



(12) **EUROPEAN PATENT APPLICATION**

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

(51) International Patent Classification (IPC):
F25B 41/20 ^(2021.01)

(21) Application number: **26203426.7**

(52) Cooperative Patent Classification (CPC):
F25B 7/00; F25B 41/20; F25B 49/02; F25B 9/008; F25B 13/00; F25B 41/39; F25B 2313/003; F25B 2313/0232; F25B 2313/0234; F25B 2339/047; F25B 2400/12; F25B 2600/2501

(22) Date of filing: **27.09.2024**

(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

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(30) Priority: **29.09.2023 JP 2023169776**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
24798712.6 / 4 553 413

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Remarks:

This application was filed on 07.09.2026 as a divisional application to the application mentioned under INID code 62.

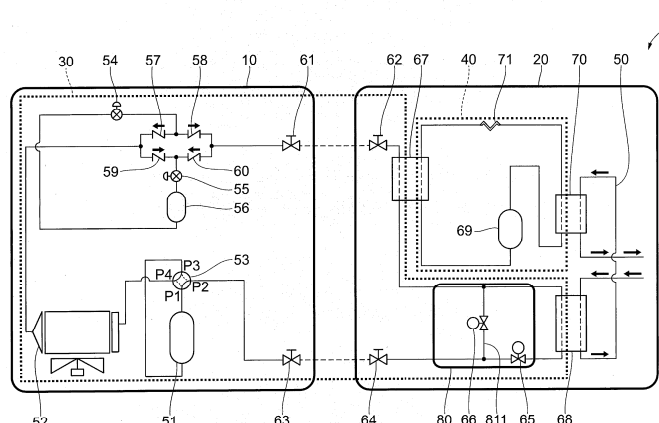
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(54) **REFRIGERANT CIRCUIT SYSTEM**

(57) Provided is a two-stage refrigerant circuit system using two refrigerants, in which a high stage-side circuit (40) and a low stage-side circuit (30) are connected to each other via a cascade heat exchanger (67). The refrigerant circuit system includes: a high stage-side compressor (69), a high stage-side utilization heat exchanger (70), and a high stage-side expansion mechanism (71) in the high stage-side circuit (40); a low stage-side compressor (51), a low stage-side utilization heat exchanger (68), low stage-side expansion

valves (54, 55), and a low stage-side heat source heat exchanger (52) in the low stage-side circuit (30); and a switching circuit (80) configured to switch between a first cycle and a second cycle, the first cycle being a cycle in which refrigerant flows from the low stage-side compressor (51) to the cascade heat exchanger (67), the second cycle being a cycle in which the refrigerant flows from the low stage-side compressor (51) via the low stage-side utilization heat exchanger (68) to the cascade heat exchanger (67).

FIG.1



Description

Technical Field

[0001] The present invention relates to a refrigerant circuit system.

Background Art

[0002] Patent Literature 1 discloses a refrigeration cycle apparatus including a high stage-side refrigerant circuit using propane, a low stage-side refrigerant circuit using carbon dioxide, and a heat medium circuit, and providing high capacity for both cooling and heating operations.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Patent No. 7146117

Summary of Invention

Technical Problem

[0004] For example, in order to further improve the cooling or heating capacity of the refrigeration cycle apparatus of Patent Literature 1, it is necessary to increase the refrigerant charge therein. However, the use of flammable natural refrigerants, such as propane, is restricted because of their flammability. Thus, for example, refrigeration cycles that use flammable natural refrigerants cannot be charged with the refrigerant above a certain volume, which limits their capacity.

[0005] An object of the present disclosure is to propose a refrigerant circuit system that can switch refrigeration cycles according to the required heating capacity.

Solution to Problem

[0006] An aspect of the present disclosure provides a two-stage refrigerant circuit system including a high stage-side circuit (40) using a first refrigerant and a low stage-side circuit (30) using a second refrigerant, the high stage-side circuit (40) and the low stage-side circuit (30) being connected to each other via a cascade heat exchanger (67). The refrigerant circuit system includes: a high stage-side compressor (69), a high stage-side utilization heat exchanger (70), and a high stage-side expansion mechanism (71) in the high stage-side circuit (40); a low stage-side compressor (51), a low stage-side utilization heat exchanger (68), low stage-side expansion valves (54, 55), and a low stage-side heat source heat exchanger (52) in the low stage-side circuit (30); and a switching circuit (80) con-

figured to switch between a first cycle and a second cycle, the first cycle being a cycle in which refrigerant flows from the low stage-side compressor (51) to the cascade heat exchanger (67), the second cycle being a cycle in which the refrigerant flows from the low stage-side compressor (51) via the low stage-side utilization heat exchanger (68) to the cascade heat exchanger (67). This feature allows the refrigeration cycles to be switched according to the required heating capacity.

[0007] In the refrigerant circuit system of the present disclosure, each of the high stage-side utilization heat exchanger (70) and the low stage-side utilization heat exchanger (68) is a water heat exchanger, and the refrigerant circuit system further includes a heat medium circuit (50) including heat medium pipes (85, 86, 87, 89), a pump (84), and a tank (82).

[0008] In the refrigerant circuit system of the present disclosure, the low stage-side circuit (30) further includes a bypass flow path (811), a first cock (65), and a second cock (66).

[0009] The refrigerant circuit system of the present disclosure switches to the second cycle upon determining that a required heating capacity is not reached during heating operation using the first cycle. This feature allows the refrigeration cycles to be switched based on comparison between the current heating capacity and the required heating capacity.

[0010] In the refrigerant circuit system of the present disclosure, the required heating capacity is determined based on three factors of: a target hot water outlet temperature set by a user; a current incoming water temperature; and a water flow rate.

[0011] The refrigerant circuit system of the present disclosure can switch to the second cycle if rotation speed of the high stage-side compressor (69) is at or above an upper limit or a certain threshold and a pump command value for controlling a heat medium flow rate is also at or below a certain threshold, but a first heat medium temperature from the heat medium pipe (87) has not reached a target value.

[0012] The refrigerant circuit system of the present disclosure switches to the second cycle upon determining that rotation speed of the high stage-side compressor (69) is at or above an upper limit or a certain threshold, and a heating capacity estimated from an incoming water temperature, a hot water outlet temperature, and a pump command value has not reached a target capacity, and the heating capacity has not improved for a certain period of time. This feature can prevent the refrigeration cycles from being switched before the heating capacity has been fully increased.

[0013] In the refrigerant circuit system of the present disclosure, a pump command value used for making a determination to switch from the first cycle to the second cycle is changed based on setting of a heat medium pipe length. This feature allows the same flow rate of water to be passed under different heat medium pipe

lengths.

[0014] The refrigerant circuit system of the present disclosure performs heating operation only with the low stage-side circuit (30) in the event of a fault occurring in the high stage-side circuit (40). This feature can ensure a certain level of heating capacity only with the low stage-side circuit even if the high stage-side circuit cannot be used.

[0015] The refrigerant circuit system of the present disclosure issues a fault notification in the event of a fault occurring in the high stage-side circuit (40). This feature allows a user to know the occurrence of the fault while he/she is outside the site of interest and also allows the user himself/herself to determine whether to enable heating operation only with the low stage-side circuit.

[0016] In the refrigerant circuit system of the present disclosure, the high stage-side circuit (40) is installed indoors. This feature allows the refrigerant circuit system to comply with regulations about the flammable refrigerant charge volume even if a flammable refrigerant is used in the high stage-side circuit, allowing the high stage-side circuit to be installed indoors where only a certain level ventilation is available.

[0017] In the refrigerant circuit system of the present disclosure, both of the two refrigerants are natural refrigerants.

[0018] In the refrigerant circuit system of the present disclosure, propane is used in the high stage-side circuit (40) and carbon dioxide is used in the low stage-side circuit (30).

[0019] In the refrigerant circuit system of the present disclosure, in the heat medium circuit (50), a heat medium supplied by the pump (84) flows sequentially through the low stage-side utilization heat exchanger (68) and the high stage-side utilization heat exchanger (70). This feature allows the refrigeration cycles to be switched according to the required heating capacity based on switching by the switching circuit (80), without switching flow paths in the heat medium circuit (50).

[0020] The refrigerant circuit system of the present disclosure further includes a four-way valve (53), and heating operation and cooling operation are switched by switching the four-way valve (53).

Brief Description of Drawings

[0021]

FIG. 1 is a refrigerant circuit diagram showing an example configuration of a refrigerant circuit system according to an exemplary embodiment.

FIG. 2 is a heat medium circuit diagram showing an example configuration of a heat medium circuit according to the embodiment.

FIG. 3 is a refrigerant circuit diagram showing the flow of refrigerant during heating operation in a first cycle according to the embodiment.

FIGS. 4A and 4B are pressure-specific enthalpy diagrams during heating operation in the first cycle, where FIG. 4A is a pressure-specific enthalpy diagram of a high stage-side circuit, and FIG. 4B is a pressure-specific enthalpy diagram of a low stage-side circuit.

FIG. 5 is a refrigerant circuit diagram showing the flow of refrigerant during heating operation in a second cycle according to the embodiment.

FIGS. 6A and 6B are pressure-specific enthalpy diagrams during heating operation in the second cycle, where FIG. 6A is a pressure-specific enthalpy diagram of the high stage-side circuit, and FIG. 6B is a pressure-specific enthalpy diagram of the low stage-side circuit.

FIG. 7A is a block diagram showing an example configuration of major devices according to the embodiment.

FIGS. 7B(B-1) and 7B (B-2) are flowcharts for switching from the first cycle to the second cycle during heating operation, where FIG. 7B(B-1) shows the case of using an upper rotation speed limit of a high stage-side compressor, and FIG. 7B(B-2) shows the case of using a rotation speed threshold of the high stage-side compressor.

FIGS. 7C(C-1) and 7C (C-2) are flowcharts for switching from the second cycle to the first cycle during heating operation, where FIG. 7C(C-1) shows the case of using the required heating capacity, and FIG. 7C(C-2) shows the case of using a target hot water outlet temperature.

FIG. 7D is a flowchart for starting up the refrigerant circuit system according to the embodiment.

FIG. 8A is a schematic refrigerant circuit diagram of a switching circuit in the refrigerant circuit system according to a first variant.

FIG. 8B is a schematic refrigerant circuit diagram of the switching circuit in the refrigerant circuit system according to a second variant.

FIG. 8C is a schematic refrigerant circuit diagram of the switching circuit in the refrigerant circuit system according to a third variant.

FIG. 9A is a schematic heat medium circuit diagram in the refrigerant circuit system according to a fourth variant.

FIG. 9B is a schematic heat medium circuit diagram in the refrigerant circuit system according to a fifth variant.

Description of Embodiments

[0022] An exemplary embodiment of the present disclosure is described below in detail with reference to the appended drawings.

<Configuration of Refrigerant Circuit System>

[0023] FIG. 1 is a refrigerant circuit diagram showing

an example configuration of a refrigerant circuit system according to the embodiment.

[0024] The refrigerant circuit system 1 according to the present embodiment is, for example, a hot water supply system. The hot water supply system provides hot water to destinations. The "destinations" as referred to herein include hot water supply destinations, such as faucets, showers, and baths, as well as heating apparatuses that use hot water. The refrigerant circuit system 1 according to the present embodiment consists of, for example, an outdoor unit 10 installed outdoors and an indoor unit 20 installed indoors. The outdoor unit 10 includes a low stage-side circuit 30, a part of which is connected to the indoor unit 20. The indoor unit 20 includes a high stage-side circuit 40 and a heat medium circuit 50. The refrigerant circuit system 1 according to the present embodiment may include a control unit 100 (see FIG. 7A).

[0025] For example, natural refrigerants are used as the first refrigerant to be charged in the high stage-side circuit 40 and as the second refrigerant to be charged in the low stage-side circuit 30. For example, the low stage-side circuit 30 is charged with carbon dioxide, and the high stage-side circuit 40 is charged with propane.

[0026] The low stage-side circuit 30 includes a low stage-side compressor 51, a low stage-side heat source heat exchanger 52, a four-way valve 53, a first expansion valve 54, stop valves 61, 62, 63, 64, a first cock 65, a second cock 66, a cascade heat exchanger 67, and a low stage-side utilization heat exchanger 68. The low stage-side circuit 30 also includes a switching circuit 80 configured to direct the refrigerant to the cascade heat exchanger 67 without directing it to the low stage-side utilization heat exchanger 68. The low stage-side circuit 30 may further include a second expansion valve 55, a receiver tank 56, and check valves 57, 58, 59, 60.

[0027] The configuration of the low stage-side circuit 30 is not limited to the above. For example, the low stage-side circuit 30 may be configured with a filter, heat sink, oil separator, and the like. The low stage-side circuit 30 may further be configured with a pressure sensor and with a high-pressure switchgear as a protective detector.

[0028] The low stage-side compressor 51 sucks in the refrigerant from its suction side and discharges the compressed refrigerant from its discharge side. The low stage-side compressor 51 may include, at its suction side, an accumulator to separate the refrigerant into gas and liquid. The low stage-side compressor 51 has its discharge side connected to a first port (P1) of the four-way valve 53 and has its suction side connected to a third port (P3) of the four-way valve 53.

[0029] The low stage-side heat source heat exchanger 52 exchanges heat between the refrigerant and the outdoor air. The low stage-side heat source heat exchanger 52 functions as an evaporator during heating

operation. The low stage-side heat source heat exchanger 52 may be configured with an outdoor fan.

[0030] The four-way valve 53 includes a first port (P1), a second port (P2), a third port (P3), and a fourth port (P4). The four-way valve 53 can switch between a state where the first port (P1) communicates with the second port (P2) and the third port (P3) communicates with the fourth port (P4) and a state where the first port (P1) communicates with the fourth port (P4) and the second port (P2) communicates with the third port (P3). During heating operation, the four-way valve 53 is in the state where the first port (P1) communicates with the second port (P2) and the third port (P3) communicates with the fourth port (P4).

[0031] The first and second expansion valves 54, 55 are examples of the low stage-side expansion mechanism. The first and second expansion valves 54, 55 have a variable opening and have the function of lowering the pressure of the refrigerant circulating through the low stage-side circuit 30 to expand the refrigerant.

[0032] The receiver tank 56 is a tank to store liquid refrigerant that has been condensed into liquid by the cascade heat exchanger 67. The low stage-side circuit 30 may be configured with pipes that connect the receiver tank 56 and the low stage-side compressor 51.

[0033] The check valves 57, 58, 59, 60 are valves to prevent backflow of the refrigerant and determine the direction of the refrigerant flow. The refrigerant flow will be detailed below.

[0034] The stop valves 61, 62, 63, 64 provide connection between the pipes in the outdoor unit 10 and the pipes in the indoor unit 20.

[0035] The cascade heat exchanger 67 exchanges heat between the low stage-side circuit 30 and the high stage-side circuit 40. The cascade heat exchanger 67 includes a flow path leading to the low stage-side circuit 30 and a flow path leading to the high stage-side circuit 40. The cascade heat exchanger 67 is, for example, a double-pipe heat exchanger composed of two pipes of different diameters, one inside and the other outside. Alternatively, the cascade heat exchanger 67 may be any other type of heat exchanger, such as a plate heat exchanger.

[0036] During heating operation, the cascade heat exchanger 67 functions as a condenser in the low stage-side circuit 30 and as an evaporator in the high stage-side circuit 40.

[0037] The low stage-side utilization heat exchanger 68 exchanges heat between the low stage-side circuit 30 and the heat medium circuit 50. The low stage-side utilization heat exchanger 68 includes a flow path leading to the low stage-side circuit 30 and a flow path leading to the heat medium circuit 50. During heating operation, the low stage-side utilization heat exchanger 68 functions as a condenser. The heat medium flowing through the heat medium circuit 50 is warmed by taking away heat from the second refrigerant flowing through the low stage-side circuit 30, thereby performing the

heating function. The low stage-side utilization heat exchanger 68 is a water heat exchanger. However, this is not limiting, and the low stage-side utilization heat exchanger 68 may be an air heat exchanger.

[0038] The low stage-side circuit 30 includes a bypass flow path 811. The bypass flow path 811 connects the flow path connecting the low stage-side utilization heat exchanger 68 and the cascade heat exchanger 67 to the flow path connecting the low stage-side utilization heat exchanger 68 and the low stage-side compressor 51.

[0039] The first and second cocks 65, 66 have the function of switching whether or not to direct the second refrigerant to the low stage-side utilization heat exchanger 68, through their opening and closing. The first cock 65 is located on the flow path connecting the low stage-side utilization heat exchanger 68 and the low stage-side compressor 51, and the second cock 66 is located on the bypass flow path 811. When the refrigerant is directed to the low stage-side utilization heat exchanger 68, the first cock 65 is opened and the second cock 66 is closed. On the other hand, when the refrigerant is not directed to the low stage-side utilization heat exchanger 68 but is directed to the cascade heat exchanger 67 through the bypass flow path 811, the first cock 65 is closed and the second cock 66 is opened. The first and second cocks 65, 66 are controlled to open and close by, e.g., the control unit 100 (see FIG. 7A), according to the switching conditions described below.

[0040] The high stage-side circuit 40 includes a cascade heat exchanger 67, a high stage-side compressor 69, a high stage-side utilization heat exchanger 70, and a high stage-side expansion mechanism 71.

[0041] The configuration of the high stage-side circuit 40 is not limited to the above. For example, the high stage-side circuit 40 may be configured with a filter, heat sink, oil separator, and the like. The high stage-side circuit 40 may further be configured with a pressure sensor and with a high-pressure switchgear as a protective detector.

[0042] The high stage-side compressor 69 sucks in the refrigerant from its suction side and discharges the compressed refrigerant from its discharge side. The high stage-side compressor 69 may include, at its suction side, an accumulator to separate the refrigerant into gas and liquid. The high stage-side compressor 69 has its discharge side connected to the high stage-side utilization heat exchanger 70 and has its suction side connected to the cascade heat exchanger 67.

[0043] The high stage-side utilization heat exchanger 70 exchanges heat between the high stage-side circuit 40 and the heat medium circuit 50. During heating operation, the high stage-side utilization heat exchanger 70 functions as a condenser. The heat medium flowing through the heat medium circuit 50 is warmed by taking away heat from the refrigerant flowing through the high stage-side circuit 40, thereby performing the heating

function. The high stage-side utilization heat exchanger 70 is a water heat exchanger. However, this is not limiting, and the high stage-side utilization heat exchanger 70 may be an air heat exchanger.

[0044] The high stage-side expansion mechanism 71 has the function of lowering the pressure of the refrigerant circulating through the high stage-side circuit 40 to expand the refrigerant. For example, the high stage-side expansion mechanism 71 is a capillary tube. Due to its narrow flow path, the capillary tube creates resistance to the refrigerant flow, reducing the pressure. The high stage-side circuit 40 may be configured with an expansion valve instead of the capillary tube.

[0045] FIG. 7A is a block diagram showing an example configuration of major components according to the present embodiment. The control unit 100 is, for example, a controller 100. The controller 100 is a device to control the operation of the hot water supply system. The controller 100 includes a micro control unit (MCU), electric circuitry, and electronic circuitry. The MCU includes a central processing unit (CPU) 101, a memory 102, and a communication interface (communication I/F) 103. The memory 102 stores various programs for execution by the CPU 101. The controller 100 may be composed of one physically independent element or two or more physically separate elements.

[0046] The controller 100 controls the low stage-side circuit 30 and the high stage-side circuit 40. Specifically, the controller 100 controls the low stage-side compressor 51, the high stage-side compressor 69, the four-way valve 53, and the first and second expansion valves 54, 55.

[0047] The heat medium circuit 50 exchanges heat with the low stage-side circuit 30 and the high stage-side circuit 40 via the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat exchanger 70, respectively, thereby providing heat exchange-based functions. The heat medium circuit 50 is charged with a heat medium, which is, e.g., water or brine such as seawater, lake water, or antifreeze. Alternatively, the heat medium circuit 50 may be charged with antifreeze such as tetra-n-butylammonium bromide hydrate (TBAB), silicone oil, or ethylene glycol, as the heat medium.

[0048] An example configuration of the heat medium circuit 50 is described with reference to FIG. 2. FIG. 2 is a heat medium circuit diagram showing an example configuration of the heat medium circuit 50 according to the present embodiment.

[0049] In addition to the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat exchanger 70, the heat medium circuit 50 includes, for example, a three-way cock 81, a tank 82, a heat exchanger 83, a pump 84, and heat medium pipes 85 to 89. The three-way cock 81 may be replaced with, e.g., a tee.

[0050] The heat medium flowing through the heat medium pipe 85 of the heat medium circuit 50 is driven

by the pump 84 to circulate through the heat medium pipe 85. The heat medium flowing through the heat medium pipe 85 passes through the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat exchanger 70, during which the heat medium is warmed through heat exchange with the refrigerant flowing through the low stage-side circuit 30 and the high stage-side circuit 40. In this example, the heat medium flows through the low stage-side utilization heat exchanger 68 and then through the high stage-side utilization heat exchanger 70. The hot water leaving the high stage-side utilization heat exchanger 70 is directed by the three-way cock 81 towards either the tank 82 or the heat medium pipe 86, depending on its use.

[0051] When heating is used, the three-way cock 81 directs the hot water towards the heat medium pipe 86. The heat medium pipe 86 leads to each room which uses heating, thus performing the heating function in each room. The water that has been used for heating and is now thus cooled returns from the heat medium pipe 89. The water returned from the heat medium pipe 89 enters the low stage-side utilization heat exchanger 68 and then the high stage-side utilization heat exchanger 70, where it is warmed by heat exchange before being sent to each room again.

[0052] When hot water is used, the three-way cock 81 directs the hot water towards the tank 82. The tank 82 stores hot water, and the heat exchanger 83 exchanges heat between the water flowing through the heat medium pipe 85 and the hot water stored in the tank 82. The hot water stored in the tank 82 is warmed by the heat exchanger 83 and sent to the heat medium pipe 87 for use as showering or other hot water supply. Meanwhile, the water flowing through the heat medium pipe 85 is cooled by the heat exchanger 83 and enters the low stage-side utilization heat exchanger 68 and then the high stage-side utilization heat exchanger 70, where it is warmed by heat exchange before being sent to the tank 82 again. When the hot water stored in the tank 82 is used, the tank 82 is replenished with city water or the like from the heat medium pipe 88.

[0053] The refrigerant circuit system 1 according to the present embodiment can switch between a first cycle and a second cycle using the switching circuit 80. The switching circuit 80 switches between the first cycle and the second cycle using the first cock 65, the second cock 66, and the bypass flow path 811. When using the first cycle, the low stage-side circuit 30 closes the first cock 65 and opens the second cock 66 to allow the second refrigerant to flow into the cascade heat exchanger 67 without allowing it to flow into the low stage-side utilization heat exchanger 68. When using the second cycle, the low stage-side circuit 30 closes the first cock 65 and opens the second cock 66 to allow the second refrigerant to flow into the low stage-side utilization heat exchanger 68 to cause heat exchange therein.

[0054] The first and second cycles and their switching conditions are described below.

<First Cycle>

[0055] The operation of the refrigerant circuit system 1 during heating operation in the first cycle according to the present embodiment is now described with reference to FIGS. 3 and 4. FIG. 3 is a refrigerant circuit diagram showing the flow of refrigerant during heating operation in the first cycle according to the present embodiment. FIGS. 4A and 4B are pressure-specific enthalpy diagrams during heating operation in the first cycle, where FIG. 4A is a pressure-specific enthalpy diagram of the high stage-side circuit 40, and FIG. 4B is a pressure-specific enthalpy diagram of the low stage-side circuit 30.

[0056] In the first cycle, the first cock 65 is closed and the second cock 66 is open. During heating operation, the four-way valve 53 in the low stage-side circuit 30 enables communication between the first port (P1) and the second port (P2) and communication between the third port (P3) and the fourth port (P4).

[0057] In the first cycle, the second refrigerant circulates along the arrows shown in FIG. 3. More specifically, in the low stage-side circuit 30, the refrigerant in the low-pressure state (see point 91 in FIGS. 3 and 4(b)) is first compressed by the low stage-side compressor 51. The compressed refrigerant passes through the four-way valve 53, the stop valve 63, the stop valve 64, and the second cock 66 and enters the cascade heat exchanger 67. In the first cycle, no refrigerant flows into the low stage-side utilization heat exchanger 68 and no heat exchange takes place therein, so that the state of the refrigerant does not change between points 92 and 93 in FIG. 3 (see points 92 and 93 in FIG. 4B).

[0058] The cascade heat exchanger 67 functions as a condenser in the low stage-side circuit 30, and the refrigerant is cooled by heat exchange with the high stage-side circuit 40 (see point 94 in FIGS. 3 and 4(b)).

[0059] The refrigerant leaving the cascade heat exchanger 67 passes through the stop valve 62, the stop valve 61, the check valve 60, and the second expansion valve 55 and enters the receiver tank 56. The refrigerant leaving the receiver tank 56 passes through the first expansion valve 54 and the check valve 57 and enters the low stage-side heat source heat exchanger 52. The refrigerant is decompressed as it passes through the second expansion valve 55 and the first expansion valve 54 (see point 95 in FIGS. 3 and 4(b)).

[0060] The low stage-side heat source heat exchanger 52 functions as an evaporator, and the refrigerant is heated by heat exchange with the outdoor air (see point 91 in FIGS. 3 and 4(b)). The refrigerant leaving the low stage-side heat source heat exchanger 52 passes through the four-way valve 53 and enters the low stage-side compressor 51 again. The refrigerant

circulates through the low stage-side circuit 30 in this manner.

[0061] In the high stage-side circuit 40, the first refrigerant circulates along the arrows shown in FIG. 3. The refrigerant in the low-pressure state (see point 96 in FIGS. 3 and 4(a)) is first compressed by the high stage-side compressor 69 (see point 97 in FIGS. 3 and 4(a)). The compressed refrigerant enters the high stage-side utilization heat exchanger 70. The high stage-side utilization heat exchanger 70 functions as a condenser, and the refrigerant flowing through the high stage-side circuit 40 is cooled as its heat is taken away by the heat medium flowing through the heat medium circuit 50 (see point 98 in FIGS. 3 and 4(a)).

[0062] The refrigerant then passes through the high stage-side expansion mechanism 71, in which the refrigerant is decompressed (see point 99 in FIGS. 3 and 4(a)). The decompressed refrigerant enters the cascade heat exchanger 67. The cascade heat exchanger 67 functions as an evaporator in the high stage-side circuit 40, and the refrigerant is heated by heat exchange with the low stage-side circuit 30 (see point 96 in FIGS. 3 and 4(a)). The refrigerant leaving the cascade heat exchanger 67 enters the high stage-side compressor 69 again. The refrigerant circulates through the high stage-side circuit 40 in this manner.

[0063] In the first cycle, the heat medium flowing through the heat medium circuit 50 is warmed by heat exchange through the high stage-side utilization heat exchanger 70 with the refrigerant flowing through the high stage-side circuit 40. On the other hand, in the first cycle, no heat exchange takes place in the low stage-side utilization heat exchanger 68.

<Second Cycle>

[0064] The operation of the refrigerant circuit system 1 during heating operation in the second cycle according to the present embodiment is now described with reference to FIGS. 5 and 6. FIG. 5 is a refrigerant circuit diagram showing the flow of refrigerant during heating operation in the second cycle according to the present embodiment. FIGS. 6A and 6B are pressure-specific enthalpy diagrams during heating operation in the second cycle, where FIG. 6A is a pressure-specific enthalpy diagram of the high stage-side circuit 40, and FIG. 6B is a pressure-specific enthalpy diagram of the low stage-side circuit 30.

[0065] In the second cycle, the first cock 65 is open and the second cock 66 is closed. During heating operation, the four-way valve 53 enables communication between the first port (P1) and the second port (P2) and communication between the third port (P3) and the fourth port (P4).

[0066] In the second cycle, the refrigerant circulates along the arrows shown in FIG. 5. More specifically, in the low stage-side circuit 30, the refrigerant in the low-pressure state (see point 91 in FIGS. 5 and 6(b)) is first

compressed by the low stage-side compressor 51 (see point 92 in FIGS. 5 and 6(b)). The compressed refrigerant passes through the four-way valve 53, the stop valve 63, the stop valve 64, and the first cock 65 and enters the low stage-side utilization heat exchanger 68. The low stage-side utilization heat exchanger 68 functions as a condenser, and the refrigerant flowing through the low stage-side circuit 30 is cooled as its heat is taken away by the heat medium flowing through the heat medium circuit 50 (see point 93 in FIG. 5 and FIG. 6B). The refrigerant leaving the low stage-side utilization heat exchanger 68 enters the cascade heat exchanger 67.

[0067] The cascade heat exchanger 67 functions as a condenser in the low stage-side circuit 30, and the refrigerant is cooled by heat exchange with the high stage-side circuit 40 (see point 94 in FIGS. 5 and 6(b)).

[0068] The refrigerant leaving the cascade heat exchanger 67 passes through the stop valve 62, the stop valve 61, the check valve 60, and the second expansion valve 55 and enters the receiver tank 56. The refrigerant leaving the receiver tank 56 passes through the first expansion valve 54 and the check valve 57 and enters the low stage-side heat source heat exchanger 52. The refrigerant is decompressed as it passes through the second expansion valve 55 and the first expansion valve 54 (see point 95 in FIGS. 5 and 6(b)).

[0069] The low stage-side heat source heat exchanger 52 functions as an evaporator, and the refrigerant is heated by heat exchange with the outdoor air (see point 91 in FIGS. 5 and 6(b)). The refrigerant leaving the low stage-side heat source heat exchanger 52 passes through the four-way valve 53 and enters the low stage-side compressor 51 again. The refrigerant circulates through the low stage-side circuit 30 in this manner.

[0070] In the high stage-side circuit 40, the refrigerant flow and the pressure-specific enthalpy diagram during heating operation in the second cycle are the same as in the first cycle.

[0071] In the second cycle, the heat medium flowing through the heat medium circuit 50 is warmed by heat exchange with the refrigerant flowing through the low stage-side circuit 30 and the high stage-side circuit 40 via the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat exchanger 70, respectively.

<Switching Conditions>

[0072] When, for example, a flammable refrigerant such as propane is used in the high stage-side circuit 40, the volume of refrigerant charge is limited. Thus, in the first cycle, only a limited heating capacity is provided by heat exchange through the high stage-side utilization heat exchanger 70. On the other hand, in the second cycle, both the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat

exchanger 70 are used for heat exchange, whereby the heat medium flowing through the heat medium circuit 50 is warmed. In the second cycle, heat exchange also takes place in the low stage-side utilization heat exchanger 68, which can provide a higher heating capacity than when the first cycle is used.

[0073] In the second cycle, the refrigerant flowing through the low stage-side circuit 30 is cooled in the low stage-side utilization heat exchanger 68 and is further cooled in the cascade heat exchanger 67. This can increase the specific enthalpy compared to when the first cycle is used, enhancing the refrigeration effect.

[0074] On the other hand, in the second cycle, it is necessary to increase the high pressure to ensure the hot water outlet temperature (first heat medium temperature), which requires a higher rotation speed of compressor. In contrast, the first cycle does not require as high a pressure as is required in the second cycle, allowing for a more efficient operation.

[0075] From the above, it is desirable to implement a highly efficient operation using the first cycle when the required heating capacity is small and, when the required heating capacity is large, switch to the second cycle to ensure the heating capacity.

[0076] The switching between the first and second cycles in the refrigerant circuit system 1 according to the present embodiment is described below.

(Switching from the first cycle to the second cycle during heating operation)

[0077] In the refrigerant circuit system 1 according to the present embodiment, switching from the heating operation using the first cycle to the heating operation using the second cycle is performed in response to, for example, the control unit 100 determining that the required heating capacity is not reached. When the first cycle is switched to the second cycle, the first cock 65 is opened and the second cock 66 is closed. The required heating capacity is determined by the control unit 100 based on the following three factors: the hot water outlet temperature set by a user (target hot water outlet temperature), the current incoming water temperature, and the water flow rate.

[0078] An example of the case where the control unit 100 determines that the required heating capacity is not reached is when the rotation speed of the high stage-side compressor 69 is at or above an upper limit or a certain threshold and the pump command value for controlling the water flow rate is also at or below a certain threshold, but the hot water outlet temperature has not reached a target value. The hot water outlet temperature refers to the temperature of the water supplied from the tank 82 to the heat medium pipe 87.

[0079] An example process flow for switching from the first cycle to the second cycle during heating operation is described with reference to FIGS. 7B(B-1) and

7B (B-2). FIGS. 7B(B-1) and 7B (B-2) are flowcharts for switching from the first cycle to the second cycle during heating operation, where FIG. 7B(B-1) shows the case of using an upper rotation speed limit of the high stage-side compressor 69, and FIG. 7B(B-2) shows the case of using a rotation speed threshold of the high stage-side compressor 69.

[0080] FIG. 7B(B-1) is described.

[0081] In FIG. 7B(B-1), operation using the first cycle is first performed (step 1001). The control unit 100 determines whether the rotation speed of the high stage-side compressor 69 is at or above the upper limit (step 1002). If the rotation speed is at or below the upper limit (NO in step 1002), the process returns to step 1001, and the operation using the first cycle is performed.

[0082] If the rotation speed is at or above the upper limit (YES in step 1002), the control unit 100 determines whether the pump command value for controlling the water flow rate is at or below a threshold (step 1003). If the pump command value is at or above the threshold (NO in step 1003), the process returns to step 1001, and the operation using the first cycle is performed.

[0083] If the pump command value is at or below the threshold (YES in step 1003), the control unit 100 determines whether the hot water outlet temperature has reached a target value (step 1004). If the hot water outlet temperature has not reached the target value (NO in step 1004), the process returns to step 1001, and the operation using the first cycle is performed.

[0084] If the hot water outlet temperature has reached the target value (YES in step 1004), the control unit 100 switches to operation using the second cycle (step 1005).

[0085] FIG. 7B(B-2) is now described.

[0086] In FIG. 7B(B-2), operation using the first cycle is first performed (step 1011). The control unit 100 determines whether the rotation speed of the high stage-side compressor 69 is at or above a threshold (step 1012). If the rotation speed is at or below the threshold (NO in step 1012), the process returns to step 1011, and the operation using the first cycle is performed.

[0087] If the rotation speed is at or above the threshold (YES in step 1012), the control unit 100 determines whether the pump command value for controlling the water flow rate is at or below a threshold (step 1013). If the pump command value is at or above the threshold (NO in step 1013), the process returns to step 1011, and the operation using the first cycle is performed.

[0088] If the pump command value is at or below the threshold (YES in step 1013), the control unit 100 determines whether the hot water outlet temperature has reached a target value (step 1014). If the hot water outlet temperature has not reached the target value (NO in step 1014), the process returns to step 1011, and the operation using the first cycle is performed.

[0089] If the hot water outlet temperature has reached the target value (YES in step 1014), the con-

trol unit 100 switches to operation using the second cycle (step 1015).

[0090] Being at the upper rotation speed limit for the high stage-side compressor 69 means that the compressor 69 rotates at a speed equal to or higher than the upper rotation speed limit for continuously operable compressors, which is set for each compressor. An example of the case where the rotation speed of the high stage-side compressor 69 is at or above a threshold is when the high stage-side compressor 69 rotates at the speed that is 75% or more of its rotation capacity. An example of the case where the pump command value for controlling the water flow rate is at or below a certain threshold is when the output value is at or below 50%. An example of the case where the hot water outlet temperature has not reached a target value is when the outlet temperature has reached only 50°C whereas the target value is 55°C. In such a case, the control unit 100 determines that the required heating capacity to achieve the target hot water outlet temperature cannot be reached by the use of the first cycle, so that the first cycle is switched to the second cycle.

[0091] The above thresholds for the rotation speed of the high stage-side compressor 69 and the pump command value are merely examples and not limiting. For example, each threshold that serves as a criterion for switching the refrigeration cycles may be variable.

[0092] By switching between the first and second cycles according to the above switching conditions, the refrigeration cycles can be switched based on the rotation speed of the high stage-side compressor 69, the pump command value, and the hot water outlet temperature.

[0093] An example of the case where the control unit 100 determines that the required heating capacity is not reached is when the rotation speed of the high stage-side compressor 69 is at or above the upper limit or a certain threshold, and the heating capacity estimated from the incoming water temperature, hot water outlet temperature, and pump command value has not reached the target capacity, and also the heating capacity has not improved for a certain period of time. If, in the first cycle, the heating capacity has not reached the target capacity and also the heating capacity has not improved for a certain period of time despite the high stage-side compressor 69 running at the rotation speed at or above the upper limit or a certain threshold, it is determined that the required heating capacity is not reached by the use of the first cycle.

[0094] For example, if the high stage-side compressor 69 is rotating at the speed that is 100% of its rotation capacity and the heating capacity estimated from the incoming water temperature, hot water outlet temperature, and pump command value has not been reaching the target capacity for five minutes, the first cycle is switched to the second cycle.

[0095] The above rotation speed of the high stage-side compressor 69 and time threshold are merely ex-

amples and not limiting.

[0096] As the first and second cycles are switched according to the above switching conditions, the refrigeration cycles can be switched upon determining that the required heating capacity cannot be reached by the use of the first cycle. Also, by performing the switching upon determining that the heating capacity has not improved for a certain period of time, it is possible to prevent the refrigeration cycles from being switched before the heating capacity has been fully increased.

[0097] Alternatively, if, for example, the current rotation speed of the high stage-side compressor 69 is at the upper limit, and the current heating capacity has not reached the required heating capacity or the current hot water outlet temperature has not reached the target hot water outlet temperature, the control unit 100 may switch from heating operation using the first cycle to heating operation using the second cycle. The current heating capacity is determined by the control unit 100 based on the current hot water outlet temperature, current incoming water temperature, and water flow rate.

[0098] The switching may be controlled based on the temperature of any other portion; for example, the switching may be controlled based on the temperature of the heat medium supplied from the heat medium pipe 86. The temperature is measured by, e.g., a thermometer (not shown).

[0099] The pump command value used for making the determination to switch from the first cycle to the second cycle may be changed based on the setting of the heat medium pipe length. The heat medium pipe length refers to the length of the heat medium pipes 86, 87 (see FIG. 2) that deliver the heat medium flowing through the heat medium circuit 50 to each room where heating or hot water is used.

[0100] Even with the constant pump command value, the water flow rate cannot be made constant if the heat medium pipe lengths are different. Even if the pump 84 (see FIG. 2) is used with the same pump command value, the amount of water that can be passed varies depending on the heat medium pipe length.

[0101] When estimating the heating capacity from the pump command value, variations in the volume of water that can be passed depending on the heat medium pipe length make it impossible to accurately estimate the heating capacity. Thus, in order to reduce errors in estimating the heating capacity, for example, the control unit 100 receives input of the heat medium pipe length and changes the pump command value according to the setting of the heat medium pipe length.

[0102] For example, if the pump command value is 40% when the heat medium pipe length is 15 m, the pump command value may be set to 70% when the heat medium pipe length is 30 m. This can compensate for the difference in water volume due to different heat medium pipe lengths.

[0103] This configuration allows the same flow rate of water to be passed under different heat medium pipe

lengths.

(Switching from the second cycle to the first cycle during heating operation)

[0104] In the refrigerant circuit system 1 according to the present embodiment, for example, if the current heating capacity has reached the required heating capacity or the current hot water outlet temperature has reached the target hot water outlet temperature, and also there is a margin between the current rotation speed of the high stage-side compressor 69 and the upper rotation speed limit of the high stage-side compressor 69, the controller may switch from heating operation using the second cycle to heating operation using the first cycle. When switching from the second cycle to the first cycle, the first cock 65 is closed and the second cock 66 is opened.

[0105] An example of the case where there is a margin between the current rotation speed of the high stage-side compressor 69 and its upper limit is when the current rotation speed of the high stage-side compressor 69 is less than 90% of its upper rotation speed limit.

[0106] An example process flow for switching from the second cycle to the first cycle during heating operation is described with reference to FIGS. 7C(C-1) and 7C(C-2). FIGS. 7C(C-1) and 7C(C-2) are flowcharts for switching from the second cycle to the first cycle during heating operation, where FIG. 7C(C-1) shows the case of using the required heating capacity, and FIG. 7C(C-2) shows the case of using the target hot water outlet temperature.

[0107] FIG. 7C(C-1) is described.

[0108] In FIG. 7C(C-1), operation using the second cycle is first performed (step 2001). The control unit 100 determines whether the current heating capacity has reached the required heating capacity (step 2002). If the current heating capacity has not reached the required heating capacity (NO in step 2002), the process returns to step 2001, and the operation using the second cycle is performed.

[0109] If the current heating capacity has reached the required heating capacity (YES in step 2002), the control unit 100 determines whether there is a margin between the current rotation speed of the high stage-side compressor 69 and the upper rotation speed limit of the high stage-side compressor 69 (step 2003). If there is no margin to the upper limit (No in step 2003), the process returns to step 2001, and the operation using the second cycle is performed.

[0110] If there is a margin to the upper limit (YES in step 2003), the control unit 100 switches to the operation using the first cycle (step 2004).

[0111] FIG. 7C(C-2) is now described.

[0112] In FIG. 7C(C-2), operation using the second cycle is first performed (step 2011). The control unit 100 determines whether the current hot water outlet

temperature has reached the target hot water outlet temperature (step 2012). If the current hot water outlet temperature has not reached the target hot water outlet temperature (NO in step 2012), the process returns to step 2011, and the operation using the second cycle is performed.

[0113] If the current hot water outlet temperature has reached the target hot water outlet temperature (YES in step 2012), the control unit 100 determines whether there is a margin between the current rotation speed of the high stage-side compressor 69 and the upper rotation speed limit of the high stage-side compressor 69 (step 2013). If there is no margin to the upper limit (No in step 2013), the process returns to step 2011, and the operation using the second cycle is performed.

[0114] If there is a margin to the upper limit (YES in step 2013), the control unit 100 switches to the operation using the first cycle (step 2014).

(At the startup of the refrigerant circuit system 1)

[0115] FIG. 7D is a flowchart for starting up the refrigerant circuit system according to the present embodiment.

[0116] When starting up the refrigerant circuit system 1 according to the present embodiment, the control unit determines whether to perform heating operation using the first cycle or heating operation using the second cycle, based on the switching criterion capacity. The switching criterion capacity refers to an index for determining whether to use the first cycle or the second cycle during heating operation, which is determined by the control unit 100 based on the target hot water outlet temperature and the outdoor air temperature.

[0117] For example, as shown in FIG. 7D, if the switching criterion capacity exceeds the required heating capacity (YES in step 3001), the control unit 100 puts the refrigerant circuit system 1 into operation in the first cycle (step 3002). On the other hand, if the switching criterion capacity is below the required heating capacity (NO in step 3001), the control unit 100 puts the refrigerant circuit system 1 into operation in the second cycle (step 3003).

(Control steps for the refrigerant circuit system 1)

[0118] The control flow for the refrigerant circuit system 1 according to the present embodiment includes, for example a first step of a user setting the hot water outlet temperature, a second step of the control unit 100 calculating the required heating capacity and the switching criterion capacity, and a third step of determining whether to perform heating operation using the first cycle or heating operation using the second cycle based on the calculated switching criterion capacity. If heating operation using the first cycle is performed in the third step, then the control flow includes a fourth step of switching to heating operation using the second

cycle if (1) the current rotation speed of the high stage-side compressor 69 is at the upper limit, and (2) the current heating capacity has not reached the required heating capacity or (3) the current hot water outlet temperature has not reached the target hot water outlet temperature. If heating operation using the second cycle is performed in the third step, then the control flow includes a fifth step of switching to heating operation using the first cycle if (1) there is a margin between the current rotation speed of the high stage-side compressor 69 and the upper rotation speed limit of the high stage-side compressor 69, and (2) the current heating capacity has reached the required heating capacity or (3) the current hot water outlet temperature has reached the target hot water outlet temperature.

[0119] For example, if the heating operation is currently running in the first cycle, the control unit 100 may periodically determine whether any of the following conditions (1) to (3) has been met: (1) the current rotation speed of the high stage-side compressor 69 is at the upper limit, (2) the current heating capacity has not reached the required heating capacity, and (3) the current hot water outlet temperature has not reached the target hot water outlet temperature. Also, for example, if the heating operation is currently running in the second cycle, the control unit 100 may periodically determine whether any of the following conditions (1) to (3) has been met: (1) there is a margin between the current rotation speed of the high stage-side compressor 69 and the upper rotation speed limit of the high stage-side compressor 69, (2) the current heating capacity has reached the required heating capacity, and (3) the current hot water outlet temperature has reached the target hot water outlet temperature.

[0120] An implementation is possible where, in the event of a fault occurring in the high stage-side circuit 40, heating operation is performed only with the low stage-side circuit 30. A fault is any event that prevents operation using the high stage-side circuit 40, such as a failure occurring in the high stage-side compressor 69. An implementation is also possible where heating operation is performed only with the low stage-side circuit 30 although the failure of interest is so minor as not to prevent the operation.

[0121] Any of these implementations can ensure a certain level of heating capacity only with the low stage-side circuit 30 even if the high stage-side circuit 40 cannot be used.

[0122] An implementation is also possible where a fault notification is issued in the event of a fault occurring in the high stage-side circuit 40. Upon receiving the fault notification, the user can know the unavailability of the high stage-side circuit 40 and take immediate actions. This implementation allows the user to know the occurrence of the fault while he/she is outside the site of interest and also allows the user himself/herself to determine whether to enable heating operation only with the low stage-side circuit.

[0123] In the present embodiment, the high stage-side circuit 40 is installed indoors. In the case of using propane as the refrigerant charged in the high stage-side circuit 40 and installing it indoors, according to IEC 60335-2-40 Ed. 7, there is no limitation to the floor area of the room where the circuit is installed if the refrigerant volume is 152 g or less, but if the refrigerant volume exceeds 152 g, a limitation is placed on the floor area of the room where the circuit is installed and also safety measures must be taken in case of leakage.

[0124] In the present invention, the maximum heating capacity can be reduced in the first cycle to reduce the heat exchanger volume and thus the refrigerant volume, and in the case of insufficiency in heating capacity, the first cycle can be switched to the second cycle to secure the heating capacity also in the low stage-side circuit 30, which can expand the maximum heating capacity. This reduction in the refrigerant volume allows the propane-charged high stage-side circuit 40 to be installed indoors where only a certain level ventilation is available.

<Advantageous Effects>

[0125] The refrigerant circuit system 1 of the present disclosure is a two-stage refrigerant circuit system including the high stage-side circuit (40) using the first refrigerant and the low stage-side circuit (30) using the second refrigerant, the high stage-side circuit (40) and the low stage-side circuit (30) being connected to each other via the cascade heat exchanger (67). The refrigerant circuit system includes: the high stage-side compressor 69, the high stage-side utilization heat exchanger 70, and the high stage-side expansion mechanism 71 in the high stage-side circuit 40; the low stage-side compressor 51, the low stage-side utilization heat exchanger 68, the first expansion valve 54, the second expansion valve 55, and the low stage-side heat source heat exchanger 52 in the low stage-side circuit 30; and the switching circuit 80 configured to switch between the first cycle and the second cycle, the first cycle being a cycle in which the refrigerant flows from the low stage-side compressor 51 to the cascade heat exchanger 67, the second cycle being a cycle in which the refrigerant flows the low stage-side compressor 51 via the low stage-side utilization heat exchanger 68 to the cascade heat exchanger 67. This feature allows the refrigeration cycles to be switched according to the required heating capacity.

[0126] In the refrigerant circuit system 1 of the present disclosure, each of the high stage-side utilization heat exchanger 70 and the low stage-side utilization heat exchanger 68 is a water heat exchanger, and the refrigerant circuit system further includes the heat medium circuit 50 including the heat medium pipes 85, 86, 87, 89, the pump 84, and the tank 82.

[0127] In the refrigerant circuit system of the present disclosure, the low stage-side circuit (30) further in-

cludes the bypass flow path (811), the first cock (65), and the second cock (66).

[0128] The refrigerant circuit system 1 of the present disclosure switches to the second cycle upon determining that the required heating capacity is not reached during heating operation using the first cycle. This feature allows the refrigeration cycles to be switched based on comparison between the current heating capacity and the required heating capacity.

[0129] In the refrigerant circuit system of the present disclosure, the required heating capacity is determined based on the three factors of: the hot water outlet temperature set by a user (target hot water outlet temperature); the current incoming water temperature; and the water flow rate.

[0130] The refrigerant circuit system 1 of the present disclosure switches to the second cycle if the rotation speed of the high stage-side compressor 69 is at or above the upper limit or a certain threshold and the pump command value for controlling the heat medium flow rate is also at or below a certain threshold, but the first heat medium temperature from the heat medium pipe 87 has not reached the target value. This feature allows the refrigeration cycles to be switched based on the rotation speed of the high stage-side compressor 69, the pump command value, and the hot water outlet temperature.

[0131] The refrigerant circuit system 1 of the present disclosure switches to the second cycle upon determining that the rotation speed of the high stage-side compressor 69 is at or above the upper limit or a certain threshold, and the heating capacity estimated from the incoming water temperature, the hot water outlet temperature, and the pump command value has not reached the target capacity, and the heating capacity has not improved for a certain period of time. This feature can prevent the refrigeration cycles from being switched before the heating capacity has been fully increased.

[0132] In the refrigerant circuit system 1 of the present disclosure, the pump command value used for making the determination to switch from the first cycle to the second cycle is changed based on the setting of heat medium pipe length. This feature allows the same flow rate of water to be passed under different heat medium pipe lengths.

[0133] The refrigerant circuit system 1 of the present disclosure performs heating operation only with the low stage-side circuit 30 in the event of a fault occurring in the high stage-side circuit 40. This feature can ensure a certain level of heating capacity only with the low stage-side circuit 30 even if the high stage-side circuit 40 cannot be used.

[0134] The refrigerant circuit system 1 of the present disclosure issues a fault notification in the event of a fault occurring in the high stage-side circuit 40. This feature allows a user to know the occurrence of the fault while he/she is outside the site of interest and also

allows the user himself/herself to determine whether to enable heating operation only with the low stage-side circuit 30.

[0135] In the refrigerant circuit system 1 of the present disclosure, the high stage-side circuit 40 is installed indoors. This feature allows the refrigerant circuit system 1 to comply with regulations about the flammable refrigerant charge volume even if a flammable refrigerant is used in the high stage-side circuit, allowing the high stage-side circuit to be installed indoors where only a certain level ventilation is available.

[0136] In the refrigerant circuit system 1 of the present disclosure, both of the above two refrigerants are natural refrigerants.

[0137] In the refrigerant circuit system 1 of the present disclosure, propane is used in the high stage-side circuit 40 and carbon dioxide is used in the low stage-side circuit 30.

[0138] In the refrigerant circuit system 1 of the present disclosure, in the heat medium circuit 50, the heat medium supplied by the pump 84 flows sequentially through the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat exchanger 70. This feature allows the refrigeration cycles to be switched according to the required heating capacity based on switching by the switching circuit 80, without switching flow paths in the heat medium circuit 50.

[0139] The refrigerant circuit system of the present disclosure further includes the four-way valve (53), and heating operation and cooling operation are switched by switching the four-way valve (53).

<Variants>

[0140] Variants of the refrigerant circuit system 1 of the present disclosure described above are now described. It should be noted that the following variants can be combined as appropriate.

<First Variant>

[0141] In the refrigerant circuit system 1 of the present disclosure described above, the first cock 65 is located on the flow path connecting the low stage-side utilization heat exchanger 68 and the low stage-side compressor 51 in the bypass flow path 811 of the low stage-side circuit 30. However, this implementation is not limiting.

[0142] FIG. 8A is a schematic refrigerant circuit diagram of the switching circuit in the refrigerant circuit system according to the first variant. As shown in FIG. 8A, the first cock 65 is located on the flow path connecting the low stage-side utilization heat exchanger 68 and the cascade heat exchanger 67 (see FIG. 1).

<Second Variant>

[0143] FIG. 8B is a schematic refrigerant circuit dia-

gram of the switching circuit in the refrigerant circuit system according to a second variant.

[0144] In the refrigerant circuit system 1 of the present disclosure described above, in the bypass flow path 811 of the low stage-side circuit 30, the first and second cocks 65, 66 are used to switch whether or not to direct the second refrigerant to the low stage-side utilization heat exchanger 68. In contrast, as shown in FIG. 8B, in the refrigerant circuit system 1 of the second variant, a three-way valve 812 is located at the junction of one end of the bypass flow path 811 and the flow path connecting the low stage-side utilization heat exchanger 68 and the low stage-side compressor 51 (see FIG. 1).

<Third Variant>

[0145] FIG. 8C is a schematic refrigerant circuit diagram of the switching circuit in the refrigerant circuit system according to a third variant.

[0146] As shown in FIG. 8C, in the refrigerant circuit system 1 of the third variant, a three-way valve 813 is located at the junction of one end of the bypass flow path 811 and the flow path connecting the low stage-side utilization heat exchanger 68 and the cascade heat exchanger 67 (see FIG. 1).

<Fourth Variant>

[0147] FIG. 9A is a schematic heat medium circuit diagram in the refrigerant circuit system according to a fourth variant.

[0148] In the heat medium circuit 50 of the refrigerant circuit system 1 of the present disclosure described above, the heat medium flows through the low stage-side utilization heat exchanger 68 and then through the high stage-side utilization heat exchanger 70. However, this implementation is not limiting. As shown in FIG. 9A, in the heat medium circuit 50 of the fourth variant, the heat medium flows through the high stage-side utilization heat exchanger 70 and then through the low stage-side utilization heat exchanger 68.

<Fifth Variant>

[0149] FIG. 9B is a schematic heat medium circuit diagram in the refrigerant circuit system according to a fifth variant.

[0150] As shown in FIG. 9B, in the heat medium circuit 50 of the fifth variant, the heat medium circulates independently through the low stage-side utilization heat exchanger 68 and the high stage-side utilization heat exchanger 70.

[0151] Although exemplary embodiments have been described above, the technical scope of the present disclosure is not limited to the scope described in the above embodiments. It will be apparent from the appended claims that combinations of two or more of the

above exemplary embodiments, as well as various changes or improvements to the above exemplary embodiments, are also within the technical scope of the present disclosure.

Reference Signs List

[0152]

10	1 Refrigerant circuit system
	10 Outdoor unit
	20 Indoor unit
	30 Low stage-side circuit
	40 High stage-side circuit
15	50 Heat medium circuit
	51 Low stage-side compressor
	52 Low stage-side heat source heat exchanger
	53 Four-way valve
	54 First expansion valve
20	55 Second expansion valve
	67 Cascade heat exchanger
	68 Low stage-side utilization heat exchanger
	69 High stage-side compressor
	70 High stage-side utilization heat exchanger
25	71 High stage-side expansion mechanism
	80 Switching circuit

The following items are also part of the invention:

[Item 1] A two-stage refrigerant circuit system including a high stage-side circuit (40) using a first refrigerant and a low stage-side circuit (30) using a second refrigerant, the high stage-side circuit (40) and the low stage-side circuit (30) being connected to each other via a cascade heat exchanger (67), the refrigerant circuit system comprising:

a high stage-side compressor (69), a high stage-side utilization heat exchanger (70), and a high stage-side expansion mechanism (71) in the high stage-side circuit (40);
a low stage-side compressor (51), a low stage-side utilization heat exchanger (68), low stage-side expansion valves (54, 55), and a low stage-side heat source heat exchanger (52) in the low stage-side circuit (30); and
a switching circuit (80) configured to switch between a first cycle and a second cycle, the first cycle being a cycle in which refrigerant flows from the low stage-side compressor (51) to the cascade heat exchanger (67), the second cycle being a cycle in which the refrigerant flows from the low stage-side compressor (51) via the low stage-side utilization heat exchanger (68) to the cascade heat exchanger (67).

[Item 2] The refrigerant circuit system according to item 1, wherein

each of the high stage-side utilization heat exchanger (70) and the low stage-side utilization heat exchanger (68) is a water heat exchanger, and

the refrigerant circuit system further comprises a heat medium circuit (50) including heat medium pipes (85, 86, 87, 89), a pump (84), and a tank (82).

[Item 3] The refrigerant circuit system according to item 2, wherein the low stage-side circuit (30) further comprises a bypass flow path (811), a first cock (65), and a second cock (66).

[Item 4] The refrigerant circuit system according to item 1 or 2, wherein the refrigerant circuit system switches to the second cycle upon determining that a required heating capacity is not reached during heating operation using the first cycle.

[Item 5] The refrigerant circuit system according to item 4, wherein the required heating capacity is determined based on three factors of: a target hot water outlet temperature set by a user; a current incoming water temperature; and a water flow rate.

[Item 6] The refrigerant circuit system according to item 4, wherein the refrigerant circuit system switches to the second cycle if rotation speed of the high stage-side compressor (69) is at or above an upper limit or a certain threshold and a pump command value for controlling a heat medium flow rate is also at or below a certain threshold, but a first heat medium temperature from the heat medium pipe (87) has not reached a target value.

[Item 7] The refrigerant circuit system according to item 4, wherein the refrigerant circuit system switches to the second cycle upon determining that rotation speed of the high stage-side compressor (69) is at or above an upper limit or a certain threshold, and a heating capacity estimated from an incoming water temperature, a hot water outlet temperature, and a pump command value has not reached a target capacity, and the heating capacity has not improved for a certain period of time.

[Item 8] The refrigerant circuit system according to item 4, wherein a pump command value used for making a determination to switch from the first cycle to the second cycle is changed based on setting of a heat medium pipe length.

[Item 9] The refrigerant circuit system according to item 2, wherein the refrigerant circuit system performs heating operation only with the low stage-side circuit (30) in the event of a fault occurring in the high stage-side circuit (40).

[Item 10] The refrigerant circuit system according to items 2 to 9, wherein the refrigerant circuit system issues a fault notification in the event of a fault occurring in the high stage-side circuit (40).

[Item 11] The refrigerant circuit system according to items 2 to 9, wherein the high stage-side circuit

(40) is installed indoors.

[Item 12] The refrigerant circuit system according to any one of items 2, 4, and 9, wherein both of the two refrigerants are natural refrigerants.

[Item 13] The refrigerant circuit system according to item 12, wherein propane is used in the high stage-side circuit (40) and carbon dioxide is used in the low stage-side circuit (30).

[Item 14] The refrigerant circuit system according to item 2, wherein, in the heat medium circuit (50), a heat medium supplied by the pump (84) flows sequentially through the low stage-side utilization heat exchanger (68) and the high stage-side utilization heat exchanger (70).

[Item 15] The refrigerant circuit system according to item 2, further comprising a four-way valve (53), wherein heating operation and cooling operation are switched by switching the four-way valve (53).

Claims

1. A two-stage refrigerant circuit system comprising:

a high stage-side circuit (40) including a high stage-side compressor (69), a high stage-side utilization heat exchanger (70), and a high stage-side expansion mechanism (71), the high stage-side circuit (40) using a first refrigerant;

a low stage-side circuit (30) including a low stage-side compressor (51), a low stage-side utilization heat exchanger (68), low stage-side expansion valves (54, 55), and a low stage-side heat source heat exchanger (52), the low stage-side circuit (30) using a second refrigerant; and

a cascade heat exchanger (67) configured to exchange heat between the low stage-side circuit (30) and the high stage-side circuit (40), wherein

the first refrigerant is propane, the second refrigerant is carbon dioxide, and the high stage-side circuit (40) is installed indoors.

2. The refrigerant circuit system according to claim 1, wherein a refrigerant charge volume of the first refrigerant is 152 g or less.

3. The refrigerant circuit system according to claim 1 or 2, wherein the low stage-side circuit (30) further comprises a bypass flow path (811).

4. The refrigerant circuit system according to claim 3, wherein the low stage-side circuit (30) further comprises a first cock (65) and a second cock (66).

5. The refrigerant circuit system according to claim 4,
wherein the first cock (65) is located on either
- a) a flow path connecting the low stage-side utilization heat exchanger (68) and the low stage-side compressor (51) in the bypass flow path (811) of the low stage-side circuit (30), or
 - b) a flow path connecting the low stage-side utilization heat exchanger (68) and the cascade heat exchanger (67), and
- the second cock (66) is located on the bypass flow path (811).
6. The refrigerant circuit system according to claim 3, wherein the low stage-side circuit (30) further comprises a three-way valve (812, 813) located at the junction of one end of the bypass flow path (811) and either
- a) a flow path connecting the low stage-side utilization heat exchanger (68) and the low stage-side compressor (51), or
 - b) a flow path connecting the low stage-side utilization heat exchanger (68) and the cascade heat exchanger (67).
7. The refrigerant circuit system according to any one of claims 3 to 6, wherein the first refrigerant is flowable into the cascade heat exchanger (67) through the bypass flow path (811) without allowing the first refrigerant to flow into the low stage-side utilization heat exchanger (68).
8. The refrigerant circuit system according to any one of the preceding claims, wherein the refrigerant circuit system has a mode in which a heating operation is performed only with the low stage-side circuit (30).

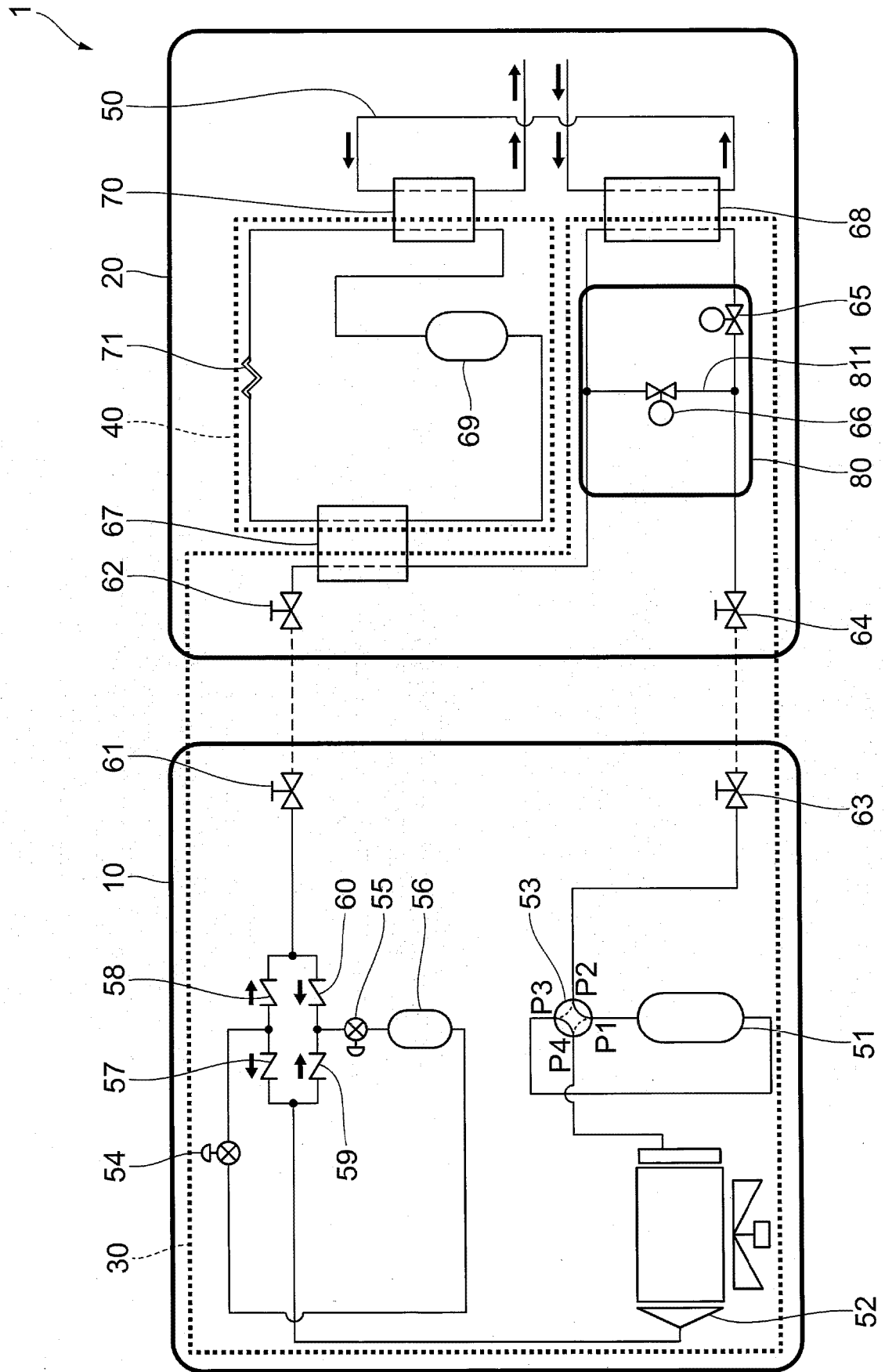


FIG. 1

FIG.2

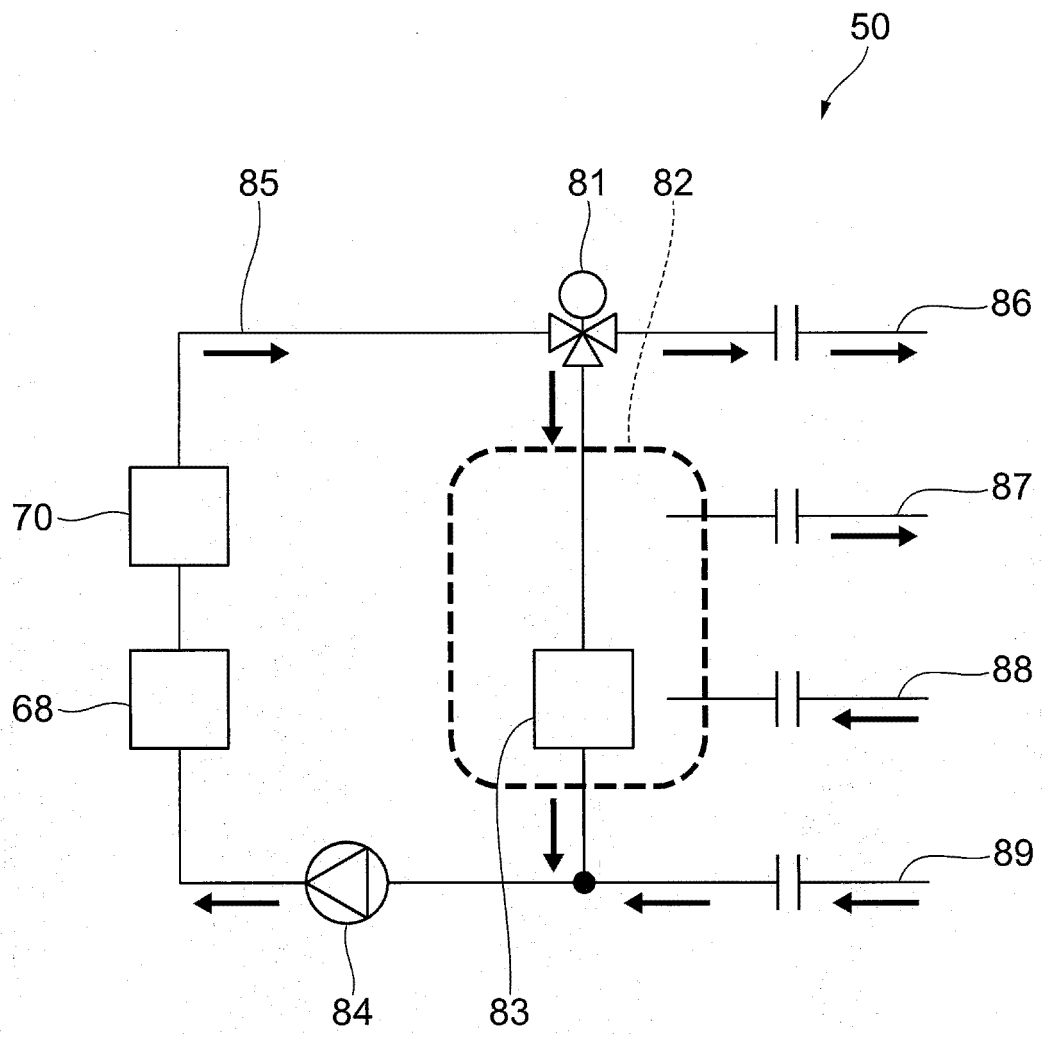


FIG. 3

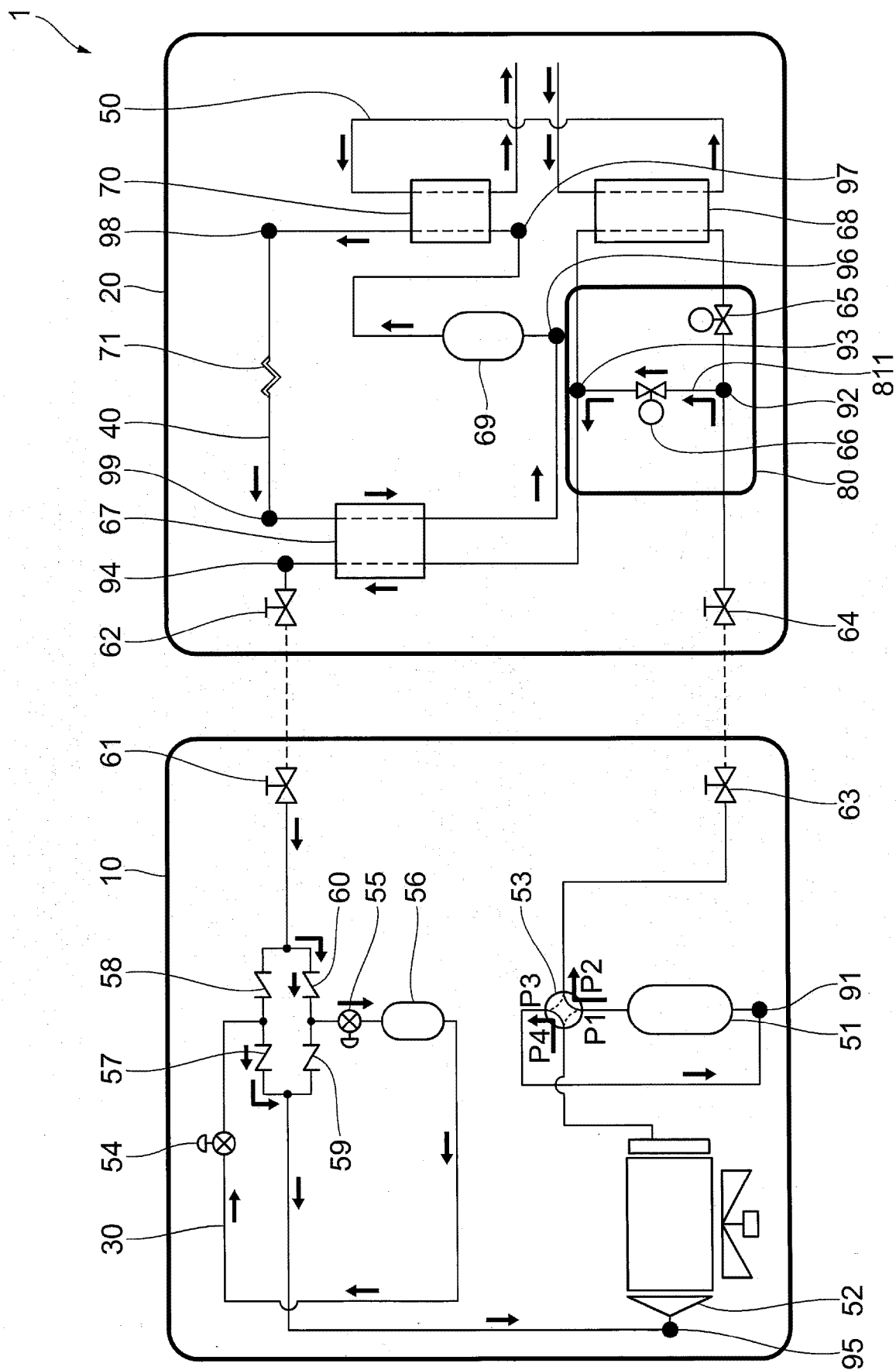


FIG.4A

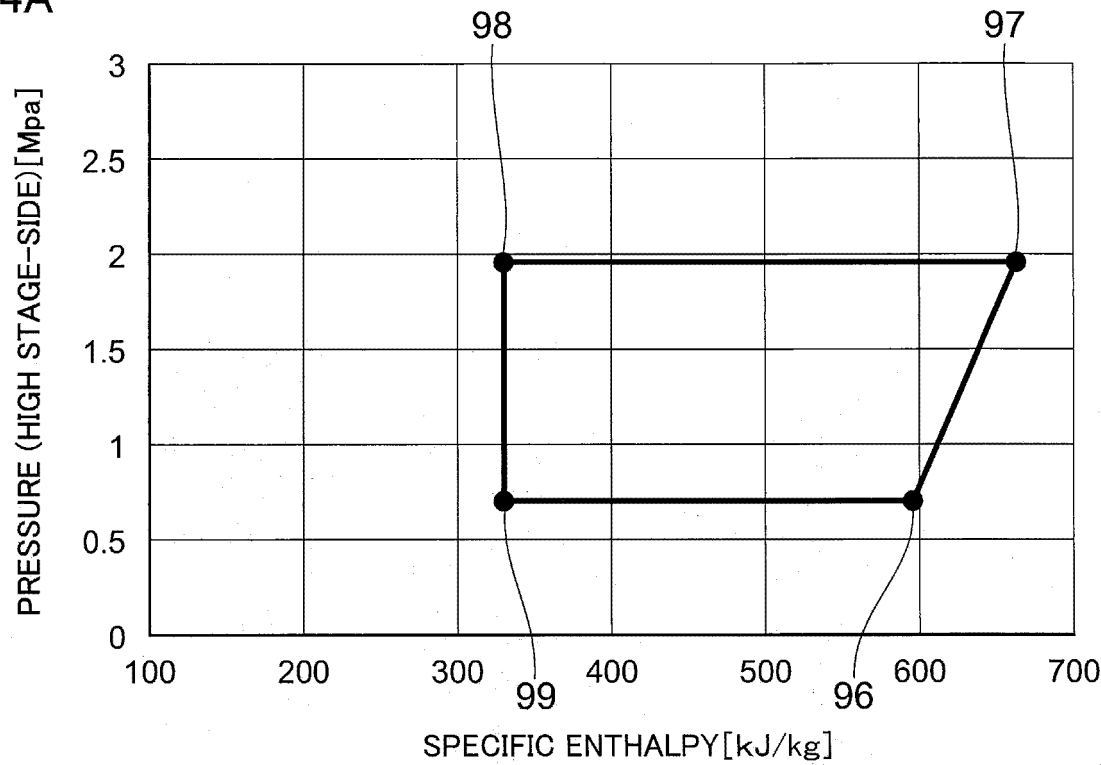


FIG.4B

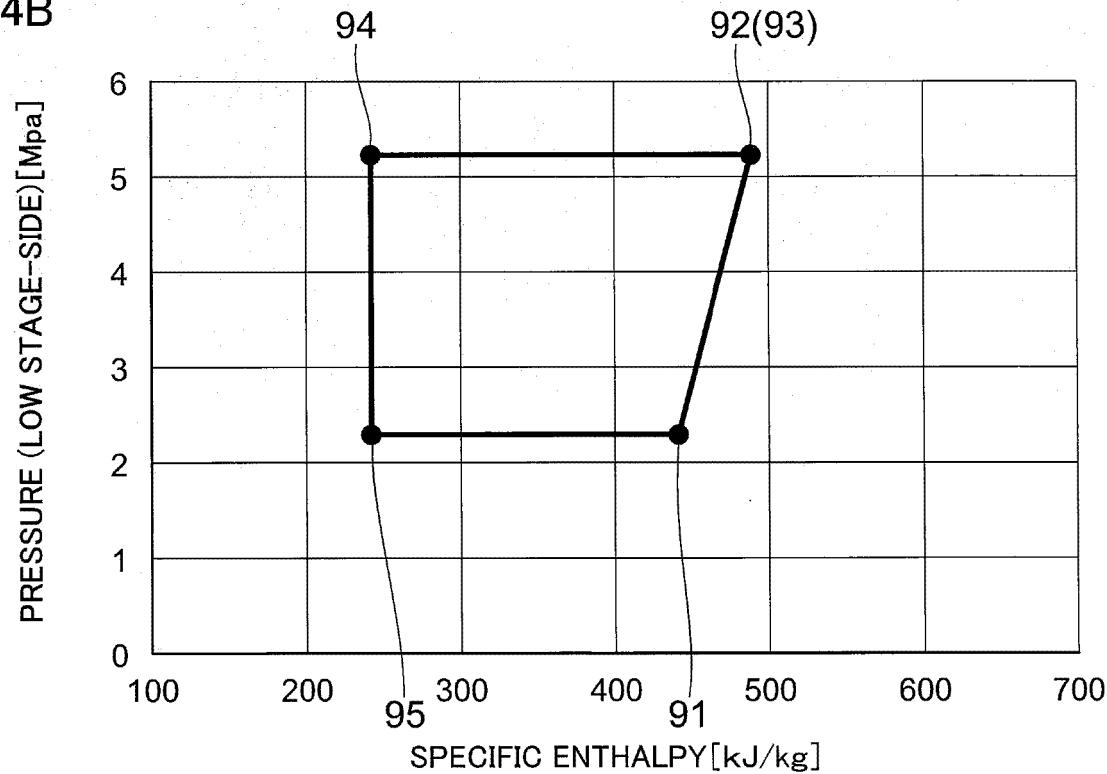


FIG.5

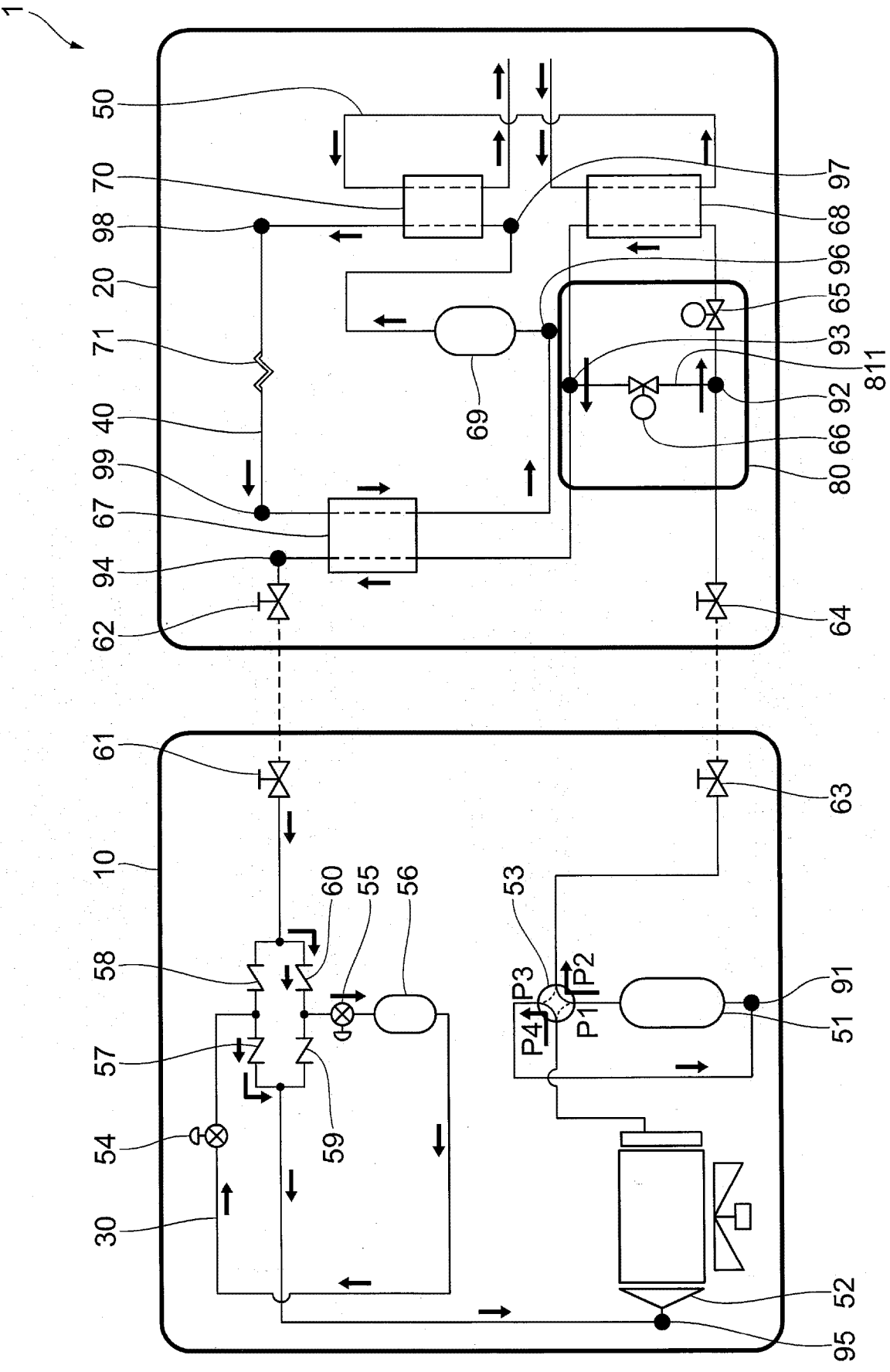


FIG.6A

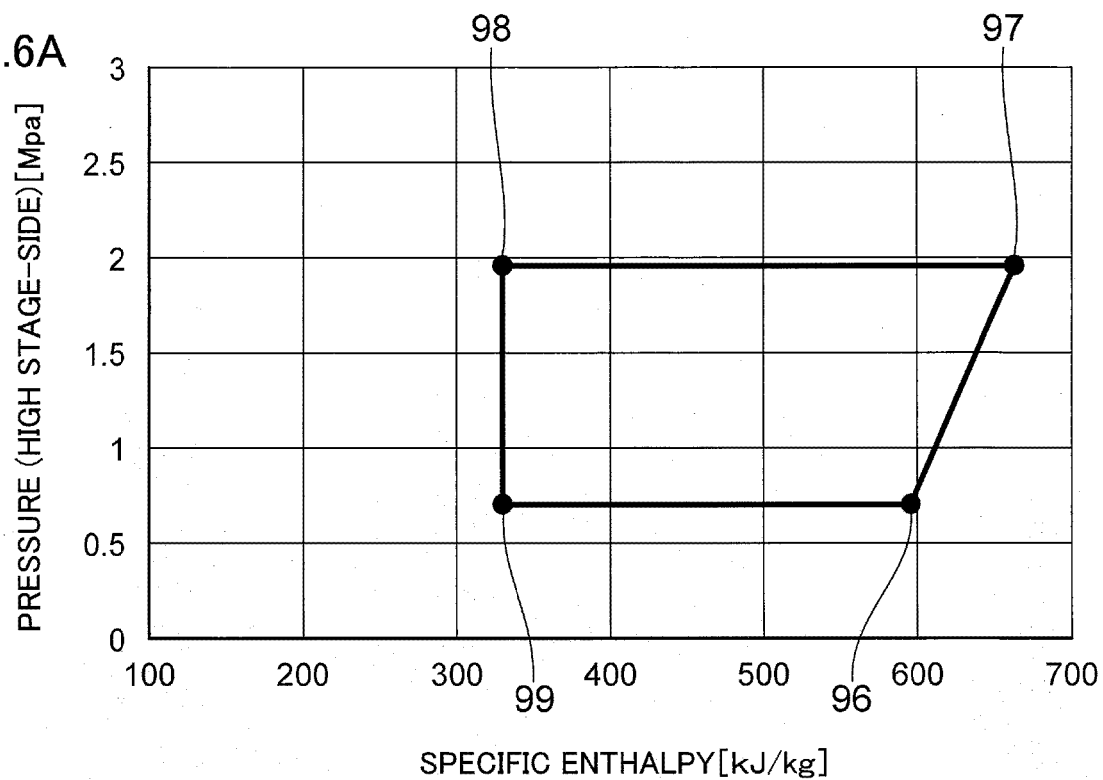


FIG.6B

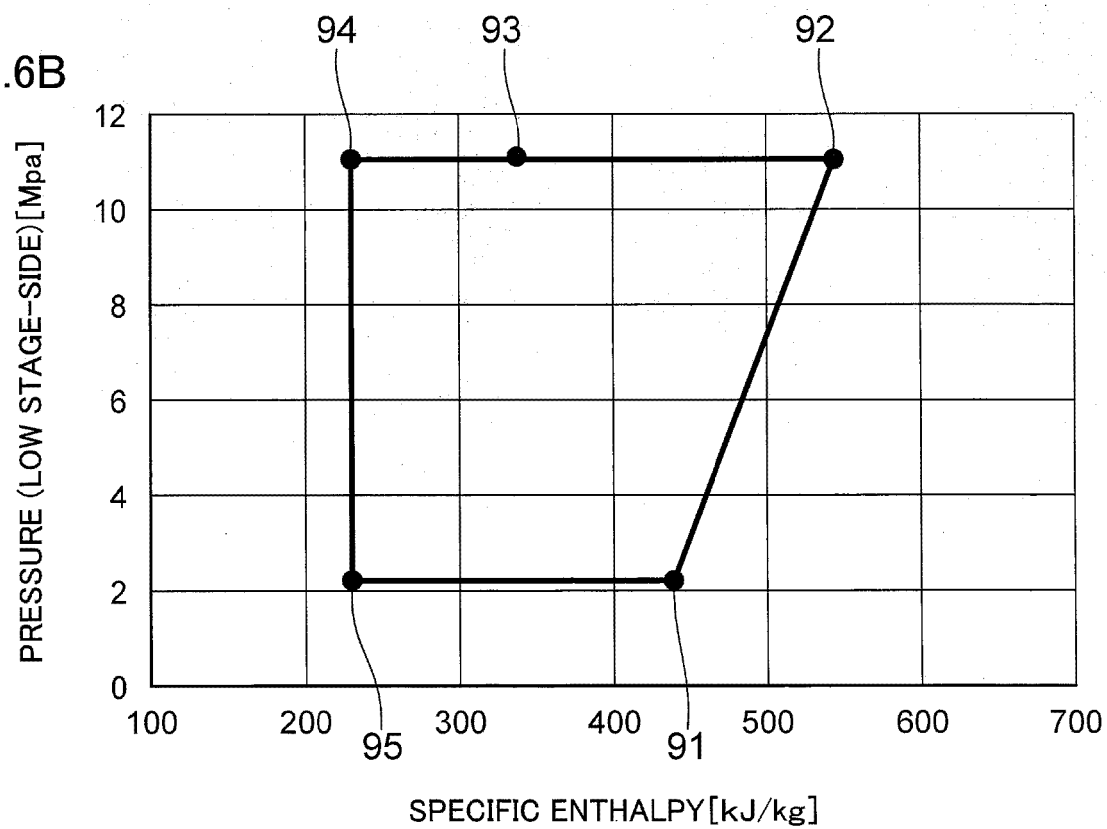


FIG.7A

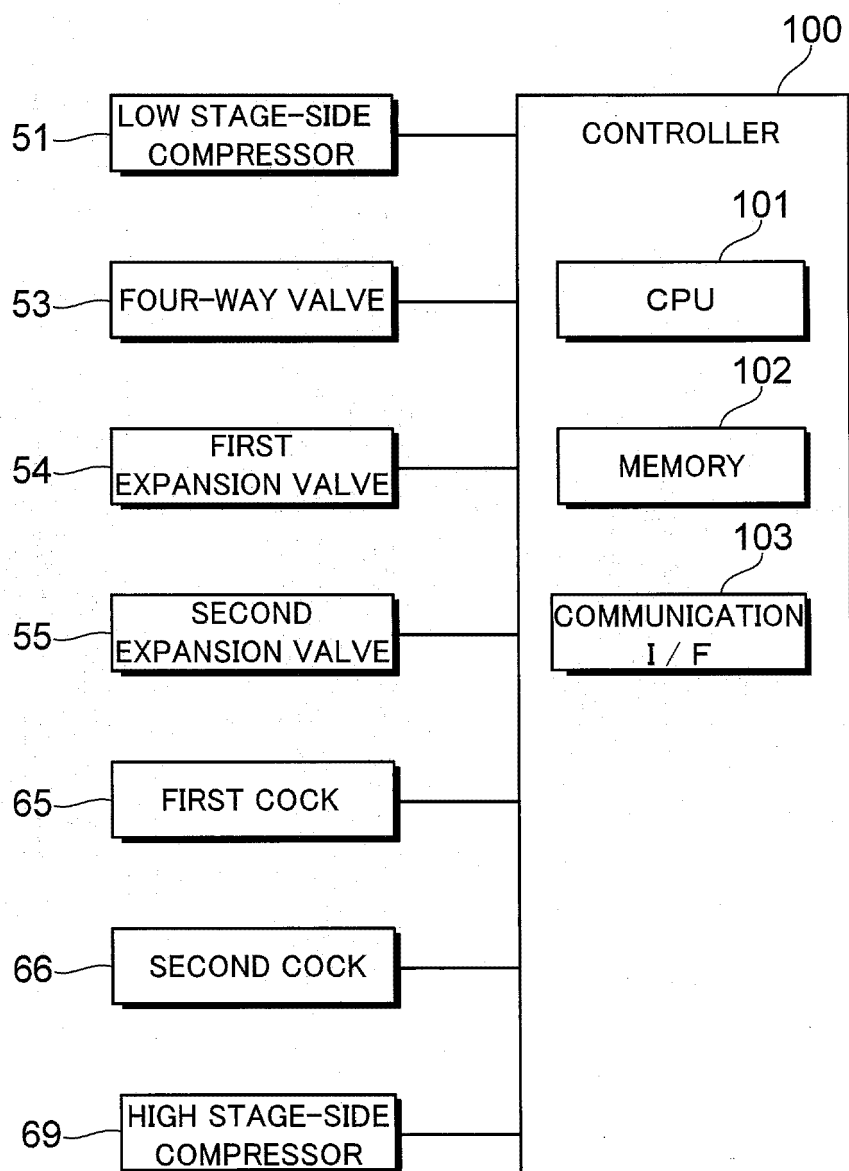
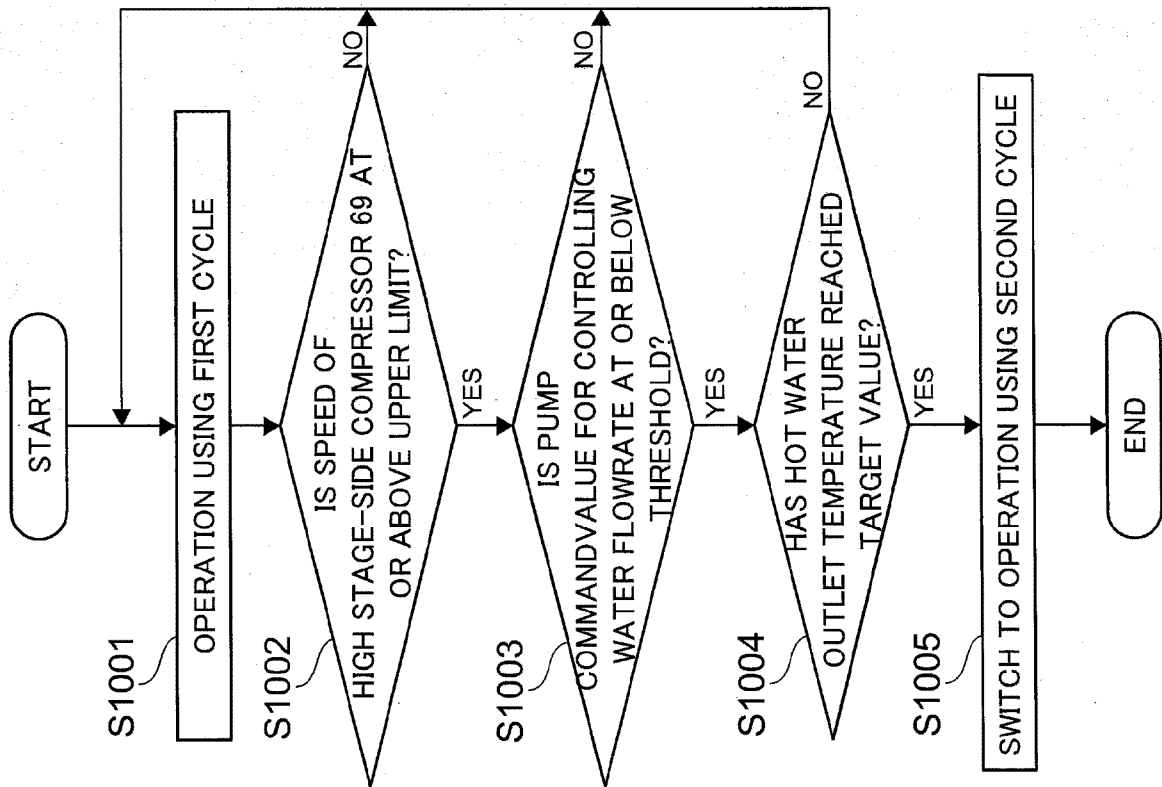


FIG.7B

(B-1)



(B-2)

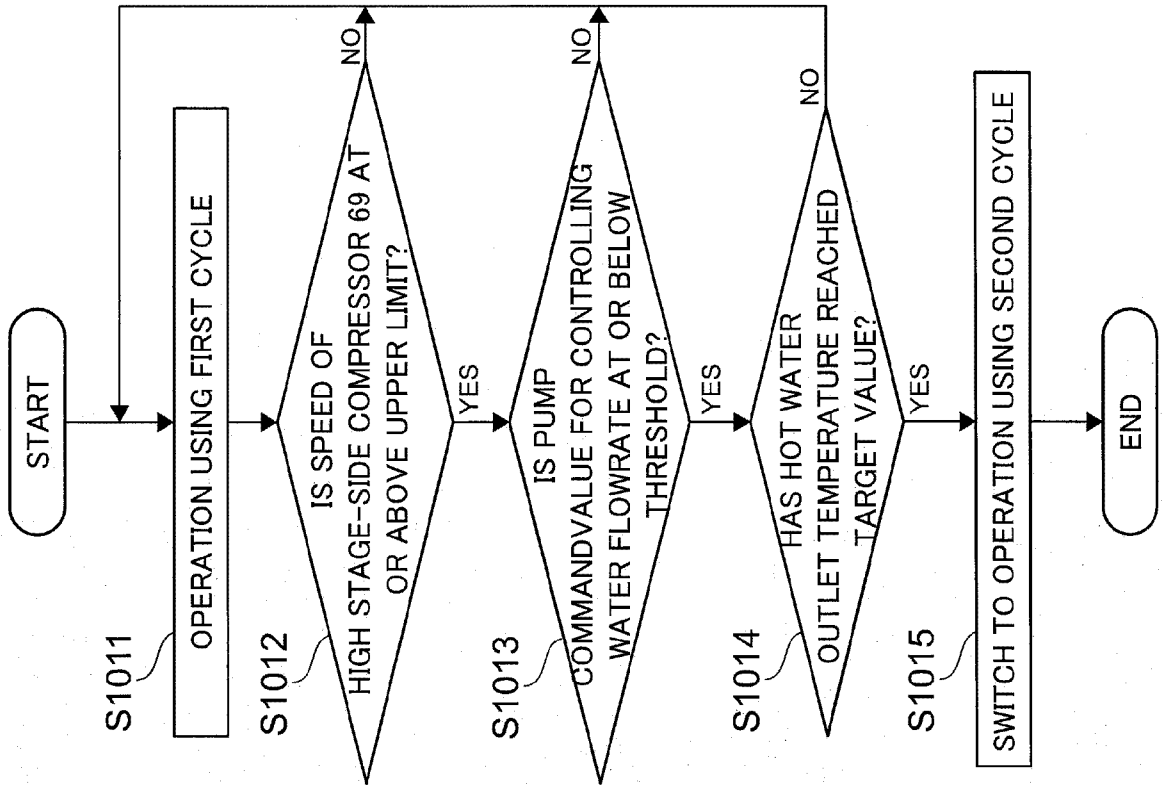
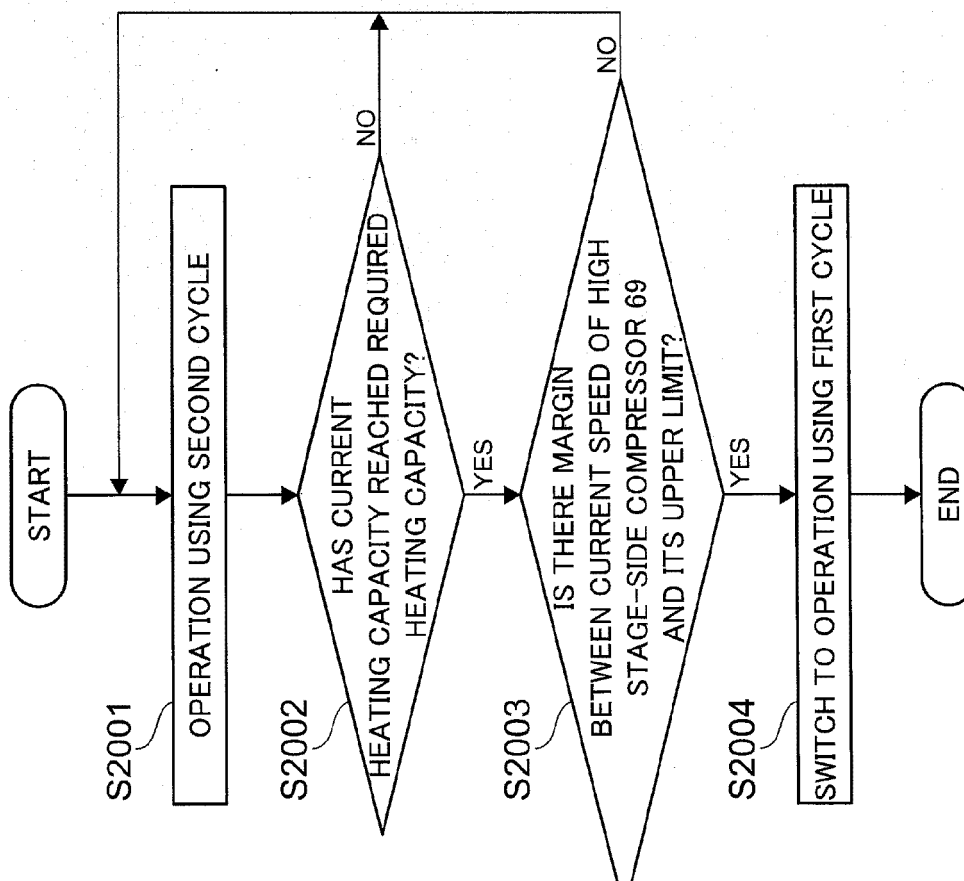


FIG.7C

(C-1)



(C-2)

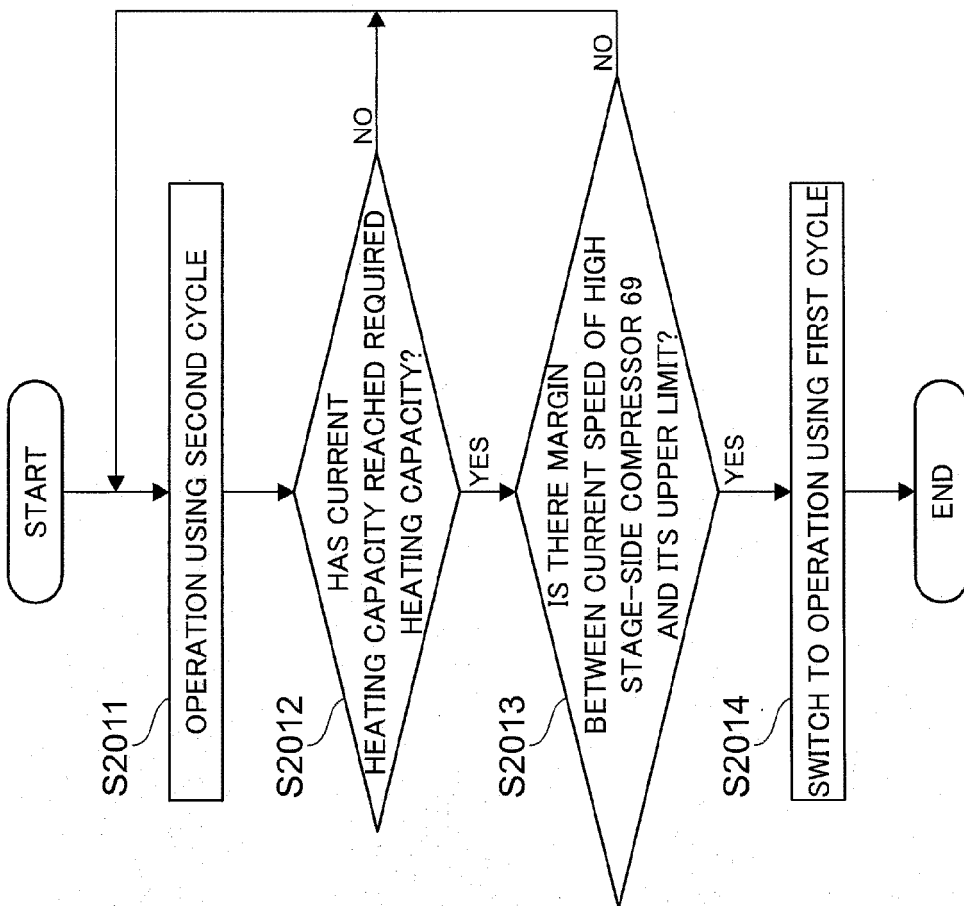


FIG.7D

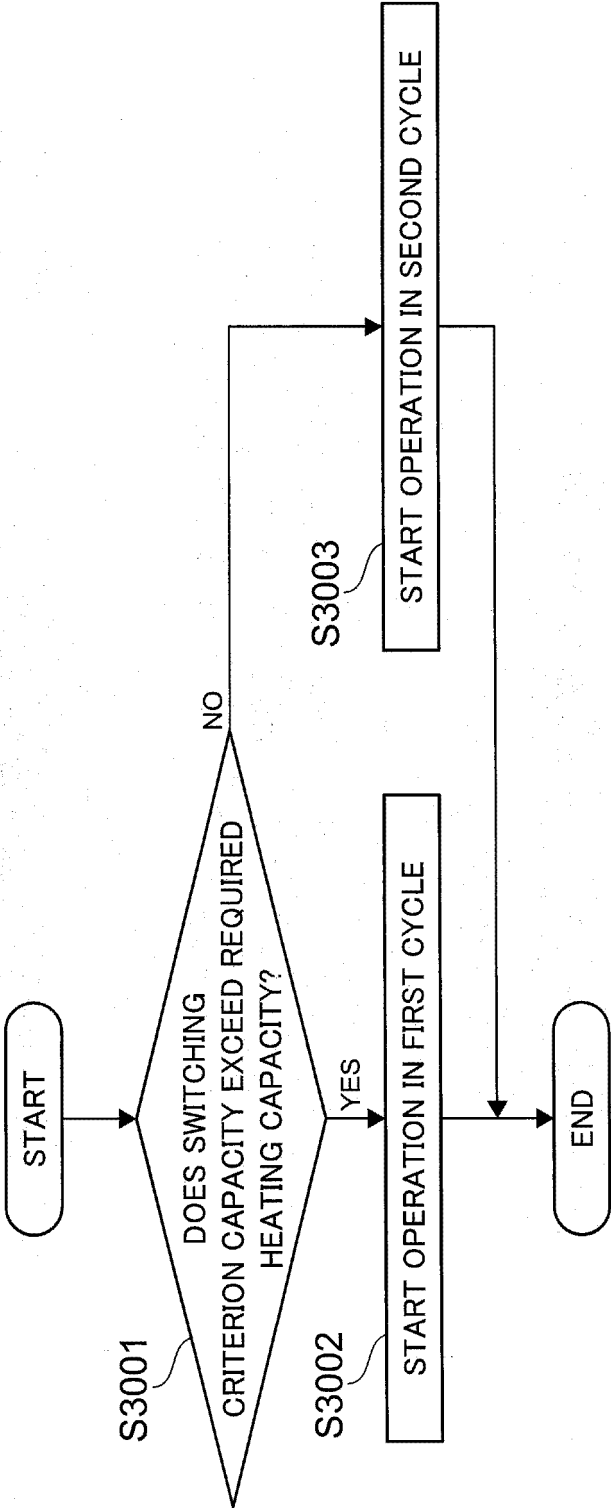


FIG.8A

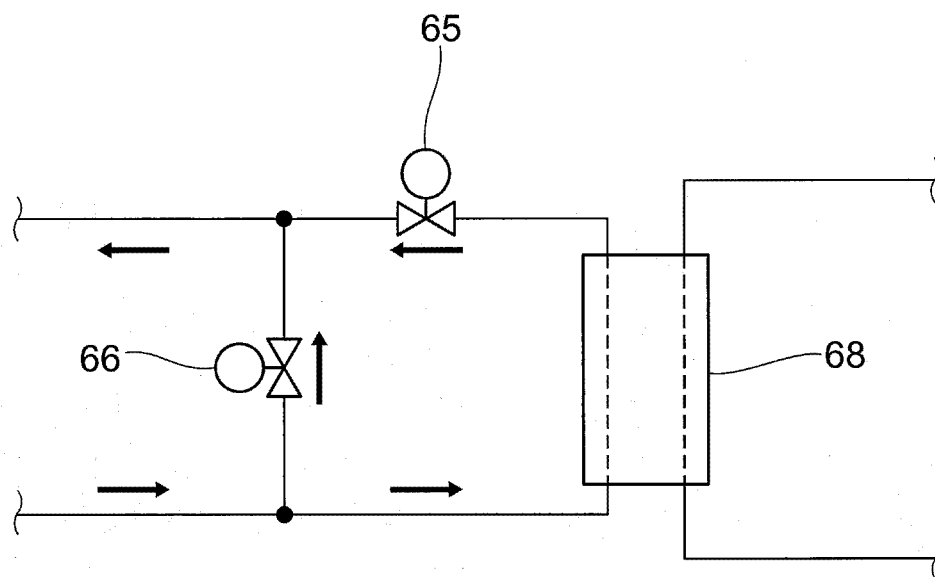


FIG.8B

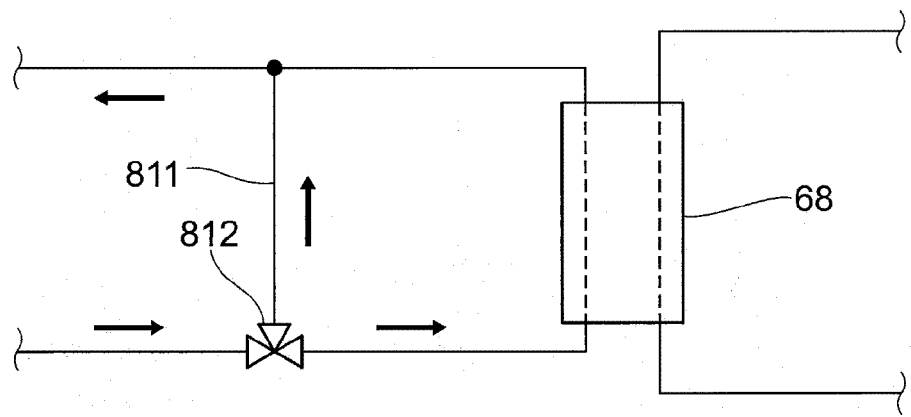


FIG.8C

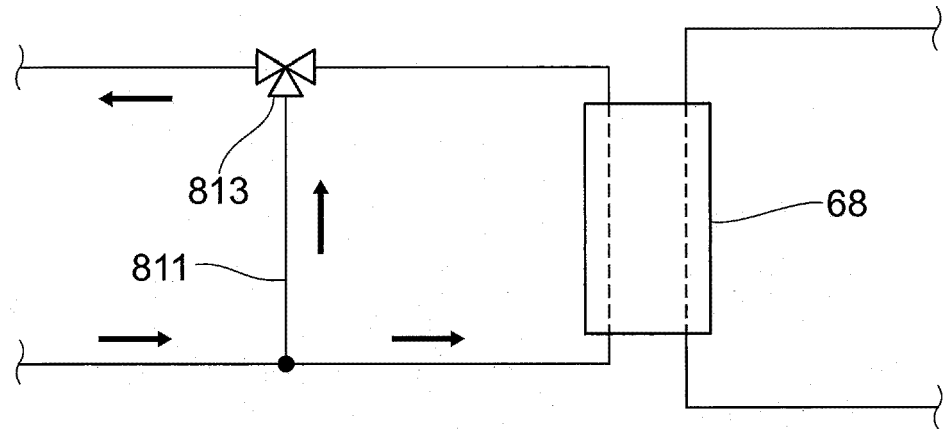


FIG.9A

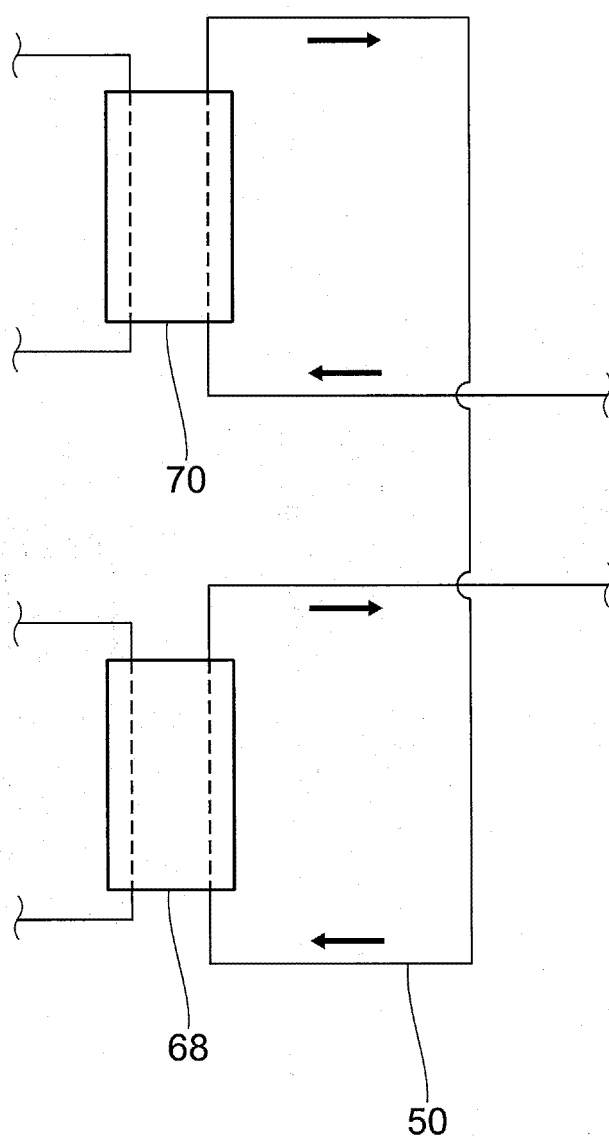
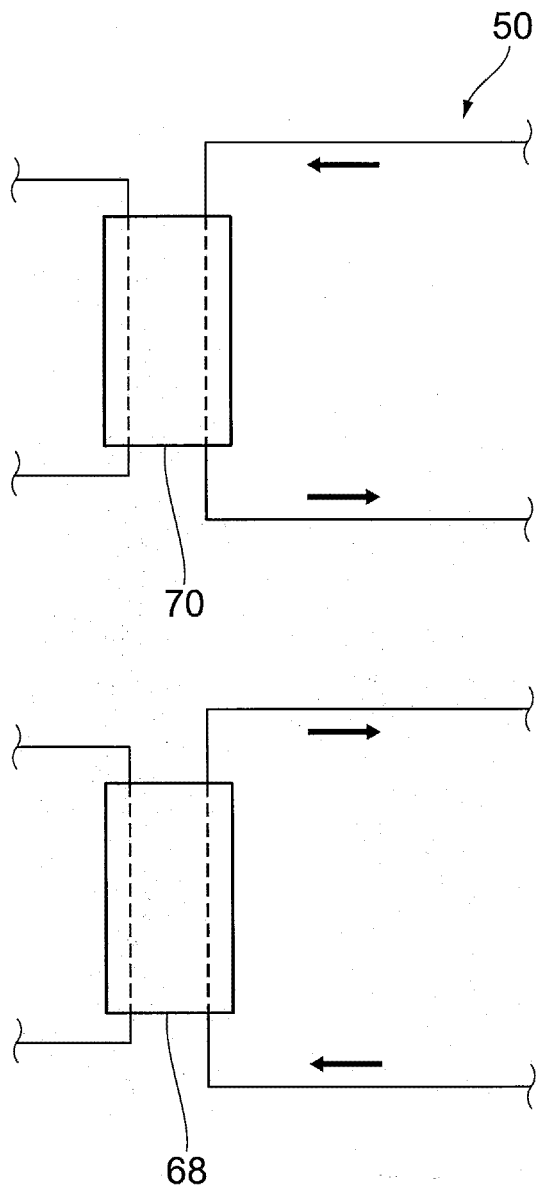


FIG.9B



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 7146117 B [0003]