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(54) **AIR CONDITIONING DEVICE**

KLIMAANLAGENVORRICHTUNG

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Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus to be applied to, for example, a multi-air-conditioning apparatus for a building.

Background Art

[0002] As a related-art air-conditioning apparatus, there is given an air-conditioning apparatus including a heat source apparatus (outdoor unit) arranged outside of a building and indoor units arranged in rooms of the building as in a case of a multi-air-conditioning apparatus for a building. Refrigerant circulating through a refrigerant circuit of the air-conditioning apparatus described above rejects heat to (takes away heat from) air supplied to a heat exchanger of each of the indoor units to heat or cool the air. Then, the heated or cooled air is sent to an air-conditioned space to perform heating or cooling.

[0003] Each of the indoor units of the multi-air-conditioning apparatus for a building described above is generally arranged for use in an indoor space where a person is present (such as an office, a residential room, or a store). Therefore, when the refrigerant leaks from the indoor unit arranged in the indoor space for some reason, there arises a problem in view of effects on a human body and safety because some kinds of refrigerant have inflammability and toxicity. Further, even when the refrigerant is not harmful to the human body, it is supposed that an oxygen concentration in the indoor space is lowered due to the refrigerant leakage to affect the human body.

[0004] In order to cope with the problem described above, it is conceivable to adopt a secondary loop system for the air-conditioning apparatus, in which the indoor space where a person is present is air-conditioned by circulating the refrigerant through a primary loop (outdoor-unit system) and using unharmful water or brine (hereinafter referred to as "heat medium") in a secondary loop (indoor-unit system) (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2000-227242 (see, for example, Abstract and Fig. 1) Patent Literature 2: JP H10 338023 A

Summary of Invention

Technical Problem

[0006] In the air-conditioning apparatus as disclosed in Patent Literature 1, the refrigerant leakage toward the indoor units does not basically occur. In a case where a heat exchanging unit (heat exchanger) is damaged in the heat exchanging unit, in which the refrigerant in the primary loop and the heat medium in the secondary loop exchange heat, resulting in the leakage of the refrigerant in the primary loop toward the secondary loop, however, the refrigerant leakage to the indoor unit arranged in the indoor space undesirably occurs.

[0007] When the refrigerant leakage occurs as described above, a pressure in the secondary loop increases. Thus, there is a problem in that the increase in pressure leads to damage to a component used in the secondary loop and the refrigerant leakage spreads due to the damage. Patent Literature 2 discloses an air-conditioning apparatus according to the preamble of claim 1.

[0008] The present invention has been made to solve the problems described above, and has an object to provide an air-conditioning apparatus capable of reducing a pressure in a secondary loop to suppress damage to a component used in the secondary loop, which is otherwise caused by an increase in pressure, to thereby suppress spread of refrigerant leakage even when a heat exchanging unit is damaged in the heat exchanging unit, in which the refrigerant in a primary loop and a heat medium in the secondary loop exchange heat, resulting in leakage of the refrigerant in the primary loop toward the secondary loop.

Solution to Problem

[0009] According to the present invention, there is provided an air-conditioning apparatus as defined in claim 1. It includes: a heat source-side refrigerant circuit for circulating heat source-side refrigerant, in which a compressor, a heat source-side heat exchanger, an expansion device, and a heat source-side refrigerant passage in an intermediate heat exchanger are connected in series by pipes; and a heat medium circuit for circulating a heat medium, in which a pump, a use-side heat exchanger, and a heat medium passage in the intermediate heat exchanger are connected in series by pipes, the heat source-side refrigerant circuit and the heat medium circuit being cascade-connected so that the heat source-side refrigerant and the heat medium exchange heat in the intermediate heat exchanger, the heat medium circuit including a relief valve, the relief valve being actuated when the heat source-side refrigerant flows into the heat medium circuit, to thereby expel the heat source-side refrigerant and the heat medium.

Advantageous Effects of Invention

[0010] According to the air-conditioning apparatus of the present invention, the relief valve is arranged. Thus, even when the refrigerant in the primary loop leaks toward the secondary loop, the heat source-side refrigerant mixed with the heat medium is expelled out of a system of the secondary loop. Therefore, the pressure in the secondary loop can be reduced to suppress the damage to the component used in the secondary loop, which is otherwise caused by the increase in pressure, to thereby suppress the spread of the refrigerant leakage.

Brief Description of Drawings

[0011]

[Fig. 1] Fig. 1 is a schematic diagram illustrating an example of installation of an air-conditioning apparatus according to an embodiment of the present invention.
[Fig. 2] Fig. 2 illustrates a first refrigerant circuit configuration example of the air-conditioning apparatus according to the embodiment of the present invention.
[Fig. 3] Fig. 3 illustrates a second refrigerant circuit configuration example of the air-conditioning apparatus according to the embodiment of the present invention.
[Fig. 4] Fig. 4 is a refrigerant circuit diagram illustrating a flow of refrigerant during a cooling only operation mode of the air-conditioning apparatus illustrated in Fig. 2.
[Fig. 5] Fig. 5 is a refrigerant circuit diagram illustrating the flow of the refrigerant during a heating only operation mode of the air-conditioning apparatus illustrated in Fig. 2.
[Fig. 6] Fig. 6 is a refrigerant circuit diagram illustrating the flow of the refrigerant during a cooling main operation mode of the air-conditioning apparatus illustrated in Fig. 2.
[Fig. 7] Fig. 7 is a refrigerant circuit diagram illustrating the flow of the refrigerant during a heating main operation mode of the air-conditioning apparatus illustrated in Fig. 2.

Description of Embodiments

[0012] Now, an embodiment of the present invention is described referring to the drawings. Note that, the present invention is not limited to the embodiment described below. The scope of the present invention is only defined by the appended claims. Moreover, in the drawings referred to below, the size relationship between components may be different from the reality in some cases. Embodiment

[0013] Fig. 1 is a schematic diagram illustrating an example of installation of an air-conditioning apparatus 100 according to an embodiment of the present invention.

[0014] Now, the example of installation of the air-conditioning apparatus 100 is described referring to Fig. 1.

[0015] The air-conditioning apparatus 100 includes a refrigeration cycle in which refrigerant is circulated. For each of indoor units 2a to 2d, a cooling mode or a heating mode can be freely selected as an operation mode. The air-conditioning apparatus 100 according to this embodiment uses as the refrigerant, for example, a single-component refrigerant such as R-22, R-32, and R-134a, a near-azeotropic refrigerant mixture such as R-410A and R-404A, a zeotropic refrigerant mixture such as R-407C, a refrigerant having a double bond in a chemical formula and a relatively small value of a global warming potential such as $CF_3CF=CH_2$ or a mixture thereof, or a natural refrigerant such as CO_2 and propane. Further, the air-conditioning apparatus 100 includes a heat source-side refrigerant circuit A using the natural refrigerant (hereinafter also referred to as "primary loop") and a heat medium circuit B using water or the like as a heat medium (hereinafter also referred to as "secondary loop") (see Fig. 2).

[0016] For the air-conditioning apparatus 100 according to this embodiment, a method (indirect method) of indirectly using the refrigerant (hereinafter referred to as "heat source-side refrigerant") is adopted. Specifically, cooling energy or heating energy stored in the heat source-side refrigerant is transferred to refrigerant (hereinafter referred to as "heat medium") different from the heat source-side refrigerant so that an air-conditioned space is cooled or heated with the cooling energy or heating energy stored in the heat medium. Further, through direct heat exchange between the heat medium and another heat source such as outdoor air, indoor air, or boiler exhaust heat, the cooling energy or the heating energy can be stored in the heat medium.

[0017] As illustrated in Fig. 1, the air-conditioning apparatus 100 according to this embodiment includes one outdoor unit 1 serving as a heat source apparatus, a plurality of the indoor units 2a to 2d (hereinafter also referred to simply as "indoor units 2"), and a heat medium relay unit 3 interposed between the outdoor unit 1 and the indoor units 2. The heat medium relay unit 3 exchanges heat between the heat source-side refrigerant and the heat medium. The outdoor unit 1 and the heat medium relay unit 3 are connected to each other by refrigerant pipes 4 through which the heat source-side refrigerant is circulated. The heat medium relay unit 3 and the indoor units 2 are connected to each other by heat medium pipes 5 through which the heat medium is circulated. Further, the cooling energy or heating energy generated by the outdoor unit 1 is delivered to the indoor units 2 through the heat medium relay unit 3.

[0018] The outdoor unit 1 is generally arranged in an outdoor space 6, which is a space outside of a structure 9 such as an building (for example, on a rooftop), and supplies the cooling energy or heating energy to the indoor units 2 through the heat medium relay unit 3.

[0019] The indoor units 2 are arranged at positions at which cooling air or heating air can be supplied to an indoor space 7 as a space inside the structure 9 (residential room, for example), and supply the cooling air or heating air to the indoor space 7 as the air-conditioned space.

[0020] The heat medium relay unit 3 is arranged as a casing independent of the outdoor unit 1 and the indoor units 2 and is installed at a position different from the outdoor space 6 and the indoor space 7. The heat medium relay unit 3 is connected to the outdoor unit 1 through the refrigerant pipes 4 and to the indoor units 2 through the heat medium pipes 5 so as to transfer the cooling energy or heating energy supplied from the outdoor unit 1 to the indoor units 2.

[0021] As illustrated in Fig. 1, in the air-conditioning apparatus 100 according to this embodiment, the outdoor unit 1 and the heat medium relay unit 3 are connected through the two refrigerant pipes 4, whereas the heat medium relay unit 3 and each of the indoor units 2a to 2d are connected through the two heat medium pipes 5. As described above, in the air-conditioning apparatus 100, each of the units (outdoor unit 1, indoor units 2, and heat medium relay unit 3) are connected through the refrigerant pipes 4 and the heat medium pipes 5. As a result, construction is facilitated.

[0022] Note that, although a state in which the heat medium relay unit 3 is installed in a space 8 inside the structure 9 such as a space above a ceiling, which is a different space from the indoor space 7 (for example, a space such as a space above a ceiling in the structure 9), is illustrated as an example in Fig. 1, the heat medium relay unit 3 may also be installed in a shared space where an elevator is installed. Further, although ceiling cassette type indoor units are illustrated as an example of the indoor units 2, the indoor units are not limited thereto. Specifically, any other types of the indoor unit such as a ceiling-concealed indoor unit or a ceiling-suspended indoor unit may be used as the indoor units 2 as long as heating air or cooling air can be blown into the indoor space 7 directly or through a duct.

[0023] Further, the heat medium relay unit 3 may also be installed in the vicinity of the outdoor unit 1. When a distance from the heat medium relay unit 3 to the indoor units 2 is excessively long, however, delivery power for the heat medium is significantly increased. Therefore, it should be noted that energy saving effects are weakened.

[0024] Fig. 2 illustrates a first refrigerant circuit configuration example of the air-conditioning apparatus 100 according to the embodiment of the present invention.

[0025] As illustrated in Fig. 2, the outdoor unit 1 and intermediate heat exchangers 15a and 15b included in the heat medium relay unit 3 are connected to each other through the refrigerant pipes 4. Further, the indoor units 2 and the intermediate heat exchangers 15a and 15b are connected to each other through the heat medium pipes 5.

[Outdoor Unit 1]

[0026] In the outdoor unit 1, a compressor 10 for compressing the refrigerant, a first refrigerant flow switching device 11 constructed of a four-way valve or the like, a heat source-side heat exchanger 12 functioning as an evaporator or a condenser, and an accumulator 19 for accumulating surplus refrigerant therein are mounted and connected by the refrigerant pipes 4.

[0027] Further, the outdoor unit 1 includes check valves 13a to 13d, which can set a direction of a flow of the heat source-side refrigerant to be controlled to flow into the heat medium relay unit 3 constant regardless of a required operation for the indoor units 2.

[0028] The check valve 13d is arranged on the refrigerant pipe 4 between the intermediate heat exchangers 15a and 15b (hereinafter sometimes referred to simply as "intermediate heat exchangers 15") and the first refrigerant flow switching device 11, the check valve 13b is arranged on a first connection pipe 4a, the check valve 13c is arranged on a second connection pipe 4b, and the check valve 13a is arranged on the refrigerant pipe 4 between the heat source-side heat exchanger 12 and the intermediate heat exchangers 15a and 15b.

[0029] The compressor 10 sucks the heat source-side refrigerant, and compresses the heat source-side refrigerant into a high-temperature and high-pressure state. The compressor 10 may be a capacity-controllable inverter compressor or the like.

[0030] The first refrigerant flow switching device 11 switches a flow of the heat source-side refrigerant between a flow of the heat source-side refrigerant during a heating operation mode (during a heating only operation mode and a heating main operation mode) and a flow of the heat source-side refrigerant during a cooling operation mode (during a cooling only operation mode and a cooling main operation mode).

[0031] The heat source-side heat exchanger 12 functions as the evaporator during the heating operation and functions as the condenser during the cooling operation, and exchanges heat between air supplied from an air sending device such as a fan (not shown) and the heat source-side refrigerant.

[0032] Here, the cooling only operation mode is a mode in which all the running indoor units 2 execute the cooling operation, the heating only operation mode is a mode in which all the running indoor units 2 execute the heating operation, the cooling main operation mode is a cooling and heating mixed operation mode in which the cooling operation and the heating operation are both executed and a cooling load is larger, and the heating main operation mode is similarly a cooling and heating mixed operation mode in which a heating load is larger.

[0033] The accumulator 19 is arranged on a suction side of the compressor 10 and has a function of accumulating the surplus refrigerant therein and a function of separating liquid refrigerant and gas refrigerant from each other. Note that, the accumulator 19 may be any reservoir as long as the surplus refrigerant can be accumulated therein.

[0034] Further, a second pressure sensor 37 and a third pressure sensor 38, which are pressure detection devices, are arranged in the front and back of the compressor 10. A refrigerant flow rate from the compressor 10 can be calculated based on a rotation speed of the compressor 10 and detection values of the second pressure sensor 37 and the third pressure sensor 38.

[Indoor Unit 2]

[0035] In the four indoor units 2a to 2d, use-side heat exchangers 26a to 26d (hereinafter also referred to simply as "use-side heat exchangers 26") are respectively mounted. The use-side heat exchangers 26 are connected to heat medium flow control devices 25a to 25d (hereinafter also referred to simply as "heat medium flow control devices 25") and second heat medium flow switching devices 23a to 23d (hereinafter also referred to simply as "second heat medium flow switching devices 23"), which are included in the heat medium relay unit 3, through the heat medium pipes 5.

[0036] The use-side heat exchangers 26 exchange the heat between the air supplied by the air sending device such as the fan (not shown) and the heat medium to generate cooling air or heating air to be supplied to the indoor space 7.

[0037] Further, sucked-air temperature detection devices 39a to 39d for detecting a suction temperature are respectively arranged in the indoor units 2a to 2d.

[Heat Medium Relay Unit 3]

[0038] The heat medium relay unit 3 includes the two intermediate heat exchangers 15a and 15b (hereinafter also referred to simply as "intermediate heat exchangers 15") for exchanging heat between the refrigerant and the heat medium, two expansion devices 16a and 16b (hereinafter also referred to simply as "expansion devices 16") for decompressing the refrigerant, two opening and closing devices 17a and 17b (hereinafter also referred to simply as "opening and closing devices 17") for opening and closing passages of the refrigerant pipes 4, two second refrigerant flow switching devices 18a and 18b (hereinafter also referred to simply as "second refrigerant flow switching devices 18") for switching the refrigerant passage, two pumps 21a and 21b (hereinafter also referred to simply as "pumps 21") for circulating the heat medium, four first heat medium flow switching devices 22a to 22d (hereinafter also referred to simply as "first heat medium flow switching devices 22"), each being connected to one of the heat medium pipes 5, the four second heat medium flow switching devices 23, each being connected to another of the heat medium pipes 5, the four heat medium flow control devices 25a to 25d connected to the heat medium pipes 5 between the first heat medium flow switching devices 22 and the use-side heat exchangers 26, and two relief valves 60a and 60b (hereinafter also referred to simply as "relief valves 60") for expelling the heat medium out of the system (for example, into the heat medium relay unit 3) when a pressure in the secondary loop increases to a predetermined value.

[0039] The two intermediate heat exchangers 15a and 15b function as condensers (radiators) or evaporators, and exchange heat between the heat source-side refrigerant and the heat medium, to thereby transfer the cooling energy or heating energy, which is generated by the outdoor unit 1 and stored in the heat source-side refrigerant, to the heat medium. The intermediate heat exchanger 15a is arranged between the expansion device 16a and the second refrigerant flow switching device 18a in the heat source-side refrigerant circuit A and serves to cool the heat medium during the cooling and heating mixed operation mode. The intermediate heat exchanger 15b is arranged between the expansion device 16b and the second refrigerant flow switching device 18b in the heat source-side refrigerant circuit A and serves to heat the heat medium during the cooling and heating mixed operation mode. Note that, the intermediate heat exchangers 15a and 15b only need to be, for example, double-pipe heat exchangers or plate heat exchangers.

[0040] The two expansion devices 16a and 16b function as pressure reducing valves and expansion valves and decompress the heat source-side refrigerant to expand the heat source-side refrigerant. The expansion device 16a is arranged on an upstream side of the intermediate heat exchanger 15a in the flow of the heat source-side refrigerant during the cooling only operation mode. The expansion device 16b is arranged on an upstream side of the intermediate heat exchanger 15b in the flow of the heat source-side refrigerant during the cooling only operation mode. Note that, the two expansion devices 16 only need to be devices capable of variably controlling their opening degrees, such as electronic expansion valves.

[0041] The two opening and closing devices 17a and 17b open and close the refrigerant pipes 4, and only need to be two-way valves or the like.

[0042] The two second refrigerant flow switching devices 18a and 18b are four-way valves and switch the flow of the heat source-side refrigerant in accordance with the operation mode. The second refrigerant flow switching device 18a is arranged on a downstream side of the intermediate heat exchanger 15a in the flow of the heat source-side refrigerant during the cooling only operation mode. The second refrigerant flow switching device 18b is arranged on a downstream side of the intermediate heat exchanger 15b in the flow of the heat source-side refrigerant during the cooling only operation mode.

[0043] The two pumps 21a and 21b circulate the heat medium in the heat medium pipes 5. The pump 21a is arranged on the heat medium pipe 5 between the intermediate heat exchanger 15a and the second heat medium flow switching devices 23. The pump 21b is arranged on the heat medium pipe 5 between the intermediate heat exchanger 15b and the second heat medium flow switching devices 23. The two pumps 21 only need to be, for example, capacity-controllable pumps. Note that, the pump 21a may be arranged on the heat medium pipe 5 between the intermediate heat exchanger 15a and the first heat medium flow switching devices 22, whereas the pump 21b may be arranged on the heat medium pipe 5 between the intermediate heat exchanger 15b and the first heat medium flow switching devices 22.

[0044] The four first heat medium flow switching devices 22a to 22d are three-way valves or the like and switch the passage of the heat medium. The first heat medium flow switching devices 22 are arranged in the number in accordance with the number of the installed indoor units 2 (four in this embodiment). Among the three ways of each of the first heat medium flow switching devices 22, one way is connected to the intermediate heat exchanger 15a, another way is connected to the intermediate heat exchanger 15b, and the remaining way is connected to the heat medium flow control device 25. The first heat medium flow switching devices 22 are arranged on an outlet side of the heat medium passages of the use-side heat exchangers 26.

[0045] Note that, the first heat medium flow switching devices 22a to 22d are arranged in order of the first heat medium flow switching devices 22a, 22b, 22c, and 22d from the bottom of the drawing sheet so as to correspond to the indoor units 2a to 2d, and are illustrated as being arranged in the heat medium relay unit 3. However, a larger number thereof may be arranged.

[0046] The four second heat medium flow switching devices 23a to 23d are three-way valves or the like and switch the passage of the heat medium. The second heat medium flow switching devices 23 are arranged in the number in accordance with the number of the installed indoor units 2 (four in this embodiment). Among the three ways of each of the second heat medium flow switching devices 23, one way is connected to the intermediate heat exchanger 15a, another way is connected to the intermediate heat exchanger 15b, and the remaining way is connected to the use-side heat exchanger 26. The second heat medium flow switching devices 23 are arranged on an inlet side of the heat medium passages of the use-side heat exchangers 26.

[0047] Note that, the second heat medium flow switching devices 23a to 23d are arranged in order of the second heat medium flow switching devices 23a, 23b, 23c, and 23d from the bottom of the drawing sheet so as to correspond to the indoor units 2a to 2d, and are illustrated as being arranged in the heat medium relay unit 3. However, a larger number thereof may be arranged.

[0048] The four heat medium flow control devices 25a to 25d are two-way valves or the like, each capable of controlling the opening area, and control the flow rate of the heat medium flowing through the heat medium pipes 5. The heat medium flow control devices 25 are arranged in the number in accordance with the number of the installed indoor units 2 (four in this embodiment). One way of each of the heat medium flow control devices 25 is connected to the use-side heat exchanger 26, whereas another way thereof is connected to the first heat medium flow switching device 22. The heat medium flow control devices 25 are arranged on the outlet side of the heat medium passages of the use-side heat exchangers 26.

[0049] Note that, the heat medium flow control devices 25a to 25d are arranged in order of the heat medium flow control devices 25a, 25b, 25c, and 25d from the bottom of the drawing sheet so as to correspond to the indoor units 2a to 2d, and are illustrated as being arranged in the heat medium relay unit 3. However, a larger number thereof may be arranged. Further, the heat medium flow control devices 25 may be arranged on the inlet side of the heat medium passages of the use-side heat exchangers 26.

[Relief Valve 60]

[0050] The two relief valves 60a and 60b are respectively arranged on the heat medium pipes 5 on an outlet side of the pumps 21a and 21b, and are actuated to expel the heat medium out of the system when the pressure in the secondary loop increases to a predetermined value (working pressure).

[0051] Note that, the working pressure of the relief valves 60 is determined based on the kind of heat source-side refrigerant and the kind of heat medium.

[0052] Further, in the air-conditioning apparatus 100 according to this embodiment, the increase in pressure in the secondary loop is assumed in a case where a communication hole is formed between the primary loop and the secondary loop of the intermediate heat exchangers 15 due to freezing of the heat medium on the secondary loop side or corrosion occurring between the heat medium and the intermediate heat exchangers 15. Therefore, a Cv value (Cv[60a]+Cv[60b]), which is a coefficient indicating a flow characteristic of the relief valves 60, is expressed as follows.

$$Cv[60a]+Cv[60b]=Cv1\times(P1-P2)^{1/2}/(P2)^{1/2}$$

P1: maximum pressure of the heat source-side refrigerant (maximum pressure in the primary loop)
P2: working pressure of the relief valves
Cv1: Cv value of the communication hole formed between the primary loop and the secondary loop
Cv[60a]: Cv value of the relief valve 60a
Cv[60b]: Cv value of the relief valve 60b

[0053] Here, for example, in a case where P1 is 3.8 MPa when the refrigerant of the primary loop is R410A, and P2 is 0.4 MPa that is a value obtained by adding a mean pressure 0.2 MPa of the heat medium and a maximum head loss 0.2 MPa of the pumps 21, the CV value is expressed as follows.

$$Cv[60a]+Cv[60b]=Cv1\times(3.4)^{1/2}/(0.4)^{1/2}=2.92\times Cv1$$

[0054] Further, for example, Cv1 is about 1 mm^2 in a case of a pin hole due to the corrosion of a copper pipe, and thus the Cv value of the relief valves 60, which corresponds to the sum of Cv[60a]+Cv[60b], is required to be 3 mm^2 or larger in total.

[0055] Note that, the working pressure of the relief valves 60 is determined in accordance with the maximum pressure of the heat medium alone. Then, when the heat source-side refrigerant leaks into the secondary loop, the relief valves 60 are actuated along with a sudden increase in pressure in the secondary loop. However, there is a risk in that the increase in pressure is not fully relieved and the pressure exceeds withstanding pressures of components used in the secondary loop, resulting in damage to the components. Therefore, also in consideration of a pressure different for each kind of heat source-side refrigerant, the working pressure of the relief valves 60 is determined based on the kind of heat medium and the kind of heat source-side refrigerant. Further, a size of each of the relief valves 60 is selected in accordance with the maximum pressure of the heat medium and the maximum pressure of the heat source-side refrigerant to determine (control) an expelling flow rate out of the system. In this manner, the pressure in the secondary loop is kept at an appropriate pressure.

[0056] Fig. 3 illustrates a second refrigerant circuit configuration example of the air-conditioning apparatus 100 according to the embodiment of the present invention.

[0057] As illustrated in Fig. 2, in the first refrigerant circuit configuration example, the relief valves 60a and 60b are respectively arranged on the heat medium pipes 5 on the outlet side of the pumps 21a and 21b. As illustrated in Fig. 3, however, the relief valve 60b may be omitted by connecting the heat medium pipe 5 on a discharge side of the pump 21a and the heat medium pipe 5 on a discharge side of the pump 21b through a narrow pipe. Further, a heat medium pressure detection device 62 for detecting the pressure in the secondary loop may be arranged on the heat medium pipe 5 on the outlet side of the pump 21b.

[0058] The heat medium relay unit 3 includes, as illustrated in Figs. 2 and 3, various types of detection means such as two first temperature sensors 31a and 31b (hereinafter also referred to simply as "first temperature sensors 31"), four second temperature sensors 34a to 34d (hereinafter also referred to simply as "second temperature sensors 34"), four third temperature sensors 35a to 35d (hereinafter also referred to simply as "third temperature sensors 35"), a fourth temperature sensor 50, and a first pressure sensor 36. Information pieces detected by the above-mentioned detection means (for example, temperature information and pressure information) are transmitted to a controller 52 (note that, the controller 52 is described later) for collectively controlling the operation of the air-conditioning apparatus 100, and are used for controlling a driving frequency of the compressor 10, a rotation speed of each of the air sending devices (not shown) arranged in the vicinity of the heat source-side heat exchanger 12 and in the vicinity of the use-side heat exchangers 26, switching of the first refrigerant flow switching device 11, a driving frequency of the pumps 21, switching of the second refrigerant flow switching devices 18, and the like.

[0059] Besides, in the heat medium relay unit 3, a refrigerant leakage detection device 61 is arranged on the intermediate heat exchangers 15 or in the vicinity thereof in addition to the above-mentioned detection means. Information therefrom is input to a computing device 52a described below.

[0060] The controller 52 is a microcomputer or the like and calculates an evaporating temperature, a condensing temperature, a saturation temperature, a degree of superheat, and a degree of subcooling based on the results of calculation by the computing device 52a. Then, based on the results of calculation, the controller 52 controls an opening degree of each of the expansion devices 16, the rotation speed of the compressor 10, a speed of each of the fans for the heat source-side heat exchanger 12 and the use-side heat exchangers 26 (including ON/OFF), and the like so that performance of the air-conditioning apparatus 100 is maximized.

[0061] Besides, based on the information pieces detected by the various detection means and an instruction from a remote controller, the controller 52 controls a driving frequency of the compressor 10, a rotation speed of the air sending devices (including ON/OFF), switching of the first refrigerant flow switching device 11, driving of the pumps 21, the opening degree of each of the expansion devices 16, opening and closing of the opening and closing devices 17, switching of the second refrigerant flow switching devices 18, switching of the first heat medium flow switching devices 22, switching of the second heat medium flow switching devices 23, an opening degree of each of the heat medium flow control devices 25, and the like. Specifically, the controller 52 collectively controls various types of equipment so as to execute each of the operation modes described later.

[0062] Note that, a controller 57 is also arranged in the outdoor unit 1, and controls actuators of the outdoor unit 1 based on the information pieces transmitted from the controller 52 of the heat medium relay unit 3.

[0063] Further, although the controller 52 of the heat medium relay unit 3 is described as a component independent of a computing device 57a arranged in the outdoor unit 1 in this embodiment, the controller 52 and the computing device 57a may be the same component.

[0064] The two first temperature sensors 31a and 31b detect a temperature of the heat medium flowing out of the intermediate heat exchangers 15, specifically, the heat medium at outlets of the intermediate heat exchangers 15, and only need to be, for example, thermistors. The first temperature sensor 31a is arranged on the heat medium pipe 5 on an inlet side of the pump 21a. The first temperature sensor 31b is arranged on the heat medium pipe 5 on an inlet side of the pump 21b.

[0065] The four second temperature sensors 34a to 34d are respectively arranged between the first heat medium flow switching devices 22 and the heat medium flow control devices 25, and detect the temperature of the heat medium flowing out of the use-side heat exchangers (or heat recovery heat exchangers) 26. The four second temperature sensors 34a to 34d only need to be thermistors. The second temperature sensors 34 are arranged in the number in accordance with the number of the installed indoor units 2 (four in this embodiment). Note that, the second temperature sensors 34a to 34d are illustrated as the second temperature sensors 34a, 34b, 34c, and 34d from the bottom of the drawing sheet so as to correspond to the indoor units 2.

[0066] The four third temperature sensors 35a to 35d are arranged on an inlet side or an outlet side of the intermediate heat exchangers 15 for the heat source-side refrigerant, and detect the temperature of the heat source-side refrigerant flowing into the intermediate heat exchangers 15 or the temperature of the heat source-side refrigerant flowing out of the intermediate heat exchangers 15. The four third temperature sensors 35a to 35d only need to be thermistors. The third temperature sensor 35a is arranged between the intermediate heat exchanger 15a and the second refrigerant flow switching device 18a. The third temperature sensor 35b is arranged between the intermediate heat exchanger 15a and the expansion device 16a. The third temperature sensor 35c is arranged between the intermediate heat exchanger 15b and the second refrigerant flow switching device 18b. The third temperature sensor 35d is arranged between the intermediate heat exchanger 15b and the expansion device 16b.

[0067] The fourth temperature sensor 50 obtains the temperature information that is used to calculate the evaporating temperature and a dew-point temperature, and is arranged between the expansion devices 16a and 16b.

[0068] The first pressure sensor 36 obtains the pressure information for conversion into the saturation temperature that is used to control the opening degrees of the expansion devices 16, and is arranged between the intermediate heat exchanger 15b and the expansion device 16b.

[0069] The heat medium pipes 5 for circulating the heat medium include the heat medium pipes 5 connected to the intermediate heat exchanger 15a and the heat medium pipes 5 connected to the intermediate heat exchanger 15b, each of which are split in accordance with the number of the indoor units 2 connected to the heat medium relay unit 3 (split into four branches in this embodiment). Further, the heat medium pipes 5 connected to the inlet side of the intermediate heat exchanger 15a and the heat medium pipes 5 connected to the inlet side of the intermediate heat exchanger 15b are respectively connected by the first heat medium flow switching devices 22, whereas the heat medium pipes 5 connected to the outlet side of the intermediate heat exchanger 15a and the heat medium pipes 5 connected to the outlet side of the intermediate heat exchanger 15b are respectively connected by the second heat medium flow switching devices 23.

[0070] Further, through control of the first heat medium flow switching devices 22 and the second heat medium flow switching devices 23, whether to control the heat medium from the intermediate heat exchanger 15a to flow into the use-side heat exchangers 26 or to control the heat medium from the intermediate heat exchanger 15b to flow into the use-side heat exchangers 26 is determined.

[Description of Operation Modes]

[0071] In the air-conditioning apparatus 100, the compressor 10, the first refrigerant flow switching device 11, the heat source-side heat exchanger 12, the opening and closing devices 17, the expansion devices 16, the heat source-side refrigerant passage in the intermediate heat exchanger 15a, the second refrigerant flow switching devices 18, and the accumulator 19 are connected by the refrigerant pipes 4 to form the heat source-side refrigerant circuit A.

[0072] Further, the heat medium passage in the intermediate heat exchanger 15a, the pumps 21, the second heat medium flow switching devices 23, the use-side heat exchangers 26, the heat medium flow control devices 25, and the first heat medium flow switching devices 22 are connected by the heat medium pipes 5 to form the heat medium circuit B. Specifically, the plurality of the use-side heat exchangers 26 are respectively connected in parallel to the intermediate heat exchangers 15a and 15b to form the heat medium circuit B having a plurality of systems.

[0073] Therefore, in the air-conditioning apparatus 100, the outdoor unit 1 and the heat medium relay unit 3 are connected through the intermediate heat exchangers 15a and 15b arranged in the heat medium relay unit 3, whereas the heat medium relay unit 3 and the indoor units 2 are similarly connected through the intermediate heat exchangers 15a and 15b. Specifically, in the air-conditioning apparatus 100, the heat source-side refrigerant circulating through the heat source-side refrigerant circuit A through the intermediate heat exchangers 15a and 15b and the heat medium circulating through the heat medium circuit B exchange heat.

[0074] Now, each of the operation modes to be executed by the air-conditioning apparatus 100 is described. Based on an instruction from each of the indoor units 2, the air-conditioning apparatus 100 enables the indoor units 2 to perform the cooling operation or the heating operation. Specifically, the air-conditioning apparatus 100 enables all the indoor units 2 to perform the same operation and also enables each of the indoor units 2 to perform a different operation.

[0075] The number of operation modes to be executed by the air-conditioning apparatus 100 is four, specifically, the cooling only operation mode, the heating only operation mode, the cooling main operation mode, and the heating main operation mode. Now, each of the operation modes is described with the flows of the heat source-side refrigerant and the heat medium.

[Cooling Only Operation Mode]

[0076] Fig. 4 is a refrigerant circuit diagram illustrating the flow of the refrigerant during the cooling only operation mode of the air-conditioning apparatus 100 illustrated in Fig. 2. Note that, in Fig. 4, the cooling only operation mode is described taking as an example a case where a cooling load is generated in the indoor unit 2a corresponding to the use-side heat exchanger 26a and the indoor unit 2b corresponding to the use-side heat exchanger 26b. Further, the pipes indicated by the thick lines are the pipes through which the refrigerant (heat source-side refrigerant and heat medium) flows. A direction of the flow of the heat source-side refrigerant is indicated by the solid arrows, whereas a direction of the flow of the heat medium is indicated by the dashed arrows.

[0077] In the case of the cooling only operation mode illustrated in Fig. 4, the first refrigerant flow switching device 11 in the outdoor unit 1 is switched so that the heat source-side refrigerant discharged from the compressor 10 flows into the heat source-side heat exchanger 12. In the heat medium relay unit 3, the pumps 21a and 21b are driven to open the heat medium flow control devices 25a and 25b and to close the heat medium flow control devices 25c and 25d so that the heat medium circulates between the intermediate heat changers 15a and 15b and the use-side heat exchangers 26a and 26b.

[0078] First, the flow of the heat source-side refrigerant in the heat source-side refrigerant circuit A is described.

[0079] Low-temperature and low-pressure refrigerant is compressed by the compressor 10 and discharged as high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 flows into the heat source-side heat exchanger 12 through the first refrigerant flow switching device 11, and then turns into high-pressure liquid refrigerant in the heat source-side heat exchanger 12 while rejecting heat to the outdoor air. The high-pressure refrigerant flowing out of the heat source-side heat exchanger 12 passes through the check valve 13a to flow out of the outdoor unit 1, and then passes through the refrigerant pipe 4 to flow into the heat medium relay unit 3. After passing through the opening and closing device 17a, the high-pressure refrigerant flowing into the heat medium relay unit 3 is split into a flow toward the expansion device 16a and a flow toward the expansion device 16b. Then, the refrigerant is expanded by the expansion devices 16a and 16b to turn into low-temperature and low-pressure two-phase refrigerant. Note that, the opening and closing device 17b is closed.

[0080] The two-phase refrigerant flows into each of the intermediate heat exchangers 15a and 15b functioning as the evaporators and takes away heat from the heat medium circulating through the heat medium circuit B. As a result, the two-phase refrigerant turns into low-temperature and low-pressure gas refrigerant while cooling the heat medium. The gas refrigerant flowing out of the intermediate heat exchangers 15a and 15b flows out of the heat medium relay unit 3 through the second refrigerant flow switching devices 18a and 18b, and then passes through the refrigerant pipe 4 to flow into the outdoor unit 1 again. The refrigerant flowing into the outdoor unit 1 passes through the check valve 13d to be sucked into the compressor 10 again through the first refrigerant flow switching device 11 and the accumulator 19.

[0081] At this time, the second refrigerant flow switching devices 18a and 18b are held in communication with low-pressure pipes. Further, the opening degree of the expansion device 16a is controlled so that superheat (degree of superheat) determined as a difference between the temperature detected by the third temperature sensor 35a and the temperature detected by the third temperature sensor 35b becomes constant. Similarly, the opening degree of the expansion device 16b is controlled so that superheat determined as a difference between the temperature detected by the third temperature sensor 35c and the temperature detected by the third temperature sensor 35d becomes constant.
[0082] Next, the flow of the heat medium in the heat medium circuit B is described.
[0083] In the cooling only operation mode, the cooing energy of the heat source-side refrigerant is transferred to the heat medium in each of the intermediate heat exchangers 15a and 15b. The cooled heat medium is controlled to flow through the heat medium pipes 5 by the pumps 21a and 21b. The heat medium, which is pressurized by the pumps 21a and 21b to flow out thereof, flows into the use-side heat exchangers 26a and 26b through the second heat medium flow switching devices 23a and 23b. Then, the heat medium takes away heat from the indoor air in the use-side heat exchangers 26a and 26b to cool the indoor space 7.
[0084] Thereafter, the heat medium flows out of the use-side heat exchangers 26a and 26b to flow into the heat medium flow control devices 25a and 25b. At this time, after the flow rate of the heat medium is controlled to a flow rate necessary to achieve an air conditioning load required for interior by the functions of the heat medium flow control devices 25a and 25b, the heat medium flows into the use-side heat exchangers 26a and 26b. The heat medium flowing out of the heat medium flow control devices 25a and 25b passes through the first heat medium flow switching devices 22a and 22b to flow into the intermediate heat exchangers 15a and 15b, and is then sucked into the pumps 21a and 21b again.
[0085] Note that, in the heat medium pipes 5 for the use-side heat exchangers 26a and 26b, the heat medium flows in a direction to the first heat medium flow switching devices 22a and 22b from the second heat medium flow switching devices 23a and 23b through the heat medium flow control devices 25a and 25b. Further, the air conditioning load required for the indoor space 7 can be achieved by performing control so that a difference between the temperature detected by the first temperature sensor 31a or the temperature detected by the first temperature sensor 31b and the temperature detected by the second temperature sensor 34a (or the second temperature sensor 34b) is kept as a target value. As outlet temperatures of the intermediate heat exchangers 15a and 15b, any of the temperatures obtained by the first temperature sensors 31a and 31b or an average temperature thereof may be used. At this time, the opening degree of each of the first heat medium flow switching devices 22 and the second heat medium flow switching devices 23 is set to an intermediate opening degree so that the passages to both the intermediate heat exchangers 15a and 15b are secured.
[0086] When the cooling only operation mode is executed, the heat medium is not required to be controlled to flow to the use-side heat exchangers 26 without a heat load (including a thermostat-off state). Therefore, the passages are closed by the heat medium flow control devices 25 so that the heat medium does not flow to the use-side heat exchangers 26. In Fig. 4, the heat medium is controlled to flow through the use-side heat exchangers 26a and 26b because of the presence of heat loads, whereas the use-side heat exchangers 26c and 26d are not actuated. Therefore, the corresponding heat medium flow control device 25c and heat medium flow control device 25d are fully closed. When the heat load is generated in the use-side heat exchangers 26 or a heat recovery device is operated, the heat medium flow control device 25 only needs to be opened to allow the heat medium to circulate.
[0087] Note that, the same applies to the heating only operation mode, the cooling main operation mode, and the heating main operation mode.
[0088] The refrigerant whose temperature is detected by the fourth temperature sensor 50 is the liquid refrigerant. Based on the temperature information thereof, a liquid inlet enthalpy is calculated by the computing device 52a. Further, a temperature in the low-pressure two-phase temperature state is detected by the third temperature sensor 35d. Based on the temperature information thereof, a saturated liquid enthalpy and a saturated gas enthalpy are calculated by the computing device 52a. Based on the information pieces described above, an evaporating temperature Te* and a dew-point temperature Tdew* are determined by a method described later.

[Heating Only Operation Mode]

[0089] Fig. 5 is a refrigerant circuit diagram illustrating the flow of the refrigerant during the heating only operation mode of the air-conditioning apparatus 100 illustrated in Fig. 2. Note that, in Fig. 4, the heating only operation mode is described taking as an example a case where a heating load is generated in the use-side heat exchangers 26a and 26b. Further, the pipes indicated by the thick lines are the pipes through which the refrigerant flows. The direction of the flow of the heat source-side refrigerant is indicated by the solid arrows, whereas the direction of the flow of the heat medium is indicated by the dashed arrows.
[0090] In the case of the heating only operation mode illustrated in Fig. 5, the first refrigerant flow switching device 11 in the outdoor unit 1 is switched so that the heat source-side refrigerant discharged from the compressor 10 flows into the heat medium relay unit 3 without passing through the heat source-side heat exchanger 12. In the heat medium relay unit 3, the pumps 21a and 21b are driven to open the heat medium flow control devices 25a and 25b and to close the heat medium

flow control devices 25c and 25d so that the heat medium circulates between the intermediate heat changers 15a and 15b and the use-side heat exchangers 26a and 26b.

[0091] First, the flow of the heat source-side refrigerant in the heat source-side refrigerant circuit A is described.

[0092] Low-temperature and low-pressure refrigerant is compressed by the compressor 10 and discharged as high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 passes through the first refrigerant flow switching device 11 and the check valve 13b to flow out of the outdoor unit 1. The high-temperature and high-pressure gas refrigerant flowing out of the outdoor unit 1 passes through the refrigerant pipe 4 to flow into the heat medium relay unit 3. The high-temperature and high-pressure gas refrigerant flowing into the heat medium relay unit 3 is split into the flow toward the second refrigerant flow switching device 18a and the flow toward the second refrigerant flow switching device 18b. Then, the gas refrigerant passes respectively through the second refrigerant flow switching device 18a and the second refrigerant flow switching device 18b to flow into the intermediate heat exchangers 15a and 15b.

[0093] The high-temperature and high-pressure gas refrigerant flowing into the intermediate heat exchangers 15a and 15b turns into high-pressure liquid refrigerant while rejecting heat to the heat medium circulating through the heat medium circuit B. The liquid refrigerant flowing out of the intermediate heat exchangers 15a and 15b is expanded by the expansion devices 16a and 16b to turn into low-temperature and low-pressure two-phase refrigerant. The two-phase refrigerant passes through the opening and closing device 17b to flow out of the heat medium relay unit 3, and then flows into the outdoor unit 1 again through the refrigerant pipe 4. Note that, the opening and closing device 17a is closed.

[0094] The refrigerant flowing into the outdoor unit 1 passes through the check valve 13c to flow into the heat source-side heat exchanger 12 functioning as the evaporator. Then, the refrigerant flowing into the heat source-side heat exchanger 12 takes away heat from the outdoor air in the heat source-side heat exchanger 12 to turn into low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant flowing out of the heat source-side heat exchanger 12 is sucked into the compressor 10 again through the first refrigerant flow switching device 11 and the accumulator 19.

[0095] At this time, the second refrigerant flow switching devices 18a and 18b are held in communication with high-pressure pipes. Further, the opening degree of the expansion device 16a is controlled so that subcool (degree of subcooling) determined as a difference between a value determined by converting the pressure detected by the first pressure sensor 36 into a saturation temperature and the temperature detected by the third temperature sensor 35b becomes constant. Similarly, the opening degree of the expansion device 16b is controlled so that subcool determined as a difference between the value determined by converting the pressure detected by the first pressure sensor 36 into the saturation temperature and the temperature detected by the third temperature sensor 35d becomes constant. Note that, in a case where a temperature at an intermediate position in the intermediate heat exchangers 15 can be measured, the temperature at the intermediate position may be used in place of the first pressure sensor 36. As a result, the system can be constructed at low cost.

[0096] Next, the flow of the heat medium in the heat medium circuit B is described.

[0097] In the heating only operation mode, the heating energy of the heat source-side refrigerant is transferred to the heat medium in each of the intermediate heat exchangers 15a and 15b. The heated heat medium is controlled to flow through the heat medium pipes 5 by the pumps 21a and 21b. The heat medium, which is pressurized by the pumps 21a and 21b to flow out thereof, flows into the use-side heat exchangers 26a and 26b through the second heat medium flow switching devices 23a and 23b. Then, the heat medium rejects heat to the indoor air in the use-side heat exchangers 26a and 26b to heat the indoor space 7.

[0098] Thereafter, the heat medium flows out of the use-side heat exchangers 26a and 26b to flow into the heat medium flow control devices 25a and 25b. At this time, after the flow rate of the heat medium is controlled to the flow rate necessary to achieve the air conditioning load required for the interior by the functions of the heat medium flow control devices 25a and 25b, the heat medium flows into the use-side heat exchangers 26a and 26b. The heat medium flowing out of the heat medium flow control devices 25a and 25b passes through the first heat medium flow switching devices 22a and 22b to flow into the intermediate heat exchangers 15a and 15b, and is then sucked into the pumps 21a and 21b again.

[0099] Note that, in the heat medium pipes 5 for the use-side heat exchangers 26a and 26b, the heat medium flows in the direction to the first heat medium flow switching devices 22a and 22b from the second heat medium flow switching devices 23a and 23b through the heat medium flow control devices 25a and 25b. Further, the air conditioning load required for the indoor space 7 can be achieved by performing control so that the difference between the temperature detected by the first temperature sensor 31a or the temperature detected by the first temperature sensor 31b and the temperature detected by the second temperature sensor 34a or 34b is kept as a target value. As the outlet temperatures of the intermediate heat exchangers 15a and 15b, any of the temperatures obtained by the first temperature sensors 31a and 31b or an average temperature thereof may be used.

[0100] At this time, the opening degree of each of the first heat medium flow switching devices 22 and the second heat medium flow switching devices 23 is set to an intermediate opening degree so that the passages to both the intermediate heat exchangers 15a and 15b are secured. Further, the use-side heat exchanger 26 needs to essentially be controlled based on a difference between a temperature at the inlet and a temperature at the outlet. The heat medium temperature on the inlet side of the use-side heat exchanger 26 is substantially the same as the temperature detected by the first temperature sensor 31b. Therefore, by using the first temperature sensor 31b, the number of temperature sensors can be reduced. As a result, the system can be constructed at low cost.

[Cooling Main Operation Mode]

[0101] Fig. 6 is a refrigerant circuit diagram illustrating the flow of the refrigerant during the cooling main operation mode of the air-conditioning apparatus 100 illustrated in Fig. 2. Note that, in Fig. 6, the cooling main operation mode is described taking as an example a case where the heating load is generated in the use-side heat exchanger 26d and the cooling load is generated in the use-side heat exchangers 26a to 26c. Further, the pipes indicated by the thick lines are the pipes through which the refrigerant (heat source-side refrigerant and heat medium) circulates. The direction of the flow of the heat source-side refrigerant is indicated by the solid arrows, whereas the direction of the flow of the heat medium is indicated by the dashed arrows.

[0102] In the case of the cooling main operation mode illustrated in Fig. 6, the first refrigerant flow switching device 11 in the outdoor unit 1 is switched so that the heat source-side refrigerant discharged from the compressor 10 flows into the heat source-side heat exchanger 12. In the heat medium relay unit 3, the pumps 21a and 21b are driven to open the heat medium flow control devices 25a to 25d so that the heat medium circulates between the intermediate heat changer 15a and the use-side heat exchangers 26a to 26c and between the intermediate heat changer 15b and the use-side heat exchanger 26d.

[0103] First, the flow of the heat source-side refrigerant in the heat source-side refrigerant circuit A is described.

[0104] Low-temperature and low-pressure refrigerant is compressed by the compressor 10 and discharged as high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 flows into the heat source-side heat exchanger 12 through the first refrigerant flow switching device 11, and then turns into liquid refrigerant in the heat source-side heat exchanger 12 while rejecting heat to the outdoor air. The refrigerant flowing out of the heat source-side heat exchanger 12 flows out of the outdoor unit 1, and passes through the check valve 13a and the refrigerant pipe 4 to flow into the heat medium relay unit 3. The refrigerant flowing into the heat medium relay unit 3 passes through the second refrigerant flow switching device 18b to flow into the intermediate heat exchanger 15b functioning as the condenser.

[0105] The refrigerant flowing into the intermediate heat exchanger 15b turns into refrigerant having a further lowered temperature while rejecting heat to the heat medium circulating through the heat medium circuit B. The refrigerant flowing out of the intermediate heat exchanger 15b is expanded by the expansion device 16b to turn into low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant flows into the intermediate heat exchanger 15a functioning as the evaporator through the expansion device 16a. The low-pressure two-phase refrigerant flowing into the intermediate heat exchanger 15a takes away heat from the heat medium circulating through the heat medium circuit B to turn into low-pressure gas refrigerant while cooling the heat medium. The gas refrigerant flows out of the intermediate heat exchanger 15a, flows out of the heat medium relay unit 3 through the second refrigerant flow switching device 18a, and passes through the refrigerant pipe 4 to flow into the outdoor unit 1 again. The refrigerant flowing into the outdoor unit 1 is sucked into the compressor 10 again through the check valve 13d, the first refrigerant flow switching device 11, and the accumulator 19.

[0106] At this time, the second refrigerant flow switching device 18a is held in communication with a low-pressure pipe, whereas the second refrigerant flow switching device 18b is held in communication with a high-pressure-side pipe. Further, the opening degree of the expansion device 16b is controlled so that the superheat determined as a difference between the temperature detected by the third temperature sensor 35a and the temperature detected by the third temperature sensor 35b becomes constant. In addition, the expansion device 16a is fully opened, whereas the opening and closing devices 17a and 17b are closed. Note that, the opening degree of the expansion device 16b may be controlled so that the subcool determined as a difference between the value determined by converting the pressure detected by the first pressure sensor 36 into the saturation temperature and the temperature detected by the third temperature sensor 35d becomes constant. Further, the expansion device 16b may be fully opened, while the superheat or subcool may be controlled by the expansion device 16a.

[0107] Next, the flow of the heat medium in the heat medium circuit B is described.

[0108] In the cooling main operation mode, the heating energy of the heat source-side refrigerant is transferred to the heat medium in the intermediate heat exchanger 15b. The heated heat medium is controlled to flow through the heat medium pipe 5 by the pump 21b. Further, the cooling energy of the heat source-side refrigerant is transferred to the heat medium in the intermediate heat exchanger 15a. The cooled heat medium is controlled to flow through the heat medium pipes 5 by the pump 21a. The heat medium, which is pressurized by the pumps 21a and 21b to flow out thereof, flows into the use-side heat exchangers 26a to 26d through the second heat medium flow switching devices 23a to 23d.

[0109] The heat medium rejects heat to the indoor air in the use-side heat exchanger 26d to heat the indoor space 7.

Further, the heat medium takes away heat from the indoor air in the use-side heat exchangers 26a to 26c to cool the indoor space 7. At this time, after the flow rate of the heat medium is controlled to the flow rate necessary to achieve the air conditioning load required for the interior by the functions of the heat medium flow control devices 25a to 25d, the heat medium flows into the use-side heat exchangers 26a to 26d.

[0110] The heat medium, which passes through the use-side heat exchanger 26d to have a slightly lowered temperature, passes through the heat medium flow control device 25d and the first heat medium flow switching device 22d to flow into the intermediate heat exchanger 15b, and is sucked into the pump 21b again.

[0111] Further, the heat medium, which passes through the use-side heat exchangers 26a to 26c to have a slightly increased temperature, passes through the heat medium flow control devices 25a to 25c and the first heat medium flow switching devices 22a to 22c to flow into the intermediate heat exchanger 15a, and is sucked into the pump 21a again.

[0112] During the execution of the cooling main operation mode, the heated heat medium and the cooled heat medium are introduced into the use-side heat exchangers 26a to 26d respectively with the heating loads and cooling loads without being mixed, by the functions of the first heat medium flow switching devices 22 and the second heat medium flow switching devices 23.

[0113] Note that, in the heat medium pipes 5 for the use-side heat exchangers 26a to 26d, the heat medium flows in the direction to the first heat medium flow switching devices 22 from the second heat medium flow switching devices 23 through the heat medium flow control devices 25 on both the heating side and the cooling side.

[0114] Further, the air conditioning load required for the indoor space 7 can be achieved by controlling the difference between the temperature detected by the first temperature sensor 31b and the temperature detected by the second temperature sensor 34d to be kept as a target value on the heating side and the difference between the temperatures detected by the second temperature sensors 34a to 34c and the temperature detected by the first temperature sensor 31a to be kept as a target value on the cooling side.

[Heating Main Operation Mode]

[0115] Fig. 7 is a refrigerant circuit diagram illustrating the flow of the refrigerant during the heating main operation mode of the air-conditioning apparatus 100 illustrated in Fig. 2. Note that, in Fig. 7, the heating main operation mode is described taking as an example a case where the heating load is generated in the use-side heat exchangers 26b to 26d and the cooling load is generated in the use-side heat exchanger 26a. Further, the pipes indicated by the thick lines are the pipes through which the refrigerant (heat source-side refrigerant and heat medium) circulates. The direction of the flow of the heat source-side refrigerant is indicated by the solid arrows, whereas the direction of the flow of the heat medium is indicated by the dashed arrows.

[0116] In the case of the heating main operation mode illustrated in Fig. 7, the first refrigerant flow switching device 11 in the outdoor unit 1 is switched so that the heat source-side refrigerant discharged from the compressor 10 flows into the heat medium relay unit 3 without passing through the heat source-side heat exchanger 12. In the heat medium relay unit 3, the pumps 21a and 21b are driven to open the heat medium flow control devices 25a to 25d so that the heat medium circulates between the intermediate heat changer 15a and the use-side heat exchanger 26a and between the intermediate heat changer 15b and the use-side heat exchangers 26b to 26d.

[0117] First, the flow of the heat source-side refrigerant in the heat source-side refrigerant circuit A is described.

[0118] Low-temperature and low-pressure refrigerant is compressed by the compressor 10 and discharged as high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant discharged from the compressor 10 passes through the first refrigerant flow switching device 11 and the check valve 13b to flow out of the outdoor unit 1. The high-temperature and high-pressure gas refrigerant flowing out of the outdoor unit 1 passes through the refrigerant pipe 4 to flow into the heat medium relay unit 3. The high-temperature and high-pressure gas refrigerant flowing into the heat medium relay unit 3 passes through the second refrigerant flow switching device 18b to flow into the intermediate heat exchanger 15b functioning as the condenser.

[0119] The gas refrigerant flowing into the intermediate heat exchanger 15b turns into liquid refrigerant while rejecting heat to the heat medium circulating through the heat medium circuit B. The refrigerant flowing out of the intermediate heat exchanger 15b is expanded by the expansion device 16b to turn into low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant flows into the intermediate heat exchanger 15a functioning as the evaporator through the expansion device 16a. The low-pressure two-phase refrigerant flowing into the intermediate heat exchanger 15a takes away heat from the heat medium circulating through the heat medium circuit B to evaporate and cool the heat medium. The low-pressure two-phase refrigerant flows out of the intermediate heat exchanger 15a, and flows out of the heat medium relay unit 3 through the second refrigerant flow switching device 18a to flow into the outdoor unit 1 again.

[0120] The refrigerant flowing into the outdoor unit 1 passes through the check valve 13c to flow into the heat source-side heat exchanger 12 functioning as the evaporator. Then, the refrigerant flowing into the heat source-side heat exchanger 12 takes away heat from the outdoor air in the heat source-side heat exchanger 12 to turn into low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant flowing out of the heat source-side heat exchanger 12 is sucked into the compressor 10 again through the first refrigerant flow switching device 11 and the accumulator 19.

[0121] At this time, the second refrigerant flow switching device 18a is held in communication with a low-pressure-side pipe, whereas the second refrigerant flow switching device 18b is held in communication with a high-pressure-side pipe. Further, the opening degree of the expansion device 16b is controlled so that the subcool determined as the difference between the value determined by converting the pressure detected by the first pressure sensor 36 into the saturation temperature and the temperature detected by the third temperature sensor 35b becomes constant. In addition, the expansion device 16a is fully opened, whereas the opening and closing devices 17a and 17b are closed. Note that, the expansion device 16b may be fully opened, while the subcool may be controlled by the expansion device 16a.

[0122] Next, the flow of the heat medium in the heat medium circuit B is described.

[0123] In the heating main operation mode, the heating energy of the heat source-side refrigerant is transferred to the heat medium in the intermediate heat exchanger 15b. The heated heat medium is controlled to flow through the heat medium pipes 5 by the pump 21b. Further, the cooling energy of the heat source-side refrigerant is transferred to the heat medium in the intermediate heat exchanger 15a. The cooled heat medium is controlled to flow through the heat medium pipe 5 by the pump 21a. The heat medium, which is pressurized by the pumps 21a and 21b to flow out thereof, flows into the use-side heat exchangers 26a to 26d through the second heat medium flow switching devices 23a to 23d.

[0124] The heat medium takes away heat from the indoor air in the use-side heat exchanger 26a to cool the indoor space 7. Further, the heat medium rejects heat to the indoor air in the use-side heat exchangers 26b to 26d to heat the indoor space 7. At this time, after the flow rate of the heat medium is controlled to the flow rate necessary to achieve the air conditioning load required for the interior by the functions of the heat medium flow control devices 25a to 25d, the heat medium flows into the use-side heat exchangers 26a to 26d.

[0125] The heat medium, which passes through the use-side heat exchanger 26a to have a slightly increased temperature, passes through the heat medium flow control device 25a and the first heat medium flow switching device 22a to flow into the intermediate heat exchanger 15a, and is sucked into the pump 21a again.

[0126] Further, the heat medium, which passes through the use-side heat exchangers 26b to 26d to have a slightly lowered temperature, passes through the heat medium flow control devices 25b to 25d and the first heat medium flow switching devices 22b to 22d to flow into the intermediate heat exchanger 15b, and is sucked into the pump 21b again.

[0127] During the execution of the heating main operation mode, the heated heat medium and the cooled heat medium are introduced into the use-side heat exchangers 26a to 26d respectively with the heating loads and cooling loads without being mixed, by the functions of the first heat medium flow switching devices 22 and the second heat medium flow switching devices 23.

[0128] Note that, in the heat medium pipes 5 for the use-side heat exchangers 26a to 26d, the heat medium flows in the direction to the first heat medium flow switching devices 22 from the second heat medium flow switching devices 23 through the heat medium flow control devices 25 on both the heating side and the cooling side.

[0129] Further, the air conditioning load required for the indoor space 7 can be achieved by controlling the difference between the temperature detected by the first temperature sensor 31b and the temperatures detected by the second temperature sensors 34b to 34d to be kept as a target value on the heating side and the difference between the temperature detected by the second temperature sensor 34a and the temperature detected by the first temperature sensor 31a to be kept as a target value on the cooling side.

[0130] Note that, when the heating main operation mode is executed, the heat medium is not required to be controlled to flow to the use-side heat exchangers 26 without a heat load (including the thermostat-off state). Therefore, the passages are closed by the heat medium flow control devices 25 so that the heat medium does not flow to the use-side heat exchangers 26. In Fig. 7, the heat medium is controlled to flow through all the use-side heat exchangers 26a to 26d because of the presence of heat loads. However, when any one of the use-side heat exchangers 26 does not have the heat load, the corresponding one of the heat medium flow control devices 25 is fully closed.

[0131] Next, an operation in a case where the heat source-side refrigerant leaks in the intermediate heat exchanger 15 of the heat medium relay unit 3 is described.

[0132] When the heat source-side refrigerant leaks in the intermediate heat exchanger 15, the heat source-side refrigerant of the primary loop flows into the secondary loop. As a result, the pressure in the secondary loop increases. When the pressure in the secondary loop increases to the predetermined value (working pressure), the relief valves 60 are actuated to expel the heat source-side refrigerant mixed with the heat medium from the relief valves 60. Therefore, the pressure in the secondary loop can be reduced to suppress the damage to the component used in the secondary loop, which is otherwise caused by the increase in pressure, to thereby suppress the spread of the leakage of the heat source-side refrigerant.

[0133] At this time, the working pressure of the relief valves 60 is determined based on the kind of heat medium and the kind of heat source-side refrigerant and the size of each of the relief valves 60 is selected in accordance with the maximum pressure of the heat medium and the maximum pressure of the heat source-side refrigerant to determine (control) the expelling flow rate out of the system. In this manner, the pressure in the secondary loop is kept at an appropriate pressure.

[0134] Further, the expelled heat source-side refrigerant and heat medium stagnate inside the heat medium relay unit 3, which is detected by the refrigerant leakage detection device 61. In this case, by stopping the operation of the outdoor unit 1, stopping the pumps 21a and 21b, and closing the heat medium flow control devices 25a to 25d, the spread of the leakage of the heat source-side refrigerant to the indoor side can be further suppressed.

[0135] Note that, the leakage of the heat source-side refrigerant may be determined based on a change in the refrigeration cycle of the primary loop such as a reduction in the second pressure sensor 37 of the outdoor unit 1 in place of the detection by the refrigerant leakage detection device 61. In this case, the second pressure sensor functions as refrigerant leakage detection means. Further, the heat medium pressure detection device 62 (see Fig. 3) for detecting the pressure in the secondary loop may be arranged to detect the leakage of the heat source-side refrigerant based on the increase in pressure in the secondary loop. In this case, the heat medium pressure detection device 62 functions as the refrigerant leakage detection means.

Reference Signs List

[0136]

1 outdoor unit 2 indoor unit 2a to 2d indoor unit 3 heat medium relay unit 4 refrigerant pipe 4a first connection pipe 4b second connection pipe 5 heat medium pipe 6 outdoor space 7 indoor space 8 space9 building 10 compressor 11 first refrigerant flow switching device 12 heat source-side heat exchanger 13a to 13d check valve 15 intermediate heat exchanger 15a, 15b intermediate heat exchanger 16 expansion device 16a, 16b expansion device 17a, 17b opening and closing device18 second refrigerant flow switching device 18a, 18b second refrigerant flow switching device 19 accumulator 21 pump 21a, 21b pump 22 first heat medium flow switching device 22a to 22d first heat medium flow switching device

23 second heat medium flow switching device 23a to 23d second heat medium flow switching device 25 heat medium flow control device 25a to 25d heat medium flow control device 26 use-side heat exchanger 26a to 26d use-side heat exchanger 31 first temperature sensor 31a, 31b first temperature sensor 34 second temperature sensor 34a to 34d second temperature sensor 35 third temperature sensor 35a to 35d third temperature sensor 36 first pressure sensor 37 second pressure sensor 38 third pressure sensor

39a to 39d sucked-air temperature detection device 50 fourth temperature sensor 52 (heat medium relay unit) controller 52a (heat medium relay unit) computing device 57 (outdoor unit) controller 57a (outdoor unit) computing device 60 relief valve 60a relief valve 60b relief valve 61 refrigerant leakage detection device 62 heat medium pressure detection device

100 air-conditioning apparatus A heat source-side refrigerant circuit B heat medium circuit

Claims

1. An air-conditioning apparatus (100), comprising:

a heat source-side refrigerant circuit (A) for circulating heat source-side refrigerant, in which a compressor (10), a heat source-side heat exchanger (12), an expansion device (16), and a heat source-side refrigerant passage in an intermediate heat exchanger (15) are connected in series by pipes; and
a heat medium circuit (B) for circulating a heat medium, in which a pump (21), a use-side heat exchanger (26), and a heat medium passage in the intermediate heat exchanger (15) are connected in series by pipes,
the heat source-side refrigerant circuit (A) and the heat medium circuit (B) being cascade-connected so that the heat source-side refrigerant and the heat medium exchange heat in the intermediate heat exchanger (15),
the heat medium circuit (B) including a relief valve (60),
the relief valve (60) being actuated when the heat source-side refrigerant flows into the heat medium circuit (B) and a pressure in the heat medium circuit (B) reaches a predetermined value, to thereby expel the heat source-side refrigerant and the heat medium, and
the predetermined value is determined based on a kind of the heat source-side refrigerant and a kind of the heat medium,
characterized in that
a Cv value of the relief valve (60) satisfies a value obtained by dividing
a product of a Cv value of a communication hole formed between the heat source-side refrigerant circuit (A) and the heat medium circuit (B) and a square root of a difference between the maximum pressure of the heat source-side refrigerant and a working pressure of the relief valve (60)
by a square root of the working pressure of the relief valve (60).

2. The air-conditioning apparatus (100) of claim 1, further comprising refrigerant leakage detection means configured to detect leakage of the heat source-side refrigerant,
wherein driving of the pump (21) is stopped when the refrigerant leakage detection means detects the leakage.

3. The air-conditioning apparatus (100) of claim 1, further comprising:

a heat medium flow control device (25) configured to control a flow rate of the heat medium; and
refrigerant leakage detection means configured to detect leakage of the heat source-side refrigerant,
wherein the heat medium flow control device (25) is closed when the refrigerant leakage detection means detects the leakage.

4. The air-conditioning apparatus (100) of claim 2 or 3, wherein the refrigerant leakage detection means is installed in the intermediate heat exchanger (15) or in proximity to the intermediate heat exchanger (15).

5. The air-conditioning apparatus (100) of claim 2 or 3, wherein the refrigerant leakage detection means detects the leakage when the pressure in the heat medium circuit (B) reaches the predetermined value.

6. The air-conditioning apparatus (100) of claim 2 or 3, wherein the refrigerant leakage detection means detects the leakage based on a change in an operating situation of the heat source-side refrigerant circuit (A).

Patentansprüche

1. Klimaanlage (100), umfassend:

einen wärmequellenseitigen Kältemittelkreislauf (A) zum Zirkulieren von wärmequellenseitigem Kältemittel, in dem ein Verdichter (10), ein wärmequellenseitiger Wärmetauscher (12), eine Expansionseinrichtung (16) und ein wärmequellenseitiger Kältemitteldurchgang in einem Zwischenwärmetauscher (15) durch Leitungen in Reihe verbunden sind; und
einen Wärmemediumkreislauf (B) zum Zirkulieren eines Wärmemediums, in dem eine Pumpe (21), ein nutzungsseitiger Wärmetauscher (26) und ein Wärmemediumdurchgang in dem Zwischenwärmetauscher (15) durch Leitungen in Reihe verbunden sind,
wobei der wärmequellenseitige Kältemittelkreislauf (A) und der Wärmemediumkreislauf (B) in Kaskade verbunden sind, so dass das wärmequellenseitige Kältemittel und das Wärmemedium in dem Zwischenwärmetauscher (15) Wärme austauschen,
wobei der Wärmemediumkreislauf (B) ein Überdruckventil (60) aufweist,
wobei das Überdruckventil (60) betätigt wird, wenn das wärmequellenseitige Kältemittel in den Wärmemediumkreislauf (B) strömt und ein Druck in dem Wärmemediumkreislauf (B) einen vorbestimmten Wert erreicht, um dadurch das wärmequellenseitige Kältemittel und das Wärmemedium abzuführen, und
der vorbestimmte Wert auf der Grundlage einer Art des wärmequellenseitigen Kältemittels und einer Art des Wärmemediums bestimmt wird,
dadurch gekennzeichnet, dass
ein Cv-Wert des Überdruckventils (60) einen Wert erfüllt, der erhalten wird durch Dividieren
eines Produkts aus einem Cv-Wert eines Kommunikationslochs, das zwischen dem wärmequellenseitigen Kältemittelkreislauf (A) und dem Wärmemediumkreislauf (B) ausgebildet ist, und einer Quadratwurzel aus einer Differenz zwischen dem Maximaldruck des wärmequellenseitigen Kältemittels und einem Arbeitsdruck des Überdruckventils (60), durch eine Quadratwurzel des Arbeitsdrucks des Überdruckventils (60).

2. Klimaanlage (100) nach Anspruch 1, ferner umfassend ein Kältemittelleckage-Erfassungsmittel, das eingerichtet ist, eine Leckage des wärmequellenseitigen Kältemittels zu detektieren,
wobei das Antreiben der Pumpe (21) gestoppt wird, wenn die Kältemittelleckage-Erfassungseinrichtung die Leckage detektiert.

3. Klimaanlage (100) nach Anspruch 1, ferner umfassend:

eine Wärmemedium-Strömungssteuerungseinrichtung (25), die eingerichtet ist, eine Strömungsrate des Wärmemediums zu steuern; und
ein Kältemittelleckage-Erfassungsmittel, das eingerichtet ist, eine Leckage des wärmequellenseitigen Kälte-

mittels zu detektieren,
wobei die Wärmemedium-Strömungssteuerungseinrichtung (25) geschlossen wird, wenn das Kältemittelleckage-Erfassungsmittel die Leckage detektiert.

4. Klimaanlage (100) nach Anspruch 2 oder 3, wobei das Kältemittelleckage-Erfassungsmittel im Zwischenwärmetauscher (15) oder in der Nähe des Zwischenwärmetauschers (15) installiert ist.

5. Klimaanlage (100) nach Anspruch 2 oder 3, wobei das Kältemittelleckage-Erfassungsmittel die Leckage detektiert, wenn der Druck im Wärmemediumkreislauf (B) den vorbestimmten Wert erreicht.

6. Klimaanlage (100) nach Anspruch 2 oder 3, wobei das Kältemittelleckage-Erfassungsmittel die Leckage auf der Grundlage einer Änderung einer Betriebssituation des wärmequellenseitigen Kältemittelkreislaufs (A) detektiert.

Revendications

1. Appareil de climatisation (100), comprenant :

un circuit de fluide frigorigène côté source de chaleur (A) pour faire circuler du fluide frigorigène côté source de chaleur, dans lequel un compresseur (10), un échangeur de chaleur côté source de chaleur (12), un dispositif de détente (16) et un passage de fluide frigorigène côté source de chaleur dans un échangeur de chaleur intermédiaire (15) sont connectés en série par des tuyaux ; et
un circuit de milieu caloporteur (B) pour faire circuler un milieu caloporteur, dans lequel une pompe (21), un échangeur de chaleur côté utilisation (26) et un passage de milieu caloporteur dans l'échangeur de chaleur intermédiaire (15) sont connectés en série par des tuyaux,
le circuit de fluide frigorigène côté source de chaleur (A) et le circuit de milieu caloporteur (B) étant connectés en cascade de sorte que le fluide frigorigène côté source de chaleur et le milieu caloporteur échangent de la chaleur dans l'échangeur de chaleur intermédiaire (15),
le circuit de milieu caloporteur (B) incluant un clapet de décharge (60),
le clapet de décharge (60) étant actionné lorsque le fluide frigorigène côté source de chaleur s'écoule dans le circuit de milieu caloporteur (B) et une pression dans le circuit de milieu caloporteur (B) atteint une valeur prédéterminée, pour ainsi expulser le fluide frigorigène côté source de chaleur et le milieu caloporteur, et
la valeur prédéterminée est déterminée sur la base d'un type du fluide frigorigène côté source de chaleur et d'un type du milieu caloporteur,
caractérisé en ce que
une valeur Cv du clapet de décharge (60) satisfait une valeur obtenue en divisant
un produit d'une valeur Cv d'un trou de communication formé entre le circuit de fluide frigorigène côté source de chaleur (A) et le circuit de milieu caloporteur (B) et d'une racine carrée d'une différence entre la pression maximale du fluide frigorigène côté source de chaleur et une pression de travail du clapet de décharge (60) par une racine carrée de la pression de travail du clapet de décharge (60).

2. Appareil de climatisation (100) selon la revendication 1, comprenant en outre des moyens de détection de fuite de fluide frigorigène configurés pour détecter une fuite du fluide frigorigène côté source de chaleur,
dans lequel l'entraînement de la pompe (21) est arrêté lorsque les moyens de détection de fuite de fluide frigorigène détectent la fuite.

3. Appareil de climatisation (100) selon la revendication 1, comprenant en outre :

un dispositif de commande d'écoulement de milieu caloporteur (25) configuré pour commander un débit d'écoulement du milieu caloporteur ; et
des moyens de détection de fuite de fluide frigorigène configurés pour détecter une fuite du fluide frigorigène côté source de chaleur,
dans lequel le dispositif de commande d'écoulement de milieu caloporteur (25) est fermé lorsque les moyens de détection de fuite de fluide frigorigène détectent la fuite.

4. Appareil de climatisation (100) selon la revendication 2 ou 3, dans lequel les moyens de détection de fuite de fluide frigorigène sont installés dans l'échangeur de chaleur intermédiaire (15) ou à proximité de l'échangeur de chaleur intermédiaire (15).

5. Appareil de climatisation (100) selon la revendication 2 ou 3, dans lequel les moyens de détection de fuite de fluide frigorigène détectent la fuite lorsque la pression dans le circuit de milieu caloporteur (B) atteint la valeur prédéterminée.

6. Appareil de climatisation (100) selon la revendication 2 ou 3, dans lequel les moyens de détection de fuite de fluide frigorigène détectent la fuite sur la base d'un changement dans une situation de fonctionnement du circuit de fluide frigorigène côté source de chaleur (A).

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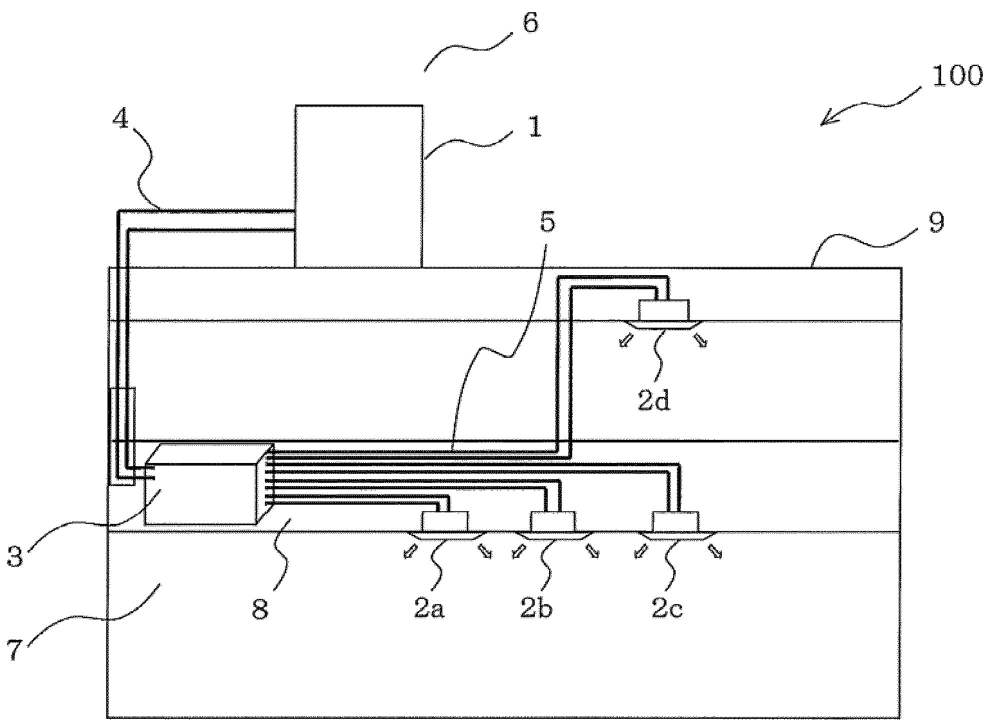

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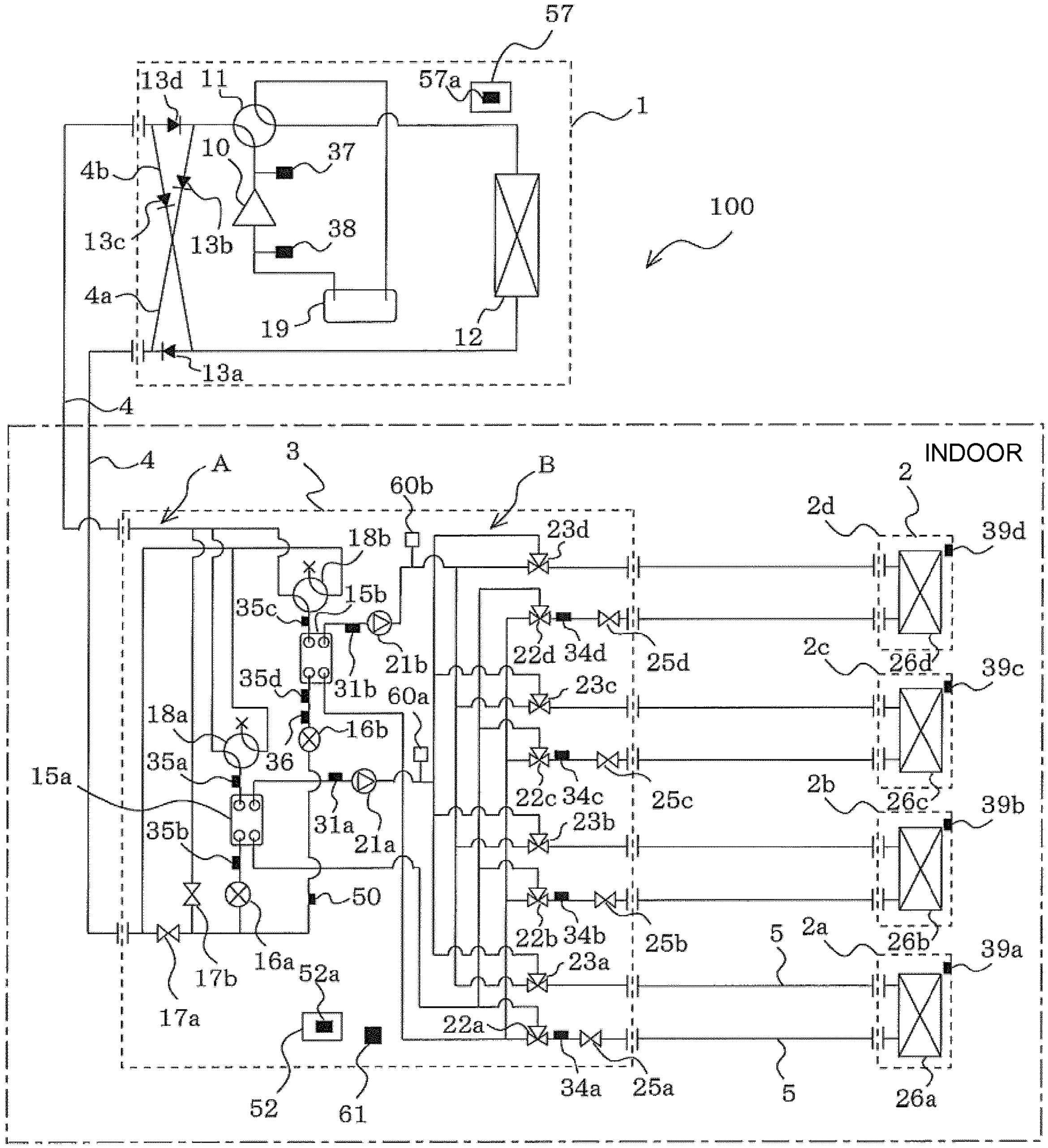
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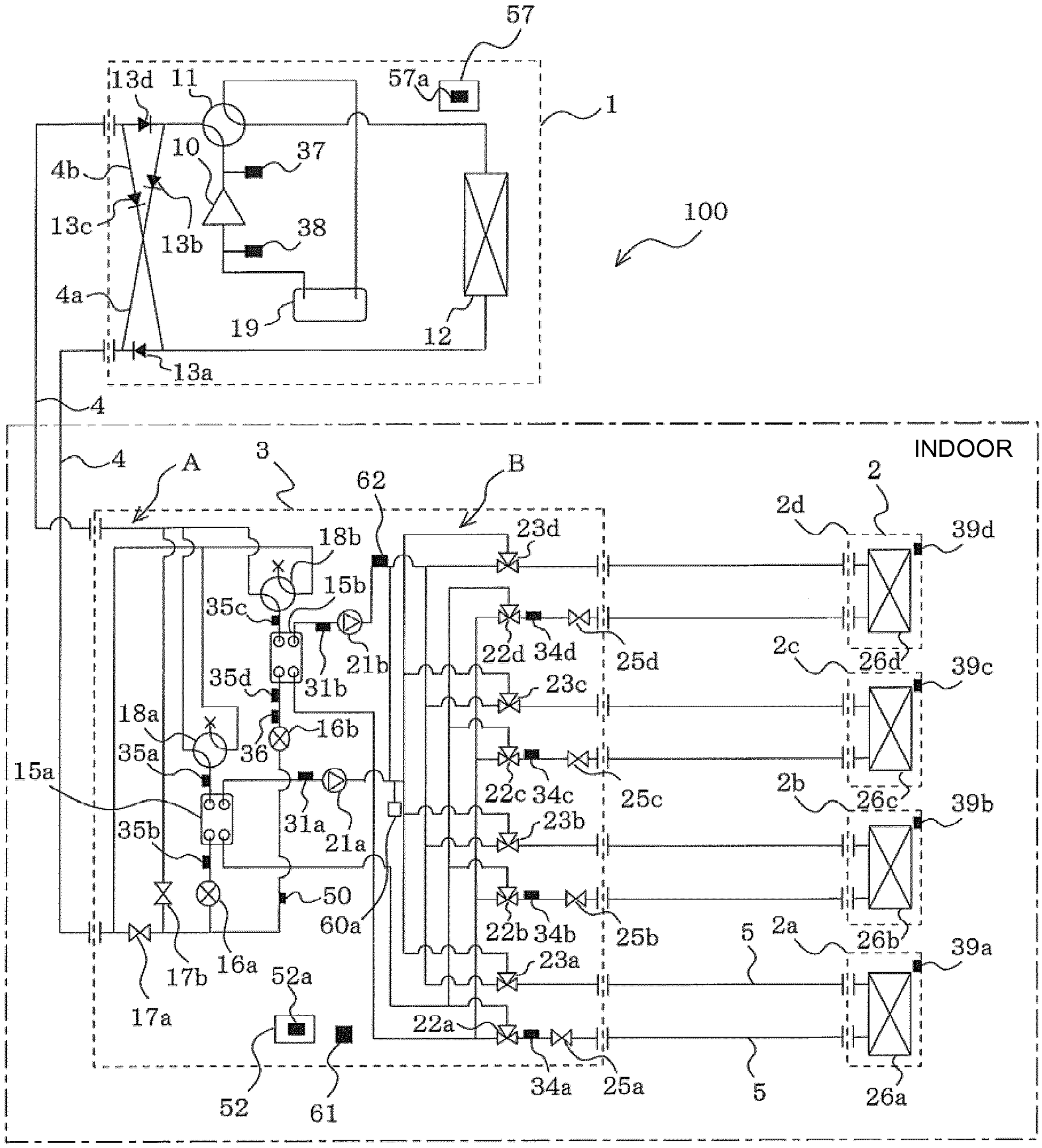
F I G. 3



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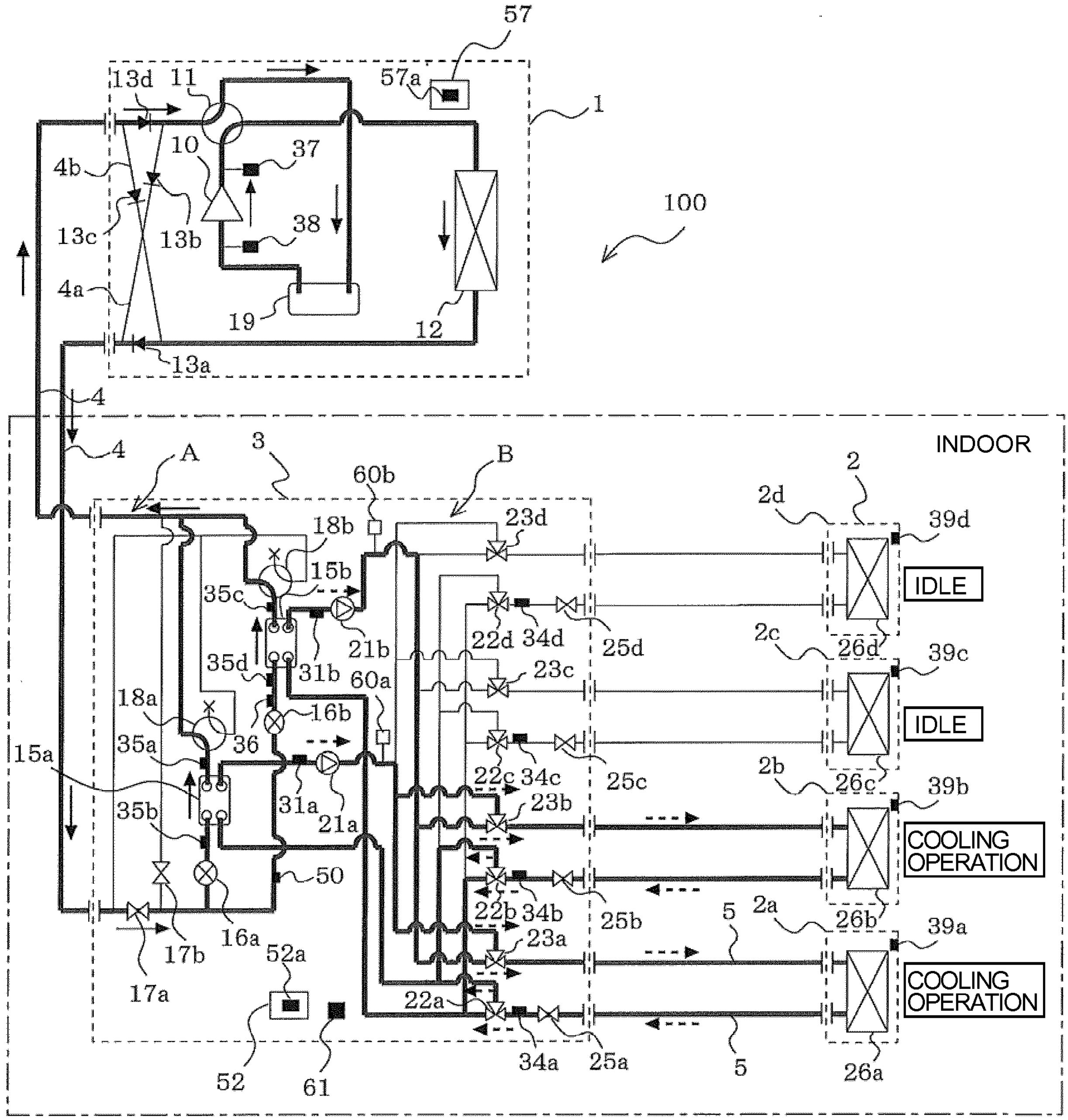
F I G. 4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F I G. 5

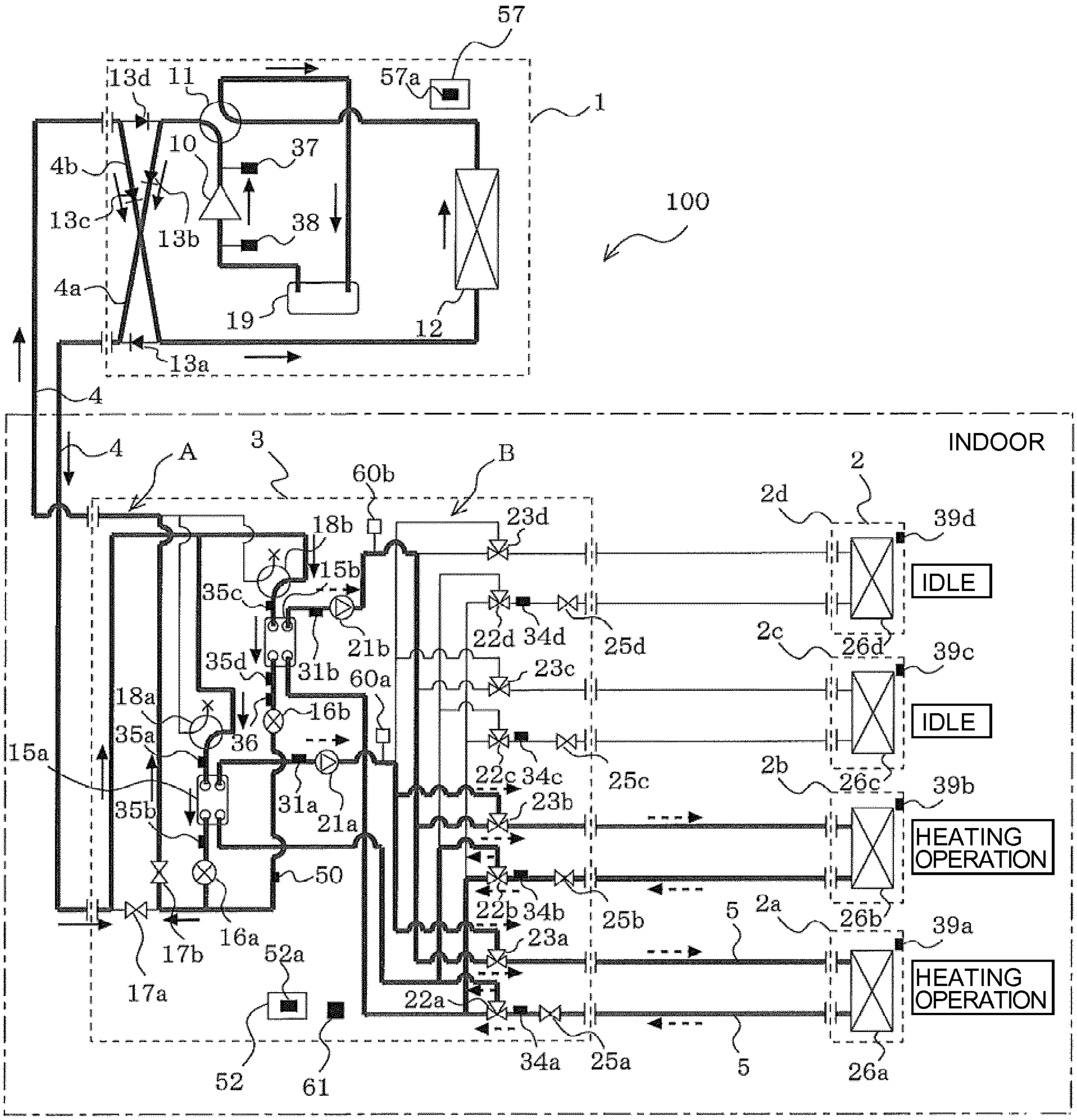
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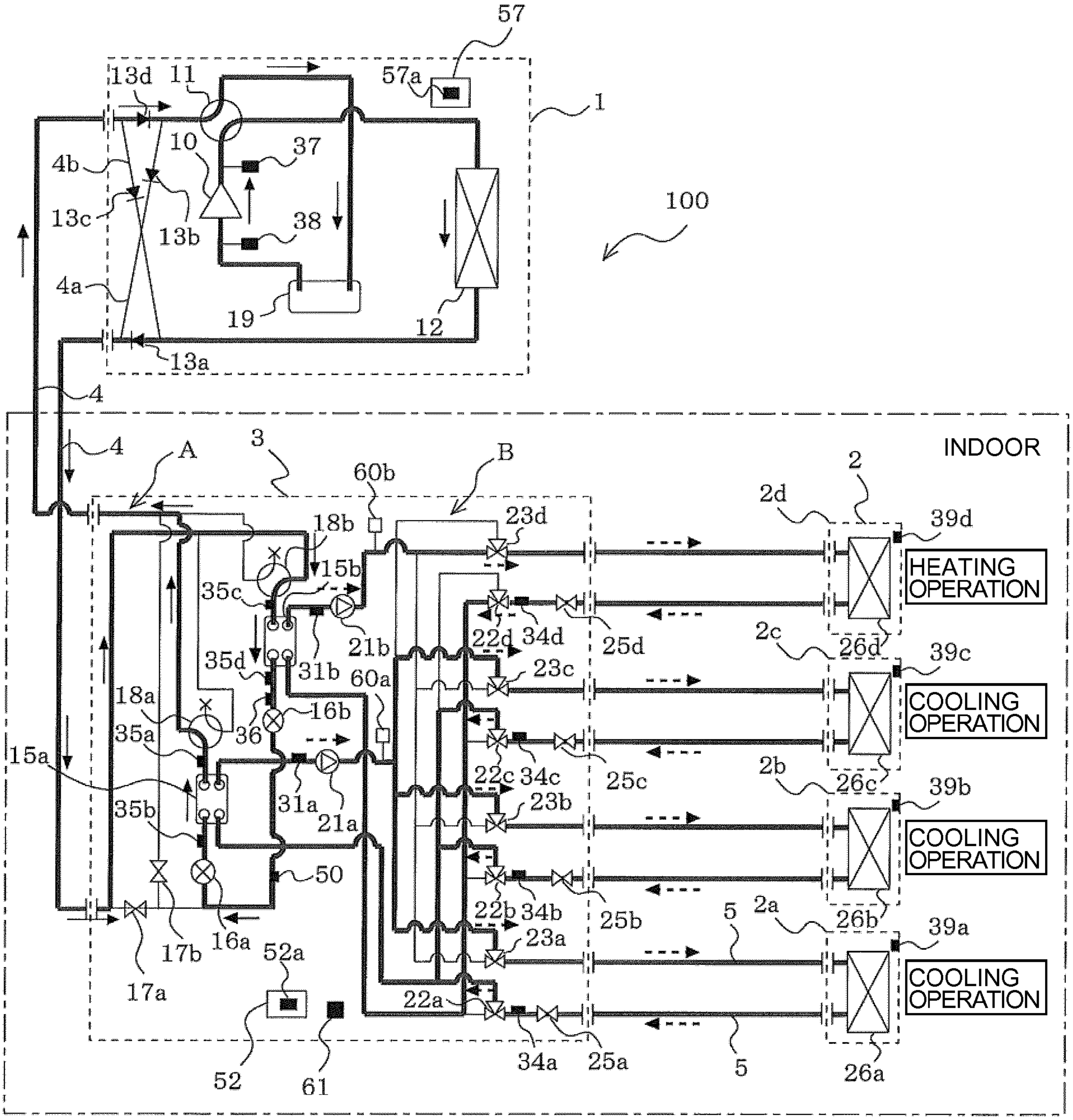
FIG. 6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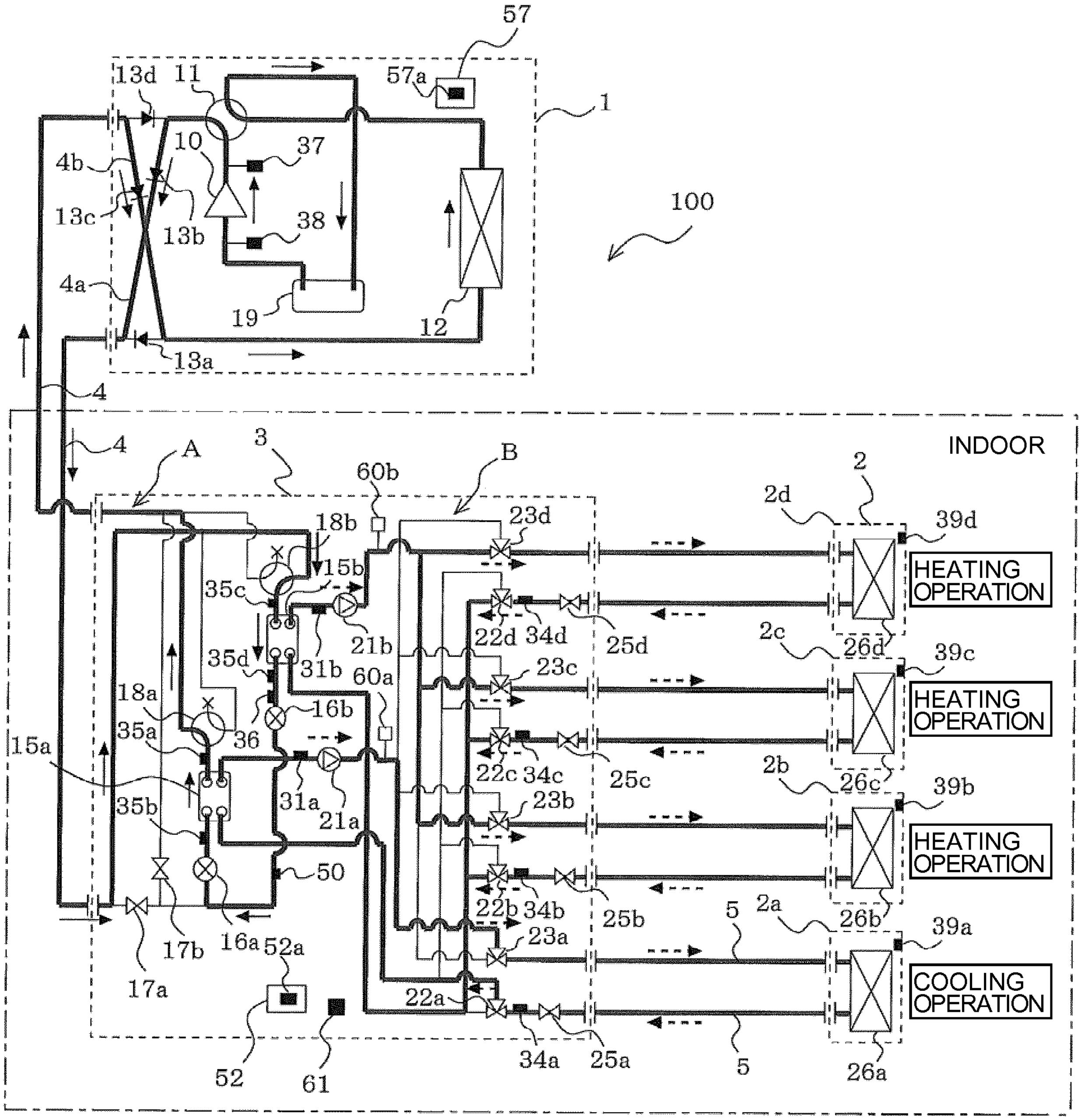
F I G. 7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