant is reduced. Such refrigerant flows through the additional utilization-side heat exchangers

and is evaporated by absorbing heat from storage room air within the coolers.

[0112] Since the cooling operation is turned off, only the second compressor 310B and the first compressor 310A are in use, the third compressor 310 is turned off. Hence, the second compressor 310 draws low pressure refrigerant from the additional utilization-side heat exchangers 301A - 301C of the coolers and provides intermediate-pressure refrigerant via the high-pressure pipe 207 to the first compressor 310A, which further compresses the refrigerant and discharges high-pressure refrigerant which flows to the heat-source-side heat exchanger 11, which acts as a gas cooler. Such refrigerant is cooled by dissipating heat to outdoor air supplied by an outdoor fan. The high-pressure refrigerant flowing out from the heat-source-side heat exchanger 11 flows then via the first fluid communication pipe 30 back to the first switching mechanism 31, thereby closing the refrigerant circuit.

Third Example: Refrigeration and cooling operation using the thermal storage

[0113] Fig. 9 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during a refrigeration and cooling operation using the thermal storage. The refrigeration and cooling operation using the thermal storage is similar to the above with regard to Fig 8 described refrigeration (only) operation using the thermal storage, except that all three compressors 310A to 310C are in use. Hence, the second compressor 310B draws low pressure refrigerant from the additional utilization-side heat exchangers 301A - 301C of the three coolers and the third compressor 310C draws refrigerant from the utilization-side heat exchanger 380C of one of the three indoor units, which is the provided as intermediate-pressure refrigerant to the first compressor 310A, which further compresses the refrigerant and discharges high-pressure refrigerant which flows to the heat-source-side heat exchanger 11.

[0114] Such refrigerant flows then as described above through the thermal storage 20, the expansion device 12, the receiver 201, the subcooling heat exchanger 204 and is then branched into the two main pipes providing the refrigerant to the refrigeration circuit and the air-conditioning circuit, closing the refrigerant circuit.

Fourth Example: Only charging operation of the thermal storage

[0115] Fig. 10 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during an only charging operation of the thermal storage.

[0116] In this operation only the third compressor 310C and the first compressor 310A are in use, the second compressor 310B is turned off. The third compressor 310C draws the refrigerant directly from the thermal storage 20 and provides intermediate-pressure refrigerant

to the first compressor which compresses the refrigerant further and discharges high-pressure refrigerant which flows to the heat-source-side heat exchanger 11, which acts as a gas cooler. The high-pressure refrigerant flowing out from the heat-source-side heat exchanger 11 flows then via the first fluid communication pipe 30 to the first switching mechanism 31. In this control mode the first valve 31A is set in such a manner that the high-pressure refrigerant flows as described above with Fig. 7 directly to the expansion device 12. From the expansion device 12 the intermediate-pressure refrigerant in a gas-liquid two-phase state (supercritical refrigerant) flows to the receiver 201 and from there liquid intermediate-pressure refrigerant flows then to the first flow path 204A of the subcooling heat exchanger 204. The refrigerant flowing into the first flow path 204A is cooled by intermediate-pressure refrigerant flowing through the second flow path 204B, and the degree of subcooling of such refrigerant is increased. The subcooled intermediate-pressure refrigerant flows then via the second valve 31B back to the thermal storage 20 and by flowing through the thermal storage 20 cools the thermal storage 20, in particular the thermal storage material, thereby charges the thermal storage with cold.

Fifth Example: Refrigeration operation while charging the thermal storage

[0117] Fig. 11 is a refrigerant circuit diagram illustrating the refrigeration apparatus of Fig. 7 during a refrigeration operation while charging the thermal storage.

[0118] The refrigeration operation while charging the thermal storage is similar to the above with regard to Fig. 10 described only charging operation of the thermal storage, except that all three compressors 310A - 310C are in use and that the second compressor 310B connects the additional utilization-side heat exchangers 301A - 301C of the coolers to the refrigerant circuit 1. Thereby, it becomes possible not only to charge the thermal storage 20 with cold by flowing the subcooled intermediate-pressure refrigerant via the second valve 31B through the thermal storage 20, but also to provide the additional utilization-side heat exchangers 301A - 301C with subcooled intermediate-pressure refrigerant. Meaning, the thermal storage 20 can be charged while performing a refrigeration operation.

[0119] Fig. 12 is a refrigerant circuit diagram illustrating a configuration of a refrigeration apparatus 300 of a second embodiment having a capacity increasing unit 320. The refrigerant apparatus 300 of the second embodiment mostly corresponds to the refrigerant apparatus of the first embodiment described with regard to Fig. 7. However, instead of being provided with the thermal storage unit 100, the two connecting pipes connecting the second heat exchanger unit fluid port 32B and the third heat exchanger unit fluid port 52B have an open end. Meaning, the unit connected via the second and third heat exchanger unit fluid ports 32B and 52B with the refrigerant appa-

ratus 300, in particular with the heat exchanger unit 200, is not shown. According to the present invention, instead of the thermal storage unit 100 also a heat exchanger, particularly a plate heat exchanger, a capacity increasing unit or a combi unit including a thermal storage unit and a capacity increasing unit can be connected to the heat exchanger unit 200.

[0120] Fig. 13 is a refrigerant circuit diagram illustrating a capacity increasing unit 320. The capacity increasing unit 320 is basically an independent refrigerant circuit that can be added to or connected with the refrigerant apparatus 300, in order to increase the refrigeration and cooling capacity of the refrigerant apparatus 300. As shown in Fig. 13, the capacity increasing unit 320 includes a heat exchanger, a compressor and an expansion device which build a closed refrigerant circuit. The heat exchanger is configured to exchange heat with the heat exchanger unit 200. Therefore, the heat exchanger can be connected with the second and third heat exchanger unit fluid ports 32B and 52B. Additionally, the capacity increasing unit 320 is provided with a heat-source-side heat exchanger that cools down the refrigerant flowing there through by dissipating heat to outdoor air supplied by an outdoor fan.

[0121] Fig. 14 is a refrigerant circuit diagram illustrating a combi unit 330 having a capacity increasing unit 320 and a thermal storage unit. As described above, the capacity increasing unit 320 includes a heat exchanger, a compressor and an expansion device which build a closed refrigerant circuit. Additionally, instead of connecting the heat exchanger directly with the refrigerant apparatus 300, in particular with the heat exchanger unit 200, the thermal storage unit is arranged between the heat exchanger unit 200 and the thermal storage unit. Accordingly, the combi unit 330 additionally includes a circulating pump that circulates a refrigerant or a coolant like water, cooled by the capacity increasing unit through the thermal storage unit, in order to charge the thermal storage unit with thermal energy, particularly cold. On the other side, the thermal storage unit is provided with a heat exchanger that is used to exchange heat with the refrigerant circuit of the refrigerant apparatus 300, in particular with the heat exchanger unit 200.

[0122] Moreover, the capacity increasing unit may include a closed refrigerant circuit including a heat exchanger, a compressor, a heat-source-side heat exchanger cooled by a fan and an expansion device, wherein the heat exchanger exchanges heat with the heat exchange unit.

[0123] According to a further aspect, the combi unit may include a capacity increasing unit, comprising a closed refrigerant circuit including a heat exchanger, a compressor, a heat-source-side heat exchanger cooled by a fan and an expansion device, and a thermal storage unit comprising a heat exchanger, a thermal storage, including a thermal storage material, particularly a phase changing material (PCM), and a circulating pump, wherein the heat exchanger exchanges heat with the heat ex-

change unit.

REFERENCE LIST

5 [0124]

1	Refrigerant Circuit
10	Compressor (First Compressor)
11	Heat-source-side heat exchanger
10 12	Expansion Device
20	Thermal Storage
21	Thermal Storage Material
22	Refrigerant Heat Exchange Pipe
30	First Fluid Communication Pipe
15 31	First Switching Mechanism
40	Second Fluid Communication Pipe
41	Second Switching Mechanism
50	Third Fluid Communication Pipe
60	First Gas Communication Pipe
20 70	Fourth Fluid Communication Pipe 70
80A	Utilization-side Heat Exchanger
80B	Additional Utilization-side Heat Exchanger
90	Heat Exchange Unit Gas Communication pipe
92	Heat Exchange Unit Gas Port 92
25 96	First Heat Exchange Unit Fluid Port
100	Thermal Storage Unit
72	First Thermal Storage Unit Fluid Port
32A	Second Thermal Storage Unit Fluid Port
30 52A	Third Thermal Storage Unit Fluid Port
62	Thermal Storage Unit Gas Port
31A	First Valve
31B	Second Valve
53	Check Valve
35 101	Expansion Device
102	Heat Exchanger
103	Circulating Pump
200	Heat Exchanger Unit
40 96	First Heat Exchanger Unit Fluid Port
32B	Second Heat Exchanger Unit Fluid Port
52B	Third Heat Exchanger Unit Fluid Port
201	Receiver
202	Third Heat Exchanger Unit Fluid Communication Pipe
45 203	Fourth Heat Exchanger Unit Fluid Port
204	Subcooling Heat Exchanger
205	Expansion Device (Subcooling Expansion Valve)
206	injection pipe
50 207	high pressure pipe
208	high pressure pipe
209	expansion device
210	fan
55 300	Refrigeration Apparatus
301A - 301C	Additional Utilization-side Heat Exchanger
310A	First Compressor

310B	Second Compressor
310C	Third Compressor
320	Capacity Increasing Unit
330	Combi Unit
380A - 380C	Utilization-side Heat Exchanger

Claims

1. A heat exchange unit (200) that is used for a refrigeration apparatus using CO₂ as refrigerant, comprising:

at least one compressor (10),
 a heat-source-side heat exchanger (11)
 an expansion device (12),
 a heat exchange unit gas port (92) configured to communicate to a utilization-side heat exchanger (80A) disposed outside the heat exchange unit (200),
 a first heat exchange unit fluid port (96) configured to communicate to the utilization-side heat exchanger (80A),
 a second heat exchange unit fluid port (32B) communicating to the heat-source-side heat exchanger (11), and
 a third heat exchange unit fluid port (52B) communicating to the expansion device (12),
 wherein
 the second heat exchange unit fluid port (32B) and the third heat exchange unit fluid port (52) are configured to communicate to a thermal storage unit (100), a heat exchanger, particularly a plate heat exchanger, a capacity increasing unit, or a combi unit including a thermal storage unit and a capacity increasing unit, which is preferably disposed outside the heat exchange unit (200).

2. The heat exchange unit (200) according to claim 1, further comprising:

a heat exchange unit gas communication pipe (90) communicating between the heat exchange unit gas port (92) and the at least one compressor (10),
 a first heat exchange unit fluid communication pipe (30) communicating between the second heat exchange unit fluid port (32B) and the heat-source-side heat exchanger (11), and
 a second heat exchange unit fluid communication pipe (50) communicating between the third heat exchange unit fluid port (52B) and the first heat exchange unit fluid port (96).

3. The heat exchange unit (200) according to claim 2, wherein the expansion device (12) is located on the second heat exchange unit fluid communication pipe

(50), preferably between the first heat exchange unit fluid port (96) and the third heat exchange unit fluid port (52B).

4. The heat exchange unit (200) according to any one of the preceding claims, further comprising a receiver (201), which is preferably located on a/the second heat exchange unit fluid communication pipe (50), particularly between the first heat exchange unit fluid port (96) and the expansion device (12), wherein the receiver (201) is configured to separate liquid refrigerant and gas refrigerant.

5. The heat exchange unit (200) according to any one of the preceding claims, further comprising a fourth heat exchange unit fluid port (203) configured to communicate between the expansion device (12) and a further utilization-side heat exchanger (80B) disposed outside the heat exchange unit (200).

6. The heat exchange unit (200) according to claim 5, further comprising a third heat exchange unit fluid communication pipe (202) communicating between the fourth heat exchange unit fluid port (203) and the expansion device (12), and is preferably connected with the second heat exchange unit fluid communication pipe (50) between the first heat exchange unit fluid port (96) and a/the receiver (201).

7. The heat exchange unit (200) according to any one of the preceding claims, further comprising a sub-cooling heat exchanger (204), which is preferably located between the first heat exchange unit fluid port (96) and the expansion device (12), more preferably between the first heat exchange unit fluid port (96) and a/the receiver (201).

8. The heat exchange unit (200) according to any one of the preceding claims, wherein the utilization-side heat exchanger (80A, 380A) is a heat exchanger of an air-conditioner, preferably of an indoor unit, and the further utilization-side heat exchanger (80B, 301A) is a heat exchanger of a cooler such as a refrigerator or a freezer.

9. The heat exchange unit (200) according to any one of the preceding claims, further comprising a second compressor (310B, 310C) that is provided upstream of the at least one compressor (10, 310A), in order to build a two-stage compressor system.

10. The heat exchange unit (200) according to any one of claims 1 to 8, further comprising a second and a third compressor (310B, 310C) that are provided parallel to each other and upstream of the at least one compressor (10, 310A), in order to build a two-stage compressor system, wherein preferably the second compressor (310B) communicates with the further

utilization-side heat exchanger (80B, 301A) to build a refrigeration circuit and the third compressor (310C) communicates with the utilization-side heat exchanger (80A, 380A) to build an air-conditioning circuit.

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11. The heat exchange unit (200) according to claim 9 or 10 and claim 4, further comprising an injection pipe (206) communicating between a gas side of the receiver (201) and a suction side of the at least one compressor (10, 310A), wherein the injection pipe (206) is configured to inject intermediate-pressure refrigerant into the compressor (10, 310A). 10

12. The heat exchange unit (200) according to claim 11, wherein the injection pipe (206) before connecting to a suction side of the at least one compressor (10, 310A) joins with two high-pressure pipes (207, 208) communicating between high-pressure sides of the second and third compressors (310B, 310C) and the suction side of the at least one compressor (10, 310A). 15
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13. The heat exchange unit (200) according to claim 12, wherein the injection pipe (206) is provided with an expansion device (209), which is preferably located before the connection point of the injection pipe (206) with the high-pressure pipes (207, 208). 25

14. The heat exchange unit (200) according to any one of the preceding claims, wherein the capacity increasing unit comprises a closed refrigerant circuit including a heat exchanger, a compressor, a heat-source-side heat exchanger cooled by a fan and an expansion device, wherein the heat exchanger exchanges heat with the heat exchange unit (200). 30
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15. The heat exchange unit (200) according to any one of the preceding claims, wherein the combi unit includes a capacity increasing unit, comprising a closed refrigerant circuit including a heat exchanger, a compressor, a heat-source-side heat exchanger cooled by a fan and an expansion device, and a thermal storage unit (100) comprising a heat exchanger (102), a thermal storage (20), including a thermal storage material (21), particularly a phase changing material (PCM), and a circulating pump (103), wherein the heat exchanger (102) exchanges heat with the heat exchange unit (200). 40
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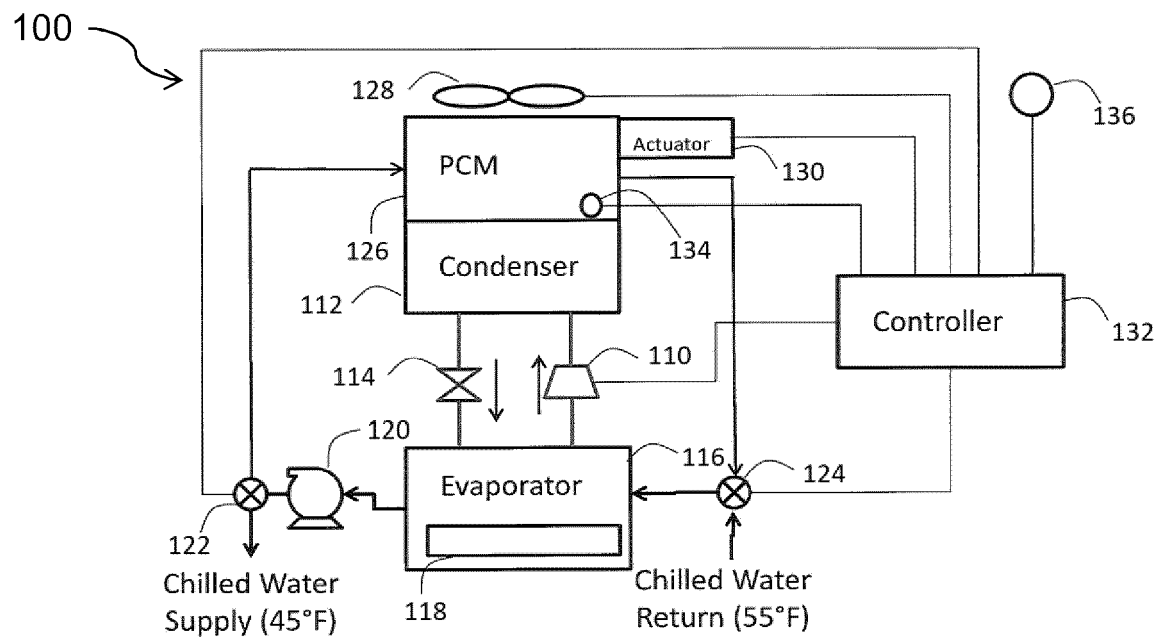


Fig. 1
(Prior Art)

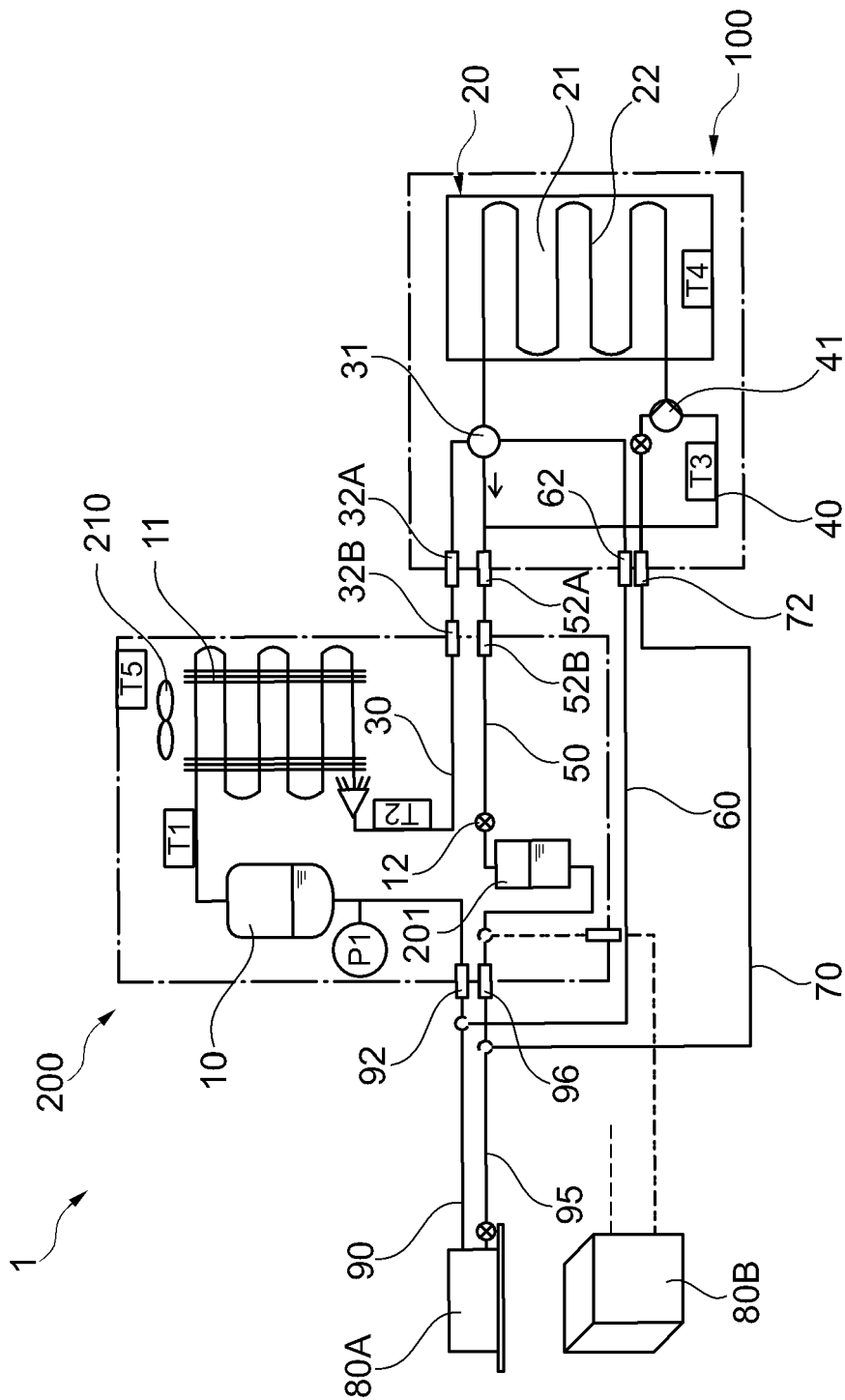


Fig. 2

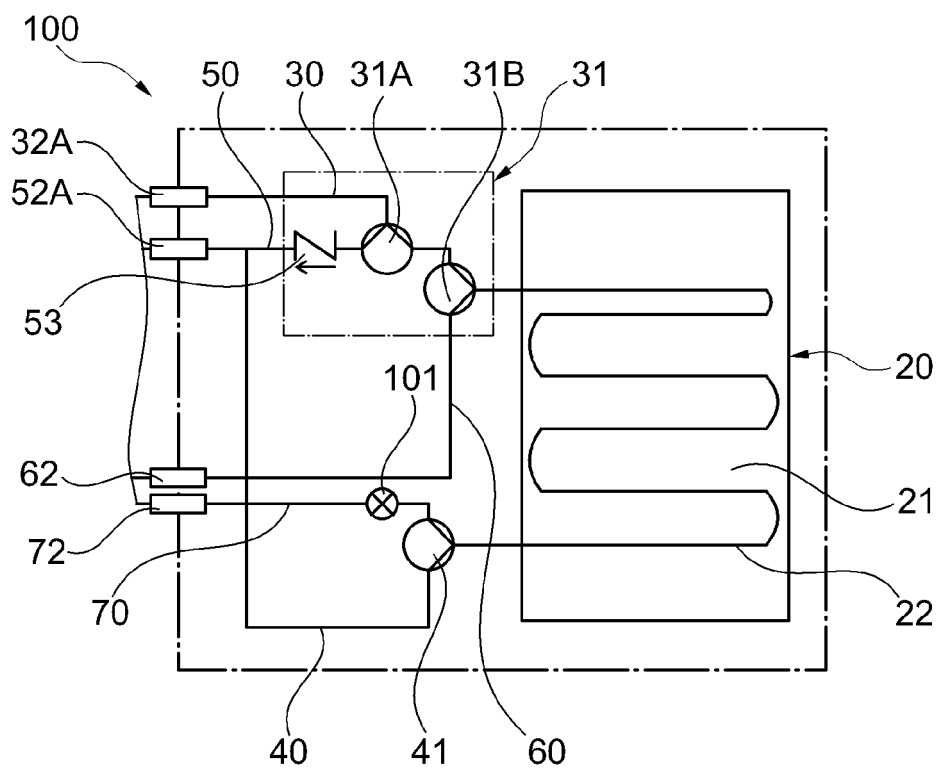


Fig. 3

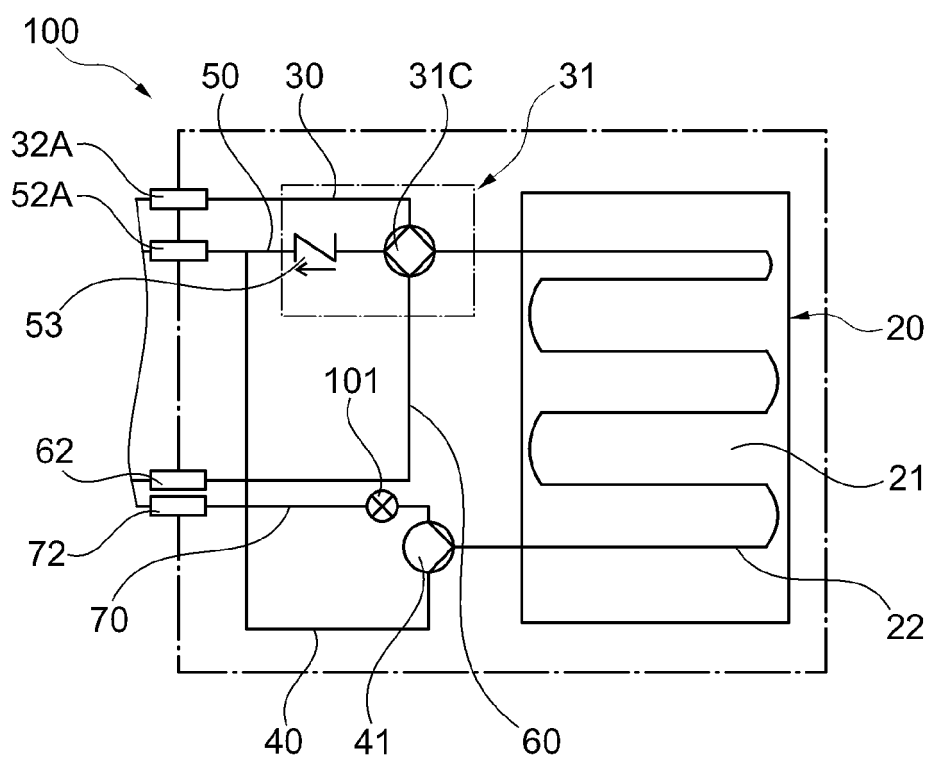


Fig. 4

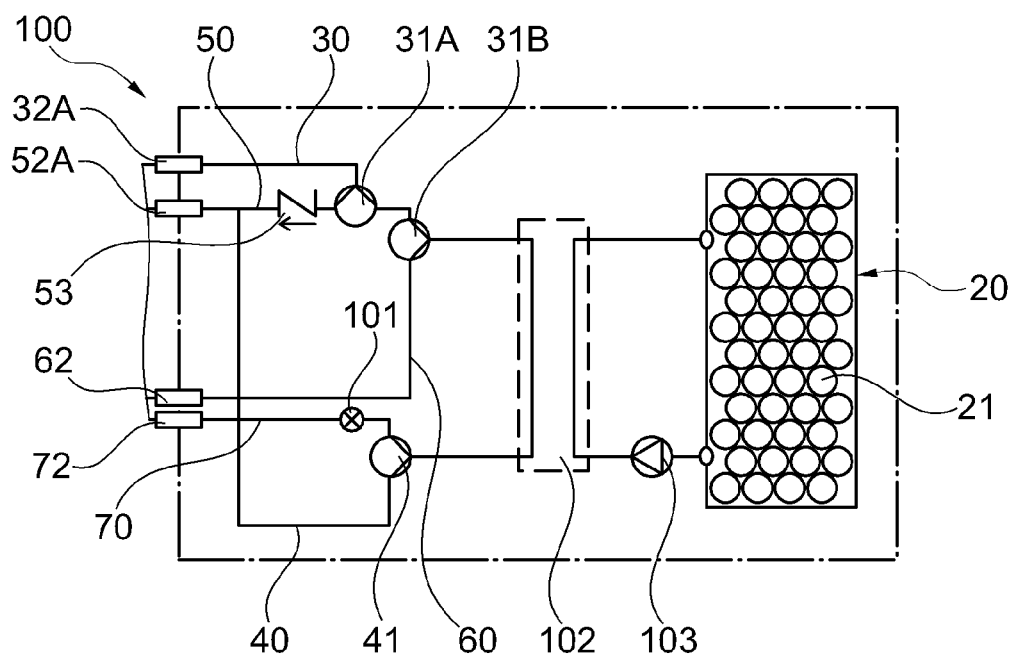


Fig. 5

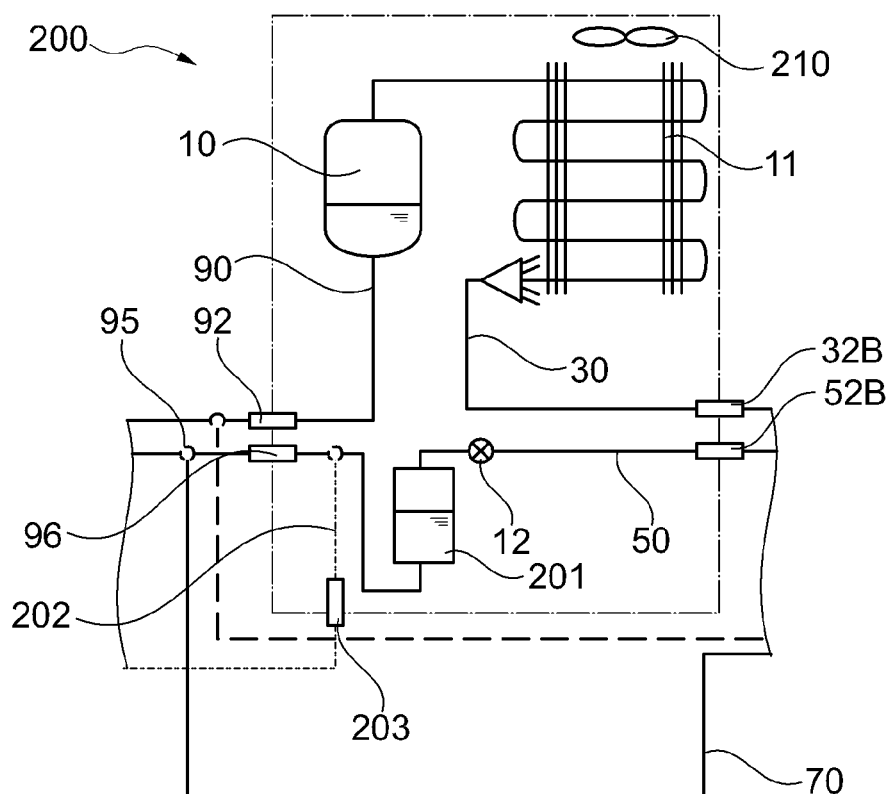


Fig. 6

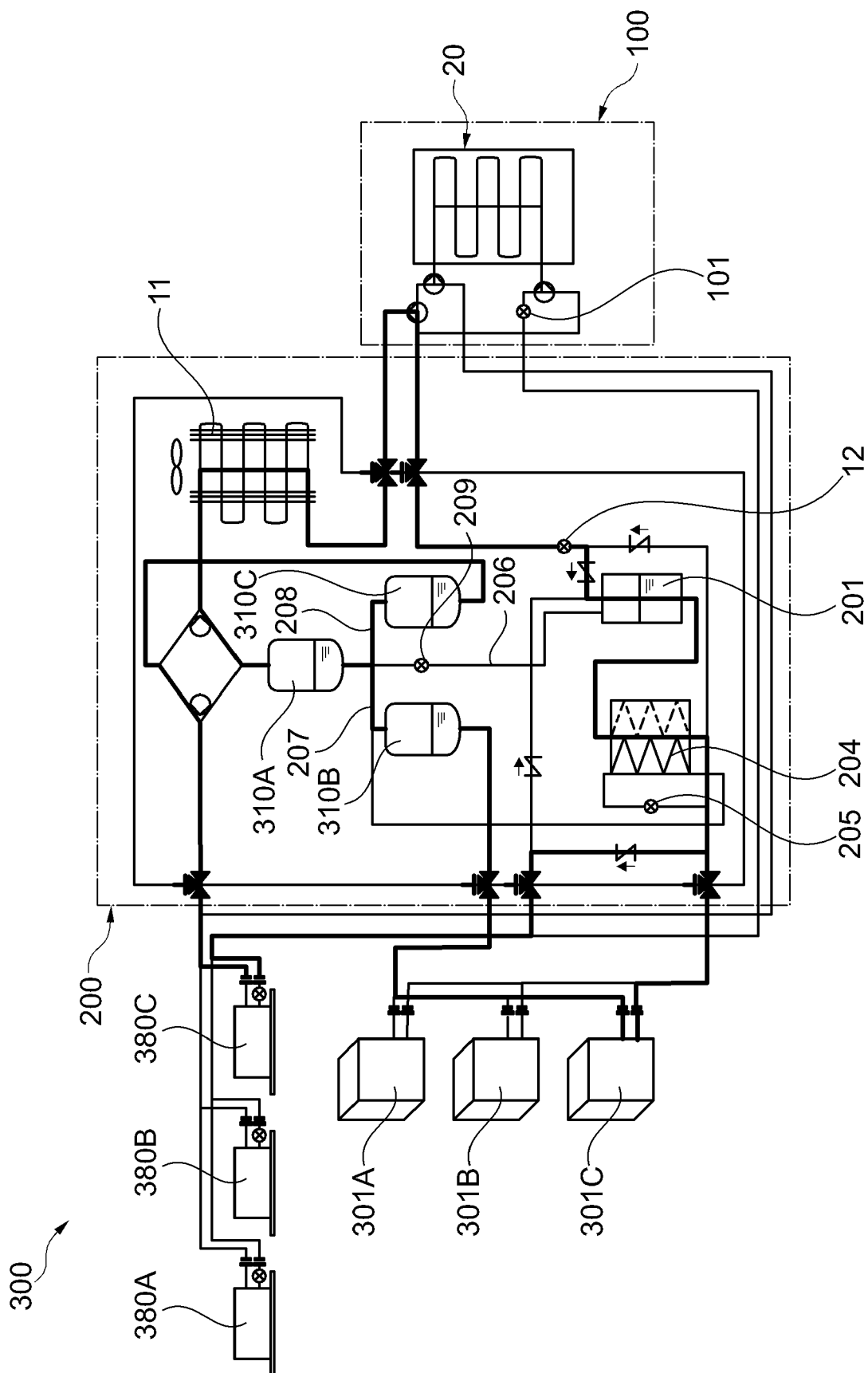


Fig. 7

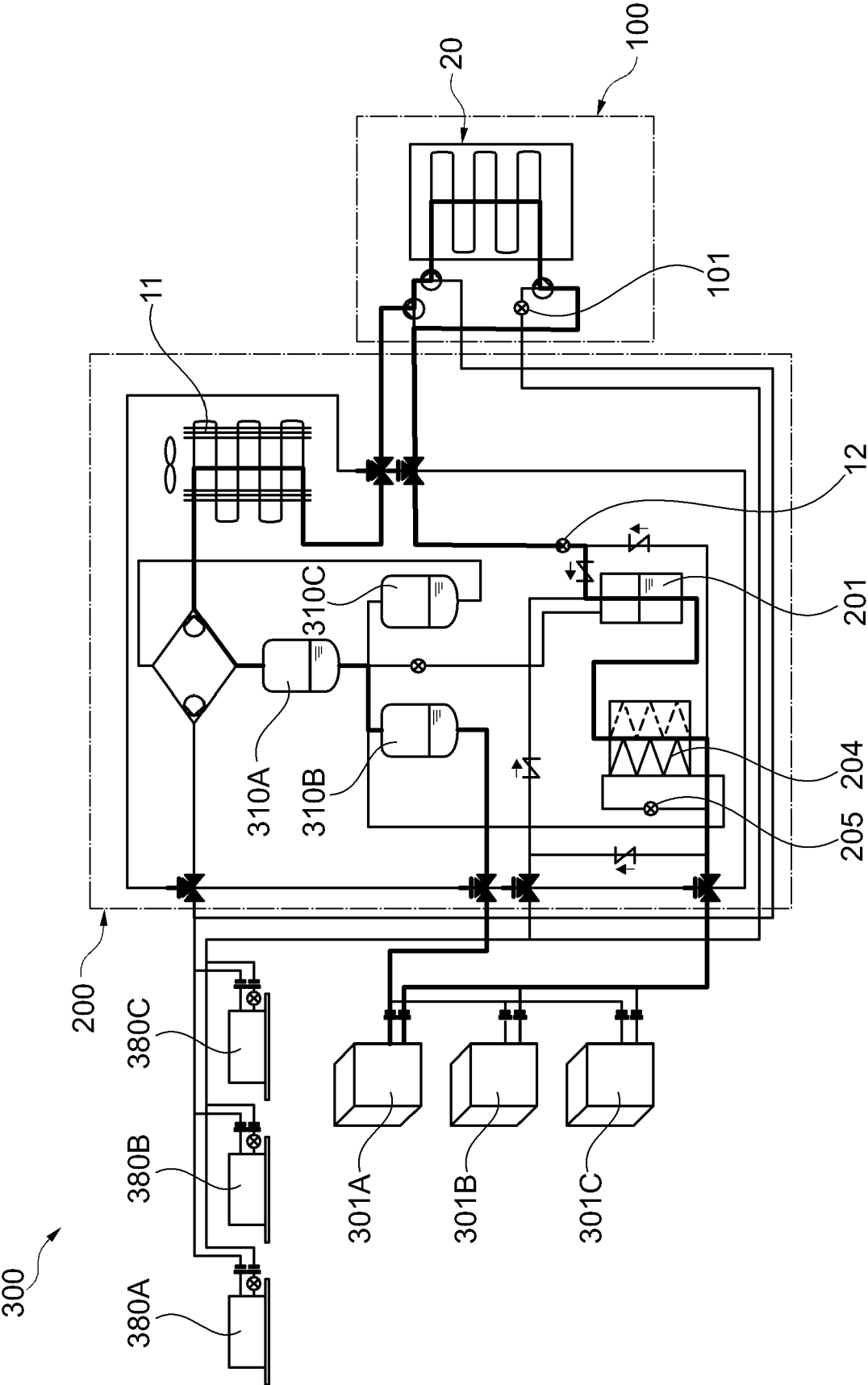


Fig. 8

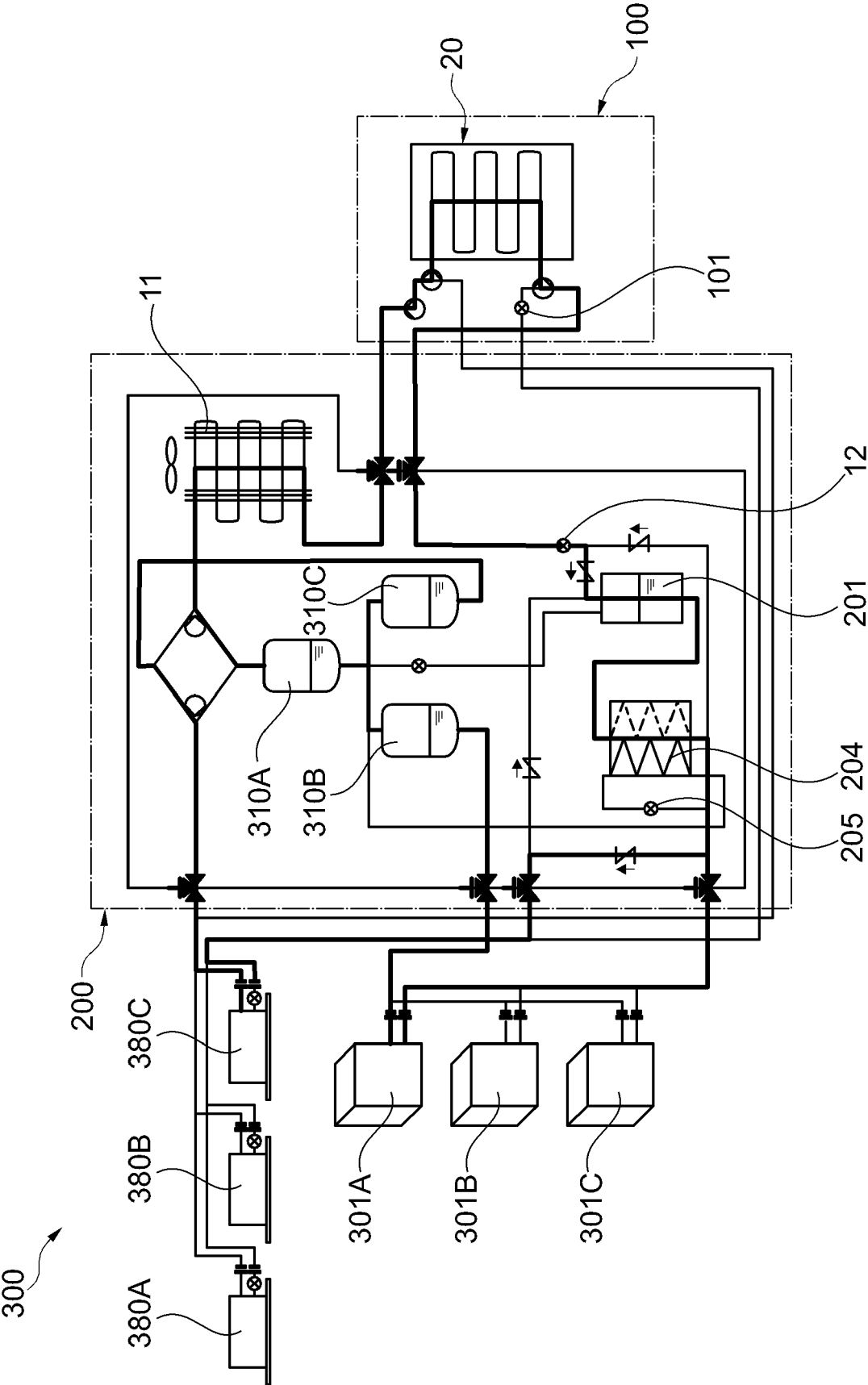


Fig. 9

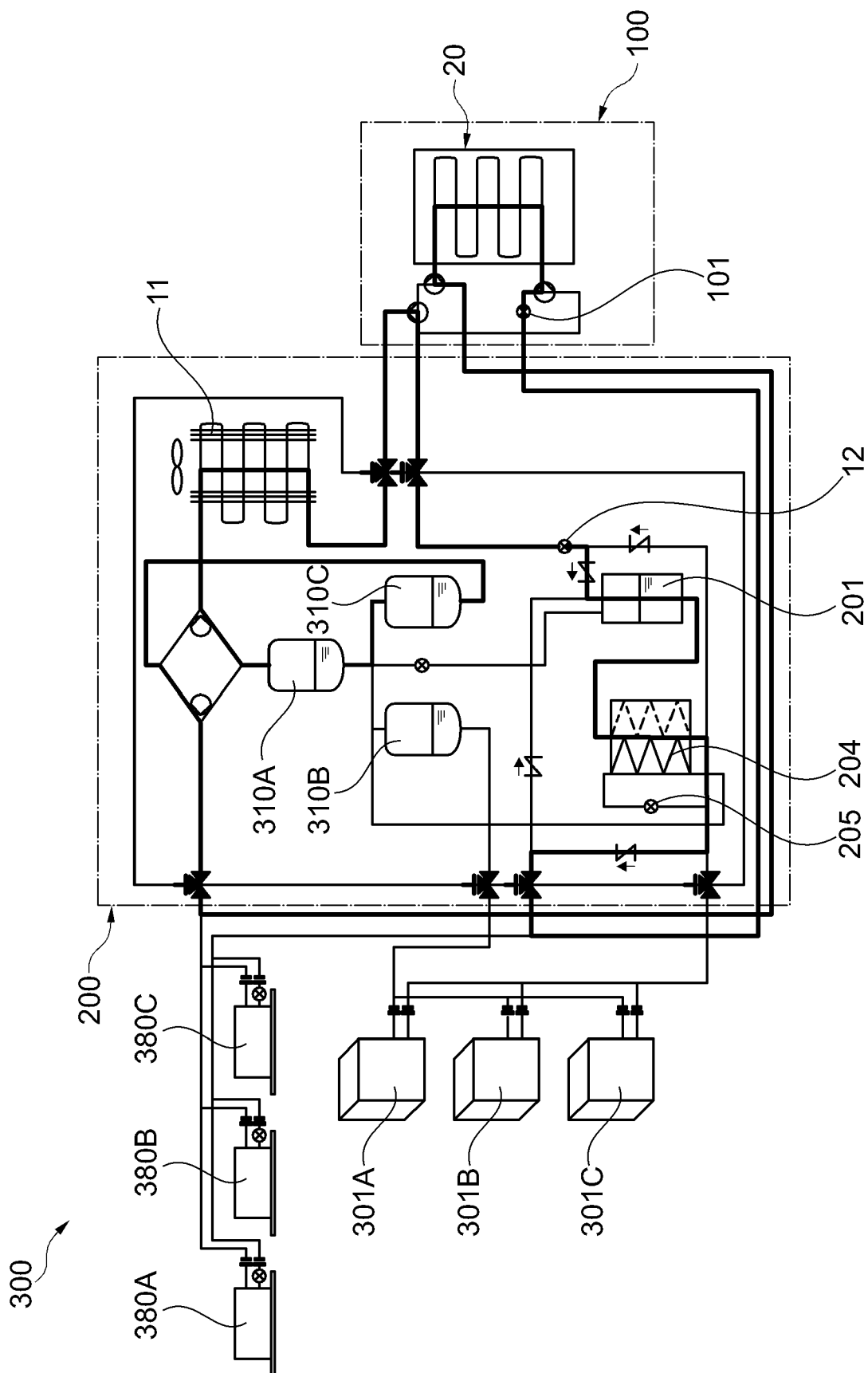


Fig. 10

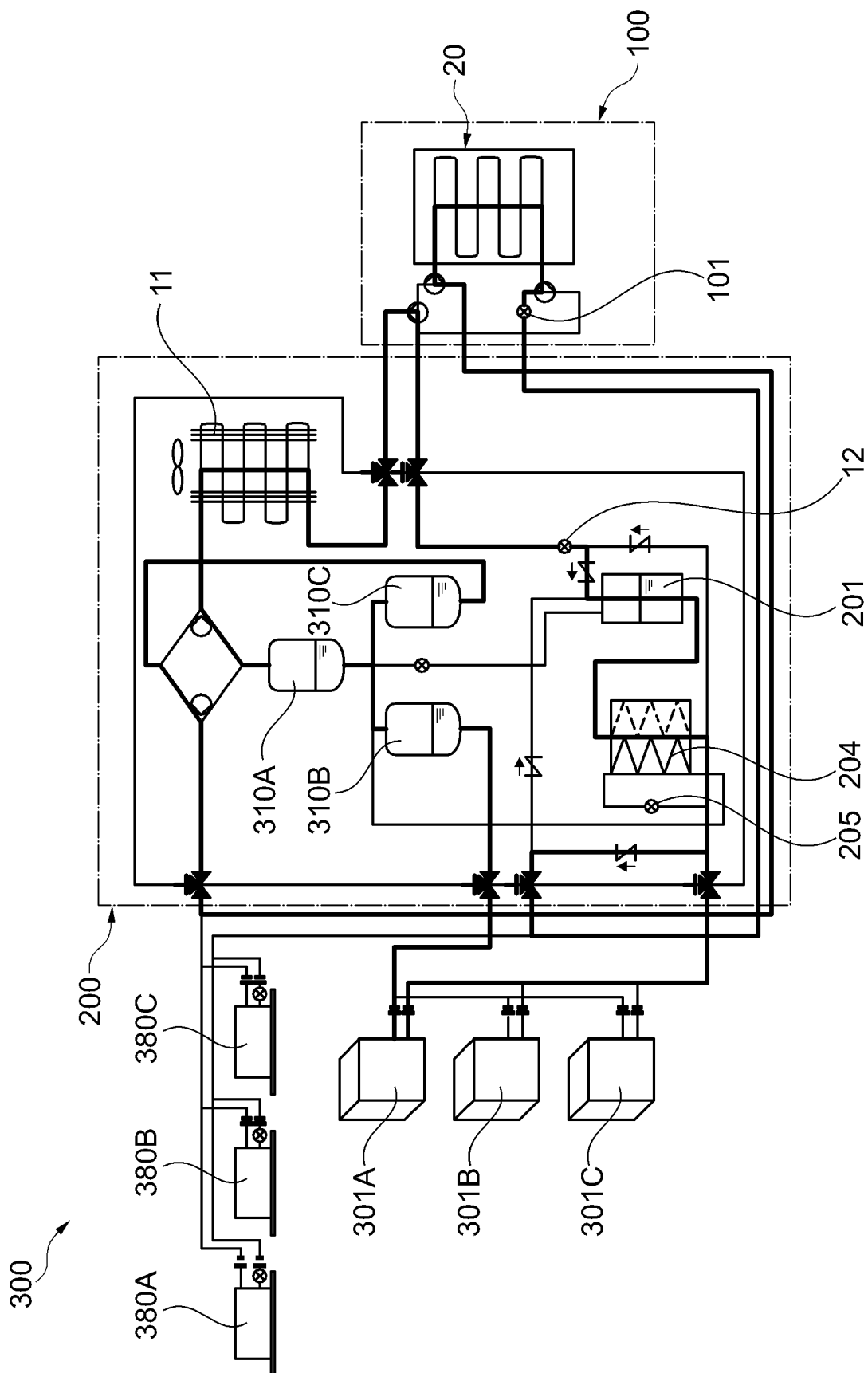


Fig. 11

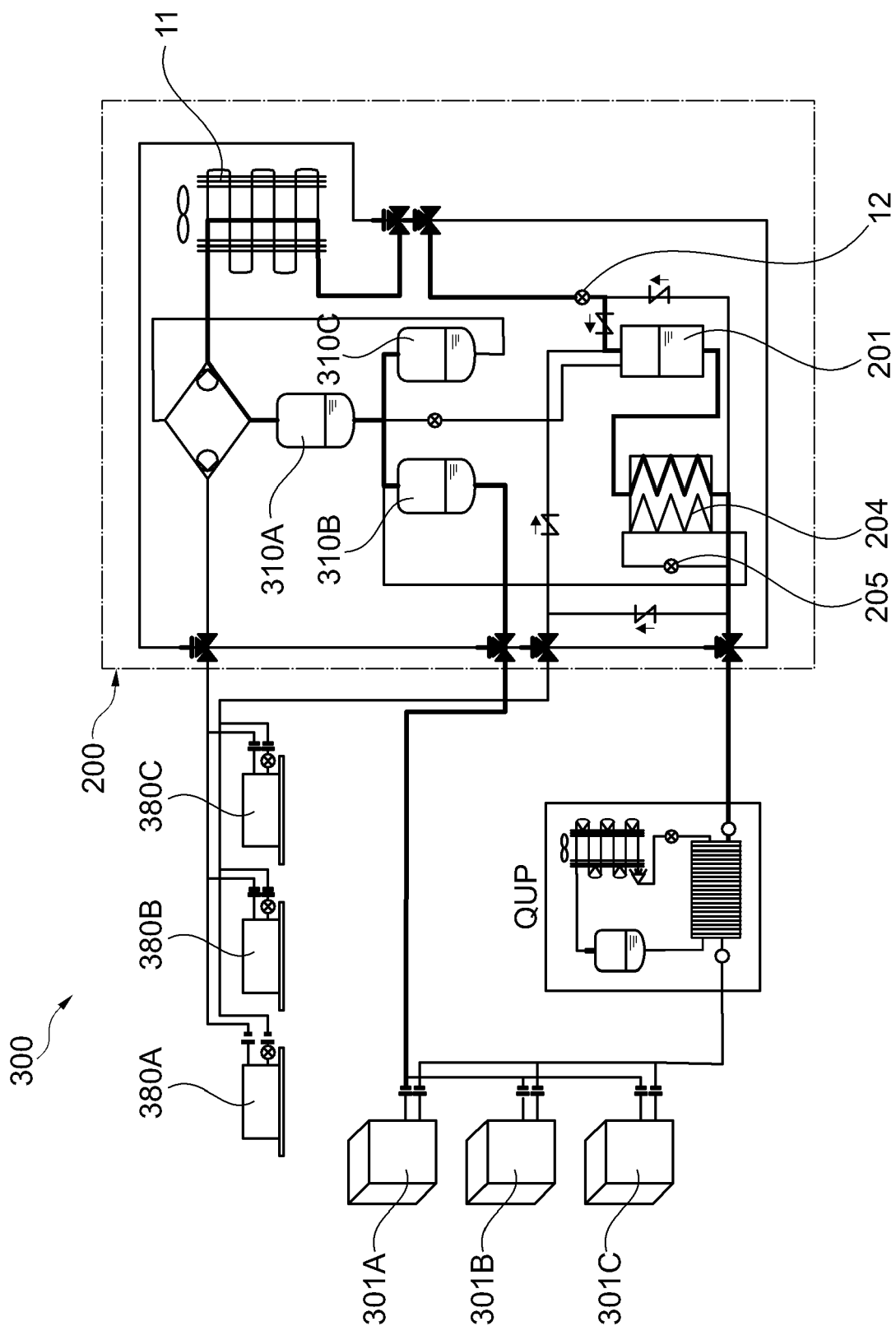


Fig. 12

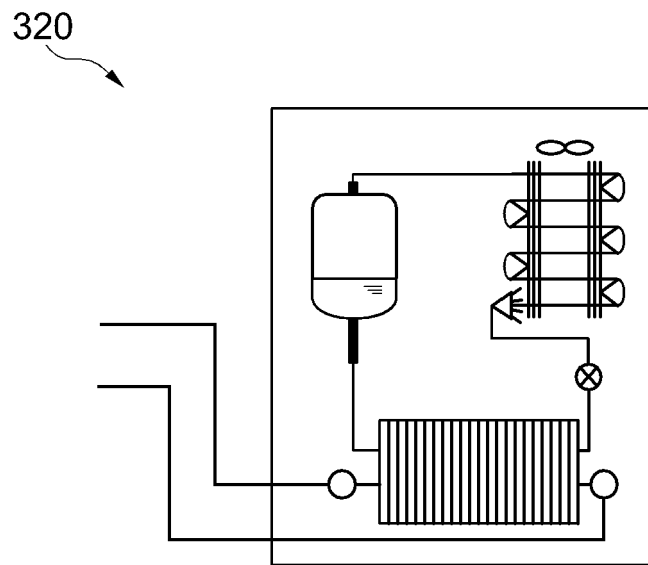


Fig. 13

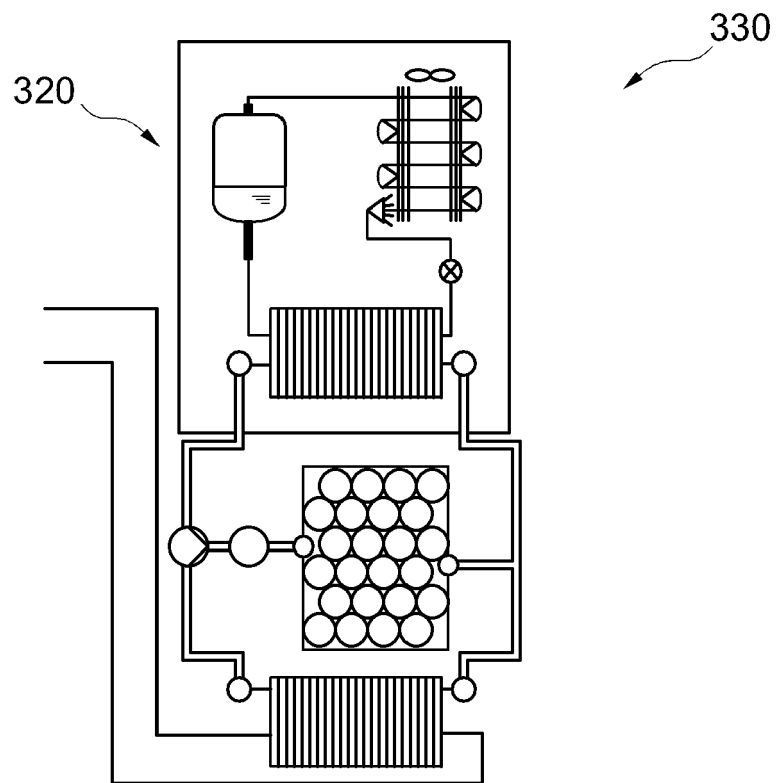


Fig. 14



EUROPEAN SEARCH REPORT

 Application Number
 EP 20 20 5893

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A	* paragraph [0015] - paragraph [0111]; figures 1-6 *	3-15	F25B9/00 F25B49/02

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			F25B
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		24 March 2021	Szilagyi, Barnabas
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			

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