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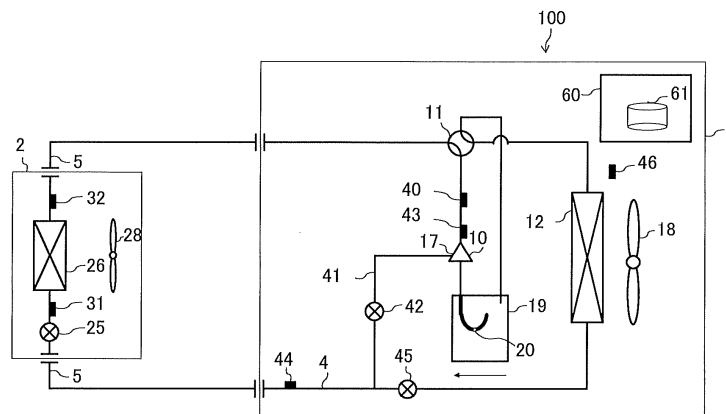
AIR CONDITIONER

- (57)

An air-conditioning apparatus includes a refrigerant circuit in which an outdoor unit, at least one load-side expansion device, and at least one load-side heat exchanger are connected by pipes to allow refrigerant to circulate. The outdoor unit includes a compressor including an injection port allowing the refrigerant to flow into a suction chamber, a heat-source-side heat exchanger for heat exchange for the refrigerant, and an accumulator. The load-side heat exchanger transfers heat between a load and the refrigerant. The outdoor unit includes: an injection pipe having one end connected between the heat-source-side heat exchanger and the

load-side expansion device, and the other end connected to the injection port, in the refrigerant circuit; an outdoor-side expansion device located downstream from the one end of the injection pipe in the flow of the refrigerant from the load-side expansion device to the heat-source-side heat exchanger; and an injection expansion device that adjusts the amount of the refrigerant flowing through the injection pipe. Also, a controller is provided to control the opening degrees of the outdoor-side expansion device and the injection expansion device.

FIG. 1



Description

Technical Field

[0001] The present disclosure relates to an air-conditioning apparatus applied to, for example, a variable refrigerant flow system.

Background Art

[0002] An air-conditioning apparatus for use in, for example, a variable refrigerant flow system includes a refrigerant circuit in which, for example, an outdoor unit that is a heat source apparatus installed outside a building and an indoor unit installed in the building are connected by a pipe. In the refrigerant circuit in the air-conditioning apparatus, refrigerant is circulated. To be more specific, in the refrigerant circuit, the refrigerant transfers heat to air or removes heat from the air to heat or cool the air, thereby heating or cooling an air-conditioned space that is a load.

[0003] For example, an air-conditioning apparatus provided with an injection circuit has been proposed. In the injection circuit, a bypass expansion device, a refrigerant heat exchanger, an open/close valve, and a compressor injection port are sequentially connected by an injection pipe that branches off from a liquid pipe between a refrigerant heat exchanger and a load-side expansion device (see, for example, Patent Literature 1). In this air-conditioning apparatus, refrigerant that has a low quality under a medium pressure is injected during a compression process in the compressor, thereby reducing the probability with which a discharge temperature will abnormally rise, while increasing the flow rate of the refrigerant. Thus, in a heating operation in which the temperature of outside air is low and the discharge temperature rises, the driving frequency of the compressor can be increased and the heating capacity can be maintained.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2008-138921

Summary of Invention

Technical Problem

[0005] In an air-conditioning apparatus for use in, for example, a variable refrigerant flow system, at a place where the air-conditioning apparatus is installed, refrigerant is added in accordance with the lengths of pipes connecting outdoor units and indoor units and the number of the indoor units. At this time, a larger amount of refrigerant than a define amount may be added. If an excessive amount of refrigerant is shut up in a refrigerant

circuit, the liquid level of the refrigerant in an accumulator is increased to a high level. Consequently, liquid backflow (return liquid) may occur. If excessive liquid backflow occurs, for example, a compressor may be damaged, as a result of which the reliability of the air-conditioning apparatus may not be ensured.

[0006] The present disclosure is applied to solve the above problem, and relates to an air-conditioning apparatus that can maintain its function for a load, and ensure reliability, without deteriorating the performance of the air-conditioning apparatus. Solution to Problem

[0007] An air-conditioning apparatus according to the present disclosure includes: an outdoor unit including a compressor, a heat-source-side heat exchanger, and an accumulator, the compressor including a suction chamber having an injection port that allows refrigerant to flow into the suction chamber, the compressor being provided to compress and discharge the refrigerant, the heat-source-side heat exchanger being provided to cause heat exchange for the refrigerant to be performed, the accumulator being provided to accumulate the refrigerant; at least one load-side expansion device that reduces the pressure of the refrigerant; and at least one load-side heat exchanger that causes heat exchange to be performed between a load and the refrigerant. The outdoor unit, the at least one load-side expansion device, and the at least one load-side heat exchanger are connected by pipes, whereby a refrigerant circuit is formed to circulate the refrigerant. The outdoor unit includes: an injection pipe having ends one of which is connected between the heat-source-side heat exchanger and the load-side expansion device and the other of which is connected to the injection port, the injection pipe being provided to allow part of the refrigerant in the refrigerant circuit to flow toward the injection port; an outdoor-side expansion device located downstream of the one end of the injection pipe in the flow of the refrigerant in the case where the refrigerant flows from the load-side expansion device to the heat-source-side heat exchanger in the refrigerant circuit, the outdoor-side expansion device being provided to reduce the pressure of the refrigerant to adjust the flow rate thereof; and an injection expansion device that adjusts the amount of the refrigerant that flows in the injection pipe. The air-conditioning apparatus further includes a controller that controls the opening degree of the outdoor-side expansion device and that of the injection expansion device. Advantageous Effects of Invention

[0008] According to the present disclosure, a controller 60 reduces the amount of refrigerant that flows into an accumulator to prevent surplus refrigerant from being accumulated therein. Thus, the liquid level of refrigerant in the accumulator is low and the refrigerant is prevented from overflowing the accumulator. It is therefore possible to prevent excessive liquid backflow to the compressor, thus preventing the compressor from being damaged, and ensuring the reliability of the air-conditioning apparatus. Brief Description of Drawings

[0009]

[Fig. 1] Fig. 1 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present disclosure.

[Fig. 2] Fig. 2 is a diagram for explaining the flow of refrigerant in a cooling operation mode of the air-conditioning apparatus 100 according to Embodiment 1 of the present disclosure.

[Fig. 3] Fig. 3 is a diagram for explaining the flow of the refrigerant in a heating operation mode of the air-conditioning apparatus 100 according to Embodiment 1 of the present disclosure.

[Fig. 4] Fig. 4 is a Mollier diagram illustrating the state of the refrigerant in the case where injection is performed on a compressor 10 in the cooling operation mode in the air-conditioning apparatus 100 according to Embodiment 1 of the present disclosure.

[Fig. 5] Fig. 5 is a Mollier diagram illustrating the state of the refrigerant in the case where the injection is performed on the compressor 10 in the cooling operation mode in the air-conditioning apparatus 100 according to Embodiment 1 of the present disclosure.

[Fig. 6] Fig. 6 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 2 of the present disclosure.

[Fig. 7] Fig. 7 is a diagram illustrating an example of control by a controller 60 in the air-conditioning apparatus 100 according to Embodiment 2 of the present disclosure.

[Fig. 8] Fig. 8 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 3 of the present disclosure.

[Fig. 9] Fig. 9 is a diagram for explaining the flow of the refrigerant in a cooling only operation mode in the air-conditioning apparatus 100 according to Embodiment 3.

[Fig. 10] Fig. 10 is a diagram for explaining the flow of the refrigerant in a cooling main operation mode in the air-conditioning apparatus 100 according to Embodiment 3.

[Fig. 11] Fig. 11 is a diagram for explaining the flow of the refrigerant in a heating only operation mode in the air-conditioning apparatus 100 according to Embodiment 3.

[Fig. 12] Fig. 12 is a diagram for explaining the flow of the refrigerant in a heating main operation mode in the air-conditioning apparatus 100 according to Embodiment 3.

[Fig. 13] Fig. 13 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 4 of the present disclosure.

[Fig. 14] Fig. 14 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 5 of the present disclosure.

closure. Description of Embodiments

[0010] Embodiments of the present disclosure will be described with reference to the accompanying drawings. In each of the figures in the drawings, components which are the same as or equivalent to those in a previous figure are denoted by the same reference signs. The same is true of the entire text of the "Description of Embodiments" section. Also, the configurations of components are described by way of example in the entire specification, and are not limited to those described in the specification. In particular, in the case where components are combined, it is not limited to the case where components according to the same embodiment are combined. A component in an embodiment can be applied to another embodiment as appropriate. Also, it is assumed that the levels of temperature, pressure, etc., are not determined in relation to absolute values, that is, they are relatively determined in accordance with the state and operation of the system or apparatus, for example. In addition, with respect to a plurality of devices that are of the same type and distinguished from each other by suffixes, in the case where they do not particularly need to be identified or distinguished from each other, the suffixes may be omitted.

Embodiment 1

[0011] Fig. 1 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present disclosure. As illustrated in Fig. 1, in the air-conditioning apparatus 100 according to Embodiment 1, an outdoor unit 1 and an indoor unit 2 are connected by, for example, two main pipes 5.

[0012] The air-conditioning apparatus 100 includes a main refrigerant circuit in which refrigerant flows and an injection flow passage. In the main refrigerant circuit of Embodiment 1, an accumulator 19, a compressor 10, a refrigerant flow switching device 11, a heat-source-side heat exchanger 12, an outdoor-side expansion device 45, a load-side expansion device 25, and a load-side heat exchanger 26 are sequentially connected by the main pipes 5 and refrigerant pipes. In the injection flow passage, the refrigerant flows from a refrigerant pipe 4 located between the outdoor-side expansion device 45 and the load-side expansion device 25 to a compressor suction chamber in the compressor 10, which is a chamber located in front of a location where compression starts.

<Outdoor Unit 1>

[0013] The outdoor unit 1 includes a compressor 10, a refrigerant flow switching device 11, a heat-source-side heat exchanger 12, an accumulator 19, an injection pipe 41, a heat-source-side fan 18, an outdoor-side expansion device 45, and an injection expansion device 42. Of these components, the compressor 10, the refrigerant flow

switching device 11, the heat-source-side heat exchanger 12, the accumulator 19, and the outdoor-side expansion device 45, which form the main refrigerant circuit, are connected by refrigerant pipes 4 in the outdoor unit 1.

[0014] The compressor 10 sucks the refrigerant, and compresses the refrigerant into high temperature, high-pressure refrigerant, and then discharges the high temperature, high-pressure refrigerant. The compressor 10 is, for example, a capacity-controllable inverter compressor. Also, the compressor 10 has, for example, a low-pressure shell structure. A compressor having a low-pressure shell structure includes a compression chamber in a sealed container, and when the internal atmosphere of the sealed container is changed to a low refrigerant pressure atmosphere, the compressor sucks and compresses low-pressure refrigerant in the sealed container. The compressor 10 of Embodiment 1 includes an injection port 17 that allows refrigerant to flow from the outside into a compression chamber. In Embodiment 1, for example, the refrigerant can be guided from the injection port 17 into a compressor suction chamber which is a chamber located immediately before a location where compression starts in the compressor 10. The refrigerant is made to flow from the outside into the compressor suction chamber to prevent the discharge temperature from rising to a level beyond the proof stress of the compressor 10.

[0015] The refrigerant flow switching device 11 switches a flow passage for the refrigerant between a refrigerant flow passage for a heating operation mode and a refrigerant flow passage for a cooling operation mode. The refrigerant flow switching device 11 is, for example, a four-way valve. It should be noted that the cooling operation mode is an operation mode in which the heat-source-side heat exchanger 12 operates as a condenser or a gas cooler. The heating operation mode is an operation mode in which the heat-source-side heat exchanger 12 operates as an evaporator.

[0016] In the heating operation mode, the heat-source-side heat exchanger 12 operates as an evaporator, and in the cooling operation mode, the heat-source-side heat exchanger 12 operates as a condenser or a gas cooler (as the condenser in Embodiment 1). The heat-source-side heat exchanger 12 in Embodiment 1 causes heat exchange to be performed between air supplied from the heat-source-side fan 18 and the refrigerant. This, however, is not limitative. Heat exchange may be performed between the refrigerant and water. In this case, the heat-source-side heat exchanger 12 operates as a water refrigerant heat exchanger.

[0017] The accumulator 19 is provided at a suction portion of the compressor 10. The accumulator 19 stores surplus refrigerant the amount of which corresponds to the difference between the amount of refrigerant required in the heating operation mode and that in the cooling operation mode, or the amount of which corresponds to the difference between the amount of the refrigerant that flows after a transient change of the operation and the

amount of the refrigerant that flows before the transient change of the operation. The oil return mechanism 20 is a through hole formed in lower part of a pipe located in the accumulator 19. Refrigerating machine oil and liquid refrigerant accumulated in lower part of the accumulator 19 pass through the oil return mechanism 20 and flows to a suction-side pipe at the compressor 10.

[0018] In the main refrigerant circuit, the outdoor-side expansion device 45 is located between the heat-source-side heat exchanger 12 and the load-side expansion device 25 of the indoor unit 2, and is provided in the outdoor unit 1. The outdoor-side expansion device 45 can arbitrarily control the opening degree (opening area) of an electronic expansion valve, etc. The outdoor-side expansion device 45 increases the pressure of refrigerant that flows between the outdoor-side expansion device 45 and the indoor unit 2, and reduces the pressure of the refrigerant that has flowed from the indoor unit 2 into the outdoor unit 1 through the main pipe 5 in the heating operation mode, thereby expanding the refrigerant. The opening degree of the outdoor-side expansion device 45 is adjusted, whereby the amount of refrigerant that is accumulated in the accumulator 19 is adjusted.

[0019] The injection pipe 41 is a pipe that forms an injection flow passage. In the outdoor unit 1, one end of the injection pipe 41 is connected to the refrigerant pipe 4, and the other end of the injection pipe 41 is connected to the injection port 17 of the compressor 10. Liquid refrigerant or two-phase gas-liquid refrigerant is made to flow into the compressor suction chamber of the compressor 10. At this time, the liquid refrigerant or the two-phase gas-liquid refrigerant is a high pressure or medium pressure refrigerant. The medium pressure is lower than a high pressure (for example, the refrigerant pressure in the condenser or the discharge pressure of the compressor 10) in a refrigeration cycle circuit, and higher than a low pressure (for example, the refrigerant pressure in the evaporator or the suction pressure of the compressor 10) in the refrigeration cycle circuit.

[0020] The injection expansion device 42 is provided at the injection pipe 41. The injection expansion device 42 adjusts the amount and pressure of the refrigerant that passes through the injection pipe 41 and flows into the injection port 17 of the compressor 10. The opening degree of the injection expansion device 42 can be adjusted continuously or in multiple stages under, for example, control by the controller 60 which will be described later.

[0021] The outdoor unit 1 is provided with a discharge temperature sensor 43, a discharge pressure sensor 40, an outside-air temperature sensor 46, and a pressure detection sensor 44. The discharge temperature sensor 43 detects the temperature of the refrigerant discharged from the compressor 10 and outputs a discharge temperature detection signal. The discharge pressure sensor 40 detects the pressure of the refrigerant discharged from the compressor 10 and outputs a discharge pressure detection signal. The outside-air temperature sen-

sor 46 is provided at an air inflow portion of the heat-source-side heat exchanger 12 in the outdoor unit 1. The outside-air temperature sensor 46 detects, for example, the temperature of outside air, i.e., an outside air temperature, which is an ambient temperature for the outdoor unit 1, and outputs an outside-air temperature detection signal. The pressure detection sensor 44 detects the pressure of the refrigerant (medium pressure) between the outdoor-side expansion device 45 and the accumulator 19, and outputs a medium-pressure detection signal. It should be noted that not only a pressure sensor but a temperature sensor can be used as the pressure detection sensor 44. In the case where a temperature sensor is used as the pressure detection sensor 44, the controller 60, which will be described later, sets a calculated saturated pressure as a medium pressure, based on the temperature detected by the pressure detection sensor 44.

<Indoor Unit 2>

[0022] The indoor unit 2 includes a load-side heat exchanger 26 and a load-side expansion device 25. In the heating operation mode, the load-side heat exchanger 26 operates as a condenser or a gas cooler (in Embodiment 1, a condenser), and in the cooling operation mode, the load-side heat exchanger 26 operates as an evaporator. The load-side heat exchanger 26 causes heat exchange to be performed between the refrigerant and a load to be subjected to the heat exchange. In Embodiment 1, air in the air-conditioned space that is sent by the load-side fan 28 is a load.

[0023] The load-side expansion device 25 is provided upstream of the load-side heat exchanger 26 in the flow of the refrigerant in the cooling operation mode of the main refrigerant circuit. The load-side expansion device 25 serves as a pressure reducing valve and an expansion valve, which reduces the pressure of the refrigerant and expands the refrigerant. The opening degree of the load-side expansion device 25 can be adjusted continuously or in multiple stages under, for example, control by the controller 60, which will be described later. The load-side expansion device 25 can arbitrarily control the opening degree of an electronic expansion valve or other devices.

[0024] The indoor unit 2 is provided with an inflow-side temperature sensor 31 and an outflow-side temperature sensor 32. The inflow-side temperature sensor 31 and the outflow-side temperature sensor 32 each include a thermistor, etc. The inflow-side temperature sensor 31 is provided at a pipe located on an inflow side of the load-side heat exchanger 26 in the flow of the refrigerant in the cooling operation mode of the main refrigerant circuit. The inflow-side temperature sensor 31 detects the temperature of refrigerant that is to flow into the load-side heat exchanger 26, and outputs an inflow-side detection signal. The outflow-side temperature sensor 32 is provided at a pipe located on an outflow side of the load-side heat exchanger 26 in the flow of the refrigerant in

the cooling operation mode of the main refrigerant circuit. The outflow-side temperature sensor 32 detects the temperature of refrigerant that has flowed out of the load-side heat exchanger 26, and outputs an outflow-side detection signal.

[0025] The air-conditioning apparatus 100 includes a controller 60. The controller 60 controls the operation of the entire air-conditioning apparatus 100 based on detection signals sent from various sensors as described above and an instruction from a remote control unit (not illustrated). For example, the controller 60 controls the driving frequency of the compressor 10, the rotation speeds of the heat-source-side fan 18 and the load-side fan 28 (including ON/OFF control), and switching of the flow passage by the refrigerant flow switching device 11. Furthermore, the controller 60 controls, for example, the opening degrees of the outdoor-side expansion device 45, the injection expansion device 42, and the load-side expansion device 25. The controller 60 performs the above controls to cause the air-conditioning apparatus 100 to enter any of the operation modes.

[0026] The controller 60 includes a microcomputer. The microcomputer includes, for example, a control arithmetic processing device such as a central processing unit (CPU), and also has an I/O port for use in managing input and output. Furthermore, the microcomputer includes a storage device 61. The storage device 61 is, for example, a volatile storage device (not illustrated) such as a random access memory (RAM) that can temporarily store data and a nonvolatile auxiliary storage device (not illustrated) such as a hard disk or a flash memory that can store data for a long time. The storage device 61 stores data that indicates as a program, the procedure of processing by the control arithmetic processing device. The control arithmetic processing device executes processing based on the data stored as the program. This, however, is not restrictive. Each of the devices may be provided as a dedicated device (hardware). It should be noted that although it is described that the controller 60 is provided in the outdoor unit 1 in the air-conditioning apparatus 100 of Embodiment 1, this is not restrictive. The controller 60 may be provided in the indoor unit 2. Alternatively, a plurality of controllers 60 may be provided such that for example, functions of the controllers 60 are dividedly assigned to the outdoor unit 1 and the indoor unit 2.

[0027] The operation modes of the air-conditioning apparatus 100 will be described. The controller 60 of the air-conditioning apparatus 100 can cause the indoor unit 2 to enter the cooling operation mode in which the indoor unit 2 performs the cooling operation or the heating operation mode in which the indoor unit 2 performs the heating operation, in response to an instruction from the indoor unit 2. At this time, the controller 60 can determine whether or not to perform injection. Each operation mode will be described together with the flow of the refrigerant.

<Cooling Operation Mode (Involving No Injection)>

[0028] Fig. 2 is a diagram for explaining the flow of the refrigerant in the cooling operation mode of the air-conditioning apparatus 100 of Embodiment 1 of the present disclosure. With reference to Fig. 2, the flow of the refrigerant that is other than the flow of the refrigerant in injection in the cooling operation mode will be described by referring to by way of example the case where a cooling load is applied to the load-side heat exchanger 26. In Fig. 2, the flow direction of the refrigerant is indicated by flows are indicated by solid arrows.

[0029] As illustrated in Fig. 2, low-temperature, low-pressure refrigerant is sucked by the compressor 10 and compressed thereby into high-temperature, high-pressure gas refrigerant. The high-temperature, high-pressure gas refrigerant is discharged from the compressor 10. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows into the heat-source-side heat exchanger 12 through the refrigerant flow switching device 11. The gas refrigerant that has flowed into the heat-source-side heat exchanger 12 is condensed while transferring heat to outside air supplied by the heat-source-side fan 18, thereby changing into high-pressure liquid refrigerant, and the high-pressure liquid refrigerant flows out of the heat-source-side heat exchanger 12. The high-pressure liquid refrigerant that has flowed out of the heat-source-side heat exchanger 12 passes through the outdoor-side expansion device 45, and flows out of the outdoor unit 1. Then, the high-pressure liquid refrigerant flows into the indoor unit 2 through the main pipe 5.

[0030] The high-pressure refrigerant that has flowed into the indoor unit 2 is expanded by the load-side expansion device 25 to change into low-temperature, low-pressure two-phase gas-liquid refrigerant. The two-phase gas-liquid refrigerant flows into the load-side heat exchanger 26 that operates as an evaporator. The two-phase gas-liquid refrigerant that has flowed into the load-side heat exchanger 26 removes heat from indoor air to cool the indoor air, thereby changing into low-temperature, low-pressure gas refrigerant while cooling the indoor air, and then the low-temperature, low-pressure gas refrigerant flows out of the load-side heat exchanger 26.

[0031] The opening degree of the load-side expansion device 25 is controlled by the controller 60 such that the superheat (the degree of superheat) becomes constant. Superheat is a value obtained as the difference between a temperature detected by the inflow-side temperature sensor 31 and a temperature detected by the outflow-side temperature sensor 32.

[0032] The low-temperature, low-pressure gas refrigerant that has flowed out of the load-side heat exchanger 26 flows out of the indoor unit 2. The low-temperature, low-pressure gas refrigerant that has flowed out of the indoor unit 2 re-flows into the outdoor unit 1 through the main pipe 5. The low-temperature, low-pressure gas refrigerant that has flowed into the outdoor unit 1 passes

through the refrigerant flow switching device 11 and the accumulator 19. At this time, the low-temperature, low-pressure gas refrigerant passes through the accumulator 19. Then, the low-temperature, low-pressure gas refrigerant is re-sucked into the compressor 10.

<Heating Operation Mode (Involving No Injection)>

[0033] Fig. 3 is a diagram for explaining the flow of the refrigerant in the heating operation mode of the air-conditioning apparatus 100 of Embodiment 1 of the present disclosure. With reference to Fig. 3, the flow of the refrigerant that is other than the flow of the refrigerant in injection in the heating operation mode will be described by referring to by way of example the case where a heating load is applied to the load-side heat exchanger 26. In Fig. 3, the flow direction of the refrigerant is indicated by solid arrows.

[0034] As illustrated in Fig. 3, low-temperature, low-pressure refrigerant is sucked by the compressor 10 and compressed thereby to change into high-temperature, high-pressure gas refrigerant. The high-temperature, high-pressure gas refrigerant is then discharged from the compressor 10. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant flow switching device 11. The high-temperature, high-pressure gas refrigerant that has flowed out the outdoor unit 1 flows into the indoor unit 2 through the main pipe 5.

[0035] The high-temperature, high-pressure gas refrigerant that has flowed into the indoor unit 2 flows into the load-side heat exchanger 26. The gas refrigerant that has flowed into the load-side heat exchanger 26 transfers heat to the indoor air to heat indoor air, thereby changing into liquid refrigerant while heating the indoor air, and the liquid refrigerant then flows out of the load-side heat exchanger 26. The liquid refrigerant that has flowed out of the load-side heat exchanger 26 is expanded by the load-side expansion device 25 to change into medium-temperature, medium-pressure two-phase gas-liquid refrigerant, and the medium-temperature, medium-pressure two-phase gas-liquid refrigerant flows out of the indoor unit 2. The refrigerant that has flowed out of the indoor unit 2 passes through the main pipe 5 and re-flows into the outdoor unit 1.

[0036] The medium-temperature, medium-pressure two-phase gas-liquid refrigerant that has flowed into the outdoor unit 1 flows into the heat-source-side heat exchanger 12. The two-phase gas-liquid refrigerant that has flowed into the heat-source-side heat exchanger 12 removes heat from outside air, thereby changing into low-temperature, low-pressure gas refrigerant while cooling the outside air, and the low-temperature, low-pressure gas refrigerant flows out of the heat-source-side heat exchanger 12. The low-temperature, low-pressure gas refrigerant that has flowed out of the heat-source-side heat exchanger 12 passes through the refrigerant flow switching device 11 and the accumulator 19. At this time, the

low-temperature, low-pressure gas refrigerant passes through the accumulator 19 as low-temperature, low-pressure refrigerant. Then, the low-temperature, low-pressure refrigerant is re-sucked into the compressor 10.

<Influence on Performance in Case Where No Injection Is Performed>

[0037] In the cooling operation mode and the heating operation mode, in the case where injection is not performed, the controller 60 adjusts the opening degree of the injection expansion device 42 in such a manner as to cause the injection expansion device 42 to be fully closed. Thus, the refrigerant does not flow through the injection pipe 41. When the injection expansion device 42 is in the fully closed state, the pressure of the compressor suction chamber of the compressor 10 is the lowest in the refrigerant circuit. As described above, the compressor 10 of Embodiment 1 has a structure that allows the refrigerant to flow into the compressor suction chamber. Thus, unlike the case where an injection port is provided in the medium-pressure compression chamber of the compressor 10, the refrigerant does not leak from the compressor suction chamber of the compressor 10 into part of the injection pipe 41 that is located between the injection expansion device 42 and the compressor suction chamber of the compressor 10. Therefore, the efficiency of the compressor 10 is not worsened, which would be worsened if a refrigerant leak occurs. It is therefore possible to prevent the performance of the apparatus from being deteriorated by a refrigerant leak.

<Cooling Operation Mode (Flow during Injection)>

(Outline of Necessity and Advantages of Injection in Cooling Operation Mode)

[0038] There are some refrigerants such as R32, which cause the discharge temperature of the compressor 10 to be high, compared with the R410A refrigerant (hereinafter referred to as R410A). In the case where the refrigerant used in the air-conditioning apparatus 100 is refrigerant that causes the discharge temperature to be high, it is necessary to reduce the discharge temperature to prevent, for example, deterioration of refrigerating machine oil and burnout of the compressor 10a. For this reason, in the cooling operation mode, in the case of using refrigerant that causes the discharge temperature to be high, injection is performed. In the injection, part of high-pressure liquid refrigerant that has flowed out of the heat-source-side heat exchanger 12 is made to flow into the compressor suction chamber of the compressor 10 through the injection pipe 41. In the case where the injection is performed, the controller 60 controls the injection expansion device 42 and the outdoor-side expansion device 45 to adjust the flow rate of the refrigerant that flows through the injection pipe 41.

[0039] Fig. 4 is a Mollier diagram illustrating the state

of the refrigerant in the case where the injection is performed on the compressor 10 in the cooling operation mode in the air-conditioning apparatus 100 of Embodiment 1 of the present disclosure. In Fig. 4, the horizontal axis represents specific enthalpy h [kJ/kg], and the vertical axis represents pressure P [MPa]. Advantages obtained by the injection in the cooling operation mode in the air-conditioning apparatus 100 of Embodiment 1 will be described with reference to Fig. 4.

[0040] In Fig. 4, the liquid refrigerant that has flowed out of the heat-source-side heat exchanger 12 is in the state indicated by point (c). The liquid refrigerant is reduced in pressure by the outdoor-side expansion device 45 to change into liquid refrigerant or two-phase refrigerant, which is indicated by point (d). Part of the liquid or two-phase refrigerant obtained through the above pressure-reduction process flows into the compressor suction chamber of the compressor 10 through the injection pipe 41 and the injection expansion device 42.

[0041] By contrast, the other part of the liquid or two-phase refrigerant is reduced in pressure by the load-side expansion device 25 to change into two-phase refrigerant the state of which is indicated by point (g), and flows into the load-side heat exchanger 26. In the load-side heat exchanger 26, the two-phase refrigerant is changed into low-temperature, low-pressure gas refrigerant as indicated by point (e). Then, the gas refrigerant flows into the compressor 10 via the main pipe 5, the refrigerant flow switching device 11, and the accumulator 19.

[0042] In the compression suction chamber, the gas refrigerant that has flowed into the compressor 10 joins the liquid or two-phase refrigerant that has flowed from the injection port 17 into the compressor suction chamber. The state of the refrigerant in the compressor suction chamber is the state of high-quality and low-pressure two-phase refrigerant as indicated by point (g). The state of the refrigerant discharged from the compressor 10 is the state of the high-pressure gas refrigerant as indicated by point (b). The high-pressure gas refrigerant the state of which is indicated by point (b) causes the discharge temperature to be low, as compared with high-pressure gas refrigerant discharged without the injection, the state of which is indicated by point (b1). It is therefore, possible to prevent deterioration of refrigerating machine oil and burnout of the compressor 10.

<Control of Injection Expansion Device 42 in Cooling Operation Mode>

[0043] The control of the injection expansion device 42 by the controller 60 in the cooling operation mode will be described. The controller 60 controls the opening degree of the injection expansion device 42 based on the discharge temperature of the compressor 10 detected by the discharge temperature sensor 43. When the opening degree of the injection expansion device 42 is increased, the flow rate of the refrigerant that flows into the compressor 10a is increased. Therefore, the discharge tem-

perature of the refrigerant that is discharged from the compressor 10 is decreased. By contrast, when the opening degree of the injection expansion device 42 is decreased, the flow rate of the refrigerant that flows into the compressor 10a is decreased. Therefore, the discharge temperature of the refrigerant that is discharged from the compressor 10 is increased.

[0044] Then, the controller 60 determines whether or not the discharge temperature of the compressor 10 that is detected by the discharge temperature sensor 43 is lower than or equal to a discharge temperature threshold. When determining that the discharge temperature is lower than or equal to the discharge temperature threshold, the controller 60 controls the injection expansion device 42 such that the amount of refrigerant to be injected is reduced. It should be noted that the discharge temperature threshold is set in accordance with a limit value of the discharge temperature of the compressor 10.

[0045] In contrast, when determining that the discharge temperature is higher than the discharge temperature threshold, the controller 60 controls the injection expansion device 42 such that the amount of refrigerant to be injected is increased. At this time, the controller 60 controls the injection expansion device 42 such that the discharge temperature is equalized to the discharge temperature threshold. For example, the controller 60 stores in a table format in the storage device 61, data indicating a relationship between the discharge temperature and the opening degree of the injection expansion device 42. The controller 60 then determines the opening degree of the injection expansion device 42, which is associated with the discharge temperature of the compressor 10 detected by the discharge temperature sensor 43, and controls the injection expansion device 42. It should be noted that the controller 60 may store, for example, a mathematical expression that uses the discharge temperature as a variable, as data in the storage device 61, instead of the data in the table format. The controller 60 calculates the opening degree of the injection expansion device 42 on the basis of the discharge temperature, and controls the injection expansion device 42.

[0046] It should be noted that although it is described above that the controller 60 makes the determination related to the control of the injection expansion device 42 on the basis of the discharge temperature and the discharge temperature threshold, this is not restrictive. For example, the determination related to the control of the injection expansion device 42 can also be made based on the degree of discharge superheat (discharge superheat) of the compressor 10 and a superheat degree threshold. It should be noted that the degree of discharge superheat of the compressor 10 is the difference between the discharge temperature of the compressor 10 that is detected by the discharge temperature sensor 43 and a saturated temperature calculated from a discharge pressure detected by the discharge pressure sensor 40.

<Operation and Advantages of Injection during Cooling Operation Mode>

[0047] As described above, the suction enthalpy of the refrigerant in the compressor suction chamber of the compressor 10 can be reduced by the injection. Thus, the discharge temperature of the compressor 10 can be prevented from excessively rising. It is therefore possible to reduce the degree of deterioration of refrigerating machine oil, and prevent the compressor 10 from being damaged. Accordingly, the reliability of the entire air-conditioning apparatus 100 can be ensured. Furthermore, the driving frequency of the compressor 10 can be made high by reducing the degree of rising of the discharge temperature of the compressor 10. It is therefore possible to ensure a large cooling capacity, deal with a great air-conditioning load, and also maintain the comfortability for the user.

<Heating Operation Mode (Flow during Injection)>

<Outline of Necessity and Advantages of Injection>

[0048] In the heating operation mode, not only in the case where refrigerant that raises the discharge temperature to a high value is used, but in the case where the driving frequency of the compressor 10 is raised, for example, when the outside air temperature is low, the discharge temperature of the compressor 10 may become higher than or equal to the discharge temperature threshold. Therefore, it is necessary to perform the injection when the driving frequency is raised to ensure a heating capacity. It will be described how the discharge temperature of the compressor 10 is controlled to be reduced in order to prevent deterioration of refrigerating machine oil and the burnout of the compressor 10, which occur when the discharge temperature of the compressor 10 is raised to a high temperature in the heating operation mode.

[0049] Fig. 5 is a Mollier diagram illustrating the state of the refrigerant in the case where injection is performed on the compressor 10 in the cooling operation mode in the air-conditioning apparatus 100 of Embodiment 1 of the present disclosure. In Fig. 5, the horizontal axis represents the specific enthalpy h [kJ/kg], and the vertical axis represents pressure P [MPa]. The advantages obtained by the injection in the heating operation mode in the air-conditioning apparatus 100 of Embodiment 1 will be described with reference to Fig. 5.

[0050] In Fig. 5, the liquid refrigerant that has flowed out of the heat-source-side heat exchanger 26 is in the state indicated by point (c). The liquid refrigerant is reduced in pressure by the load-side expansion device 25 to change into medium-pressure, medium-temperature two-phase refrigerant that is in the state indicated by point (d). The medium-pressure and medium-temperature two-phase refrigerant passes through the main pipe 5 and the refrigerant pipe 4. Part of the medium-pressure

and medium-temperature two-phase refrigerant flows into the compressor suction chamber of the compressor 10 through the injection pipe 41 and the injection expansion device 42.

[0051] By contrast, remaining part of the medium-pressure, medium-temperature two-phase refrigerant is reduced in pressure by the outdoor-side expansion device 45 to change into two-phase refrigerant that is in the state indicated by point (g), and flows into the heat-source-side heat exchanger 12. In the heat-source-side heat exchanger 12, the two-phase refrigerant removes heat from the outside air to change low-temperature, low-pressure gas refrigerant that is in the state indicated by point (e). The gas refrigerant flows into the compressor 10 via the refrigerant flow switching device 11 and the accumulator 19.

[0052] The gas refrigerant that has flowed into the compressor 10 joins the liquid or two-phase refrigerant that has flowed thereinto from the injection port 17, in the compressor suction chamber. The state of the refrigerant in the compressor suction chamber is that of a high-quality and low-pressure two-phase refrigerant, as indicated by point (g). The state of the refrigerant discharged from the compressor 10 is that of the high-pressure gas refrigerant as indicated by point (b). The discharge temperature of the high-pressure gas refrigerant the state of which is indicated by point (b) is lower than that of the high-pressure gas refrigerant which is discharged without injection and the state of which is indicated by point (b1). Therefore, deterioration of refrigerating machine oil and burnout of the compressor 10 can be prevented.

[0053] It should be noted that although it is described that the medium-pressure and medium-temperature two-phase refrigerant which is obtained through the pressure-reduction process and the state of which is indicated by point (d) passes through the injection pipe 41 as described above, it is not restrictive. For example, a gas-liquid separator may be provided at a connection point between the injection pipe 41 and the refrigerant pipe 4 in order that liquid refrigerant flow through the injection pipe 41. When the liquid refrigerant flows through the injection pipe 41, the control of the injection expansion device 42 can be stabilized.

[0054] The controller 60 controls the outdoor-side expansion device 45 and the injection expansion device 42 such that the refrigerant flows from the injection pipe 41 into the compressor suction chamber of the compressor 10. Because of the injection, the discharge temperature of the refrigerant that is discharged from the compressor 10 can be reduced, and the air-conditioning apparatus 100 can be safely used.

<Control of Injection Expansion Device 42 in Heating Operation Mode>

[0055] The control of the injection expansion device 42 in the heating operation mode is the same as that in the cooling operation mode. The controller 60 performs

processing including the determination based on the discharge temperature and the discharge temperature threshold, and controls the injection expansion device 42. It should be noted that the injection expansion device 42 may be controlled based on the degree of discharge superheat of the compressor 10 and the superheat degree threshold.

<Control of Outdoor-Side Expansion Device 45 in Heating Operation Mode>

[0056] In the heating operation mode, in order to cause a sufficient amount of liquid refrigerant or two-phase refrigerant to flow into the suction chamber of the compressor 10, it is necessary to raise the saturated temperature of the medium-pressure and medium-temperature liquid or two-phase refrigerant. Therefore, the controller 60 controls the outdoor-side expansion device 45 in such a manner as to cause the refrigerant located upstream of the outdoor-side expansion device 45 to change into medium-pressure refrigerant.

[0057] When the opening degree of the outdoor-side expansion device 45 is small, the amount of refrigerant that flows out of the outdoor-side expansion device 45 decreases. By contrast, the amount of refrigerant in part of the refrigerant pipe 4 that is located between the load-side expansion device 25 and the outdoor-side expansion device 45 increases. Thus, the pressure of the medium-pressure, medium-temperature liquid or two-phase refrigerant that passes through the injection pipe 41 rises.

[0058] When the opening degree of the outdoor-side expansion device 45 is great, the amount of refrigerant that flows out of the outdoor-side expansion device 45 increases. By contrast, the amount of refrigerant in the part of the refrigerant pipe 4 that is located between the load-side expansion device 25 and the outdoor-side expansion device 45 decreases. Thus, the pressure of the medium-pressure and medium-temperature liquid or two-phase refrigerant that passes through the injection pipe 41 drops.

[0059] Therefore, the controller 60 calculates based on the pressure detected by the pressure detection sensor 44, the saturated temperature of the medium-temperature, medium-pressure two-phase gas-liquid refrigerant that has flowed out of the load-side expansion device 25. The opening degree of the outdoor-side expansion device 45 is adjusted such that the saturated temperature approaches a predetermined value at which a flow rate of the refrigerant that is required for the injection can be secured. This predetermined value is set as an injection temperature value. The injection temperature value is, for example, 10 degrees C or higher.

[0060] Therefore, as in the cooling operation mode, the low-pressure, low-temperature gas refrigerant that has flowed out of the accumulator 19 and the liquid or two-phase refrigerant that has passed through the injection flow passage join each other in the compressor suction chamber of the compressor 10 to change into high-

quality and low-pressure two-phase refrigerant. The compressor 10 compresses the high-quality and low-pressure two-phase refrigerant.

<Operation and Advantages of Injection in Heating Operation Mode>

[0061] As described above, because of the injection, the suction enthalpy of the refrigerant in the compressor suction chamber of the compressor 10 can be reduced. Therefore, the discharge temperature of the compressor 10 can be prevented from excessively rising. It is therefore possible to reduce the degree of deterioration of refrigerating machine oil, and prevent the compressor 10 from being damaged. Thus, the reliability of the entire air-conditioning apparatus 100 can be ensured. Furthermore, the driving frequency of the compressor 10 can be raised to a high value by reducing the degree to which the discharge temperature of the compressor 10 rises. Thus, it is possible to secure a large cooling capacity, deal with a great air conditioning load, and maintain the comfortability for the user.

<Advantages of Injection Structure and Opening Degree of Outdoor-Side Expansion Device 45>

[0062] For example, in a given type of air-conditioning apparatus, a compressor having a low-pressure shell structure is used, and the injection is performed on a pipe located on the suction side of the compressor. In such an air-conditioning apparatus, if a large amount of liquid or two-phase refrigerant is injected into the pipe located on the suction side of the compressor, the liquid refrigerant stays in a lower portion of a shell of the compressor. Consequently, refrigerating machine oil is diluted with the liquid refrigerant, and the concentration of the refrigerating machine oil is reduced. If the concentration of the refrigerating machine oil is reduced, scrolls provided in the compressor may burn out. Therefore, in order to reduce the amount of refrigerant to be injected, it is necessary to use a small valve as the outdoor-side expansion device. However, if a small valve is used as the outdoor-side expansion device, it may be clogged with, for example, dust, thus causing a malfunction in the outdoor-side expansion device.

[0063] By contrast, the air-conditioning apparatus 100 of Embodiment 1, the compressor 10 has a low-pressure shell structure and a structure in which the injection is performed on the compressor suction chamber, which is located in front of a location where compression starts. Therefore, even if the amount of refrigerant for the injection is increased, the injected refrigerant can be made to flow into a scroll portion of the compressor 10. Thus, the injected liquid or two-phase refrigerant does not stay in the lower portion of the shell. Therefore, the refrigerating machine oil is not diluted, and the concentration of the refrigerating machine oil is not decreased. Furthermore, the amount of refrigerant for the injection can be in-

creased. Thus, a small valve does not need to be used as the outdoor-side expansion device 45. Needless to say, the above structure does not cause occurrence of a problem in which a small valve is clogged with dust, and a malfunction occurs in the valve.

<Liquid Backflow Preventing Processing>

[0064] For example, at a place where the air-conditioning apparatus 100 is installed, the amount of refrigerant additionally shut up in the refrigerant circuit may be larger than a defined amount of refrigerant determined based on, for example, the length of the main pipe 5. In such a case, when the amount of surplus refrigerant generated in the heating operation mode is larger than the amount of refrigerant that can be accumulated in the accumulator 19, the refrigerant overflows the accumulator 19. It is therefore necessary to prevent liquid backflow (return liquid), which is an excessive return of liquid refrigerant to the compressor 10, to prevent overflow.

[0065] For example, the controller 60 stores in a table format in the storage device 61, data indicating a relationship between a liquid backflow rate depending on the liquid level of the accumulator 19 and the discharge temperature of the compressor 10 in the case where the injection is not performed. To be more specific, this relationship is a relationship between the amount of liquid backflow at a predetermined liquid level of the accumulator 19 and the discharge temperature of the compressor 10 that depends on the operation state of the compressor 10, such as the driving frequency, suction state, and discharge state of the compressor 10, etc. The predetermined liquid level is, for example, the level of refrigerant the amount of which corresponds to 2/3 of the volume of the accumulator 19. The discharge temperature obtained in such a relationship is a liquid-level adjustment threshold in the case where the injection is not performed. The liquid-level adjustment threshold is the discharge temperature of the compressor 10 that is reduced by an increase in the liquid backflow rate according to the liquid level of the accumulator 19.

[0066] In the case where the injection is being performed, for example, the discharge temperature of the compressor 10 that is detected by the discharge temperature sensor 43 is lowered in accordance with reduction of the suction enthalpy that is caused by the injection. Therefore, the liquid-level adjustment threshold is obtained by making a calculation for obtaining a discharge temperature according with reduction of the suction enthalpy which is caused by the liquid backflow. Thus, the controller 60 determines as the liquid-level adjustment threshold, a value obtained by adding a value by which the discharge temperature is reduced in the case where refrigerant is added by the injection, to the discharge temperature of the compressor 10 detected by the discharge temperature sensor 43. It should be noted that although the liquid-level adjustment threshold, etc., are determined based on the discharge temperature of the com-

pressor 10, it may be determined based on the degree of discharge superheat, instead of the discharge temperature. Also, the controller 60 may store, for example, a mathematical expression using the discharge temperature or the degree of discharge superheat as a variable, in the storage device 61, instead of the data in the table format. For example, the controller 60 substitutes the discharge temperature or the degree of discharge superheat into the mathematical expression to calculate the liquid-level adjustment threshold.

[0067] The controller 60 determines whether or not the discharge temperature or the degree of discharge superheat of the compressor 10 that has decreased due to the liquid backflow from the accumulator 19 is less than or equal to a predetermined liquid-level adjustment threshold. When determining that the discharge temperature or the degree of discharge superheat is less than or equal to the liquid-level adjustment threshold, the controller 60 adjusts the opening degree of the outdoor-side expansion device 45 to cause the discharge temperature or the degree of discharge superheat to be increased to a higher value than the liquid-level adjustment threshold. For example, when the discharge temperature or the degree of discharge superheat of the compressor 10 decreases, the controller 60 decreases the opening degree of the outdoor-side expansion device 45 to lower the liquid level of the accumulator 19.

[0068] In the air-conditioning apparatus 100 of Embodiment 1, the controller 60 performs the above control to cause the liquid or two-phase refrigerant to stay in part of the main pipe 5 that is located between the load-side expansion device 25 and the outdoor-side expansion device 45. In addition, by reducing the amount of the refrigerant that flows into the accumulator 19, surplus refrigerant is caused not to accumulate in the accumulator 19. Thus, the liquid level of the accumulator 19 can be reduced, and the refrigerant can be prevented from overflowing the accumulator 19. It is therefore possible to reduce the degree of dilution of the refrigerating machine oil that occurs due to the liquid backflow in the compressor 10, prevent the compressor 10 from being damaged, and ensure the reliability of the air-conditioning apparatus 100.

Embodiment 2

[0069] Fig. 6 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 of Embodiment 2 of the present disclosure. Referring to Fig. 6, components denoted by the same reference numerals as those in Fig. 1 operate in the same manner as in Embodiment 1. In the air-conditioning apparatus 100 according to Embodiment 2, a plurality of outdoor units 1 are connected in parallel with each other by pipes, whereby a refrigerant circuit is formed. Referring to Fig. 6, two outdoor units 1 are connected in parallel with each other.

<Outdoor Units 1a and 1b>

[0070] The configurations of the outdoor units 1a and 1b as illustrated in Fig. 6 are the same as that of the outdoor unit 1 as described regarding Embodiment 1. Furthermore, the operations of the outdoor units 1a and 1b in the heating operation mode and the cooling operation mode, the operation in the case where the injection is performed, and other operations are basically the same as those of the outdoor unit 1 as described regarding Embodiment 1. Therefore, in the case where the outdoor units 1a and 1b do not need to be distinguished from each other, and components included in the outdoor units 1a and 1b do not need to be distinguished from each other, in the descriptions concerning them, the suffixes added to the reference signs denoting the components are omitted from the reference signs.

[0071] The outdoor unit 1a includes a compressor 10a, a refrigerant flow switching device 11a, a heat-source-side heat exchanger 12a, an accumulator 19a, an injection pipe 41a, a heat-source-side fan 18a, an outdoor-side expansion device 45a, and an injection expansion device 42a. The compressor 10a, the refrigerant flow switching device 11a, the heat-source-side heat exchanger 12a, the accumulator 19a, and the outdoor-side expansion device 45a are connected by refrigerant pipes 4a in the outdoor unit 1a. The injection pipe 41a and the injection expansion device 42a form an injection flow passage. Furthermore, a discharge temperature sensor 43a, a discharge pressure sensor 40a, an outside-air temperature sensor 46a, and a pressure detection sensor 44a are provided.

[0072] The outdoor unit 1b includes a compressor 10b, a refrigerant flow switching device 11b, a heat-source-side heat exchanger 12b, an accumulator 19b, an injection pipe 41b, a heat-source-side fan 18b, an outdoor-side expansion device 45b, and an injection expansion device 42b. The compressor 10b, the refrigerant flow switching device 11b, the heat-source-side heat exchanger 12b, the accumulator 19b, and the outdoor-side expansion device 45b are connected by refrigerant pipes 4b in the outdoor unit 1b. The injection pipe 41b and the injection expansion device 42b form an injection flow passage. Furthermore, a discharge temperature sensor 43b, a discharge pressure sensor 40b, an outside-air temperature sensor 46b, and a pressure detection sensor 44b are provided.

<Liquid Leveling Control in Heating Operation Mode (Involving No Injection)>

[0073] The air-conditioning apparatus 100 determines the amount of refrigerant to be shut up in the refrigerant circuit, on the assumption that the operation mode is the cooling operation mode. In the heating operation mode, when the air-conditioning apparatus 100 is in a given operation state, the required amount of refrigerant is smaller than that in the cooling operation mode. There-

fore, surplus refrigerant the amount of which corresponds to the difference between the amount of refrigerant in the refrigerant circuit and the amount of refrigerant required in the heating operation mode is accumulated in the accumulator 19.

[0074] It should be noted that for example, the operation capacities of the two outdoor units 1 are different from each other, and the angles at which the main pipes 5 are connected to the outdoor units 1 are also different from each other. Therefore, there is a case where the amounts of surplus refrigerant that stays in the accumulators 19 of the outdoor units 1 are not equal to each other. For example, if a larger amount of surplus refrigerant stays in one of the accumulators 19 than in the other accumulator 19, and exceeds an amount of refrigerant that is allowed to be accumulated in the above one accumulator 19 in the capacity thereof, the refrigerant overflows the accumulator 19. If the refrigerant overflows the accumulator 19, a larger amount of refrigerant is liquid-backed into an associated compressor 10, the refrigerating machine oil is diluted, and the scroll portion of the compressor 10 may be burned out. Therefore, it is necessary to adjust the opening degrees of the outdoor-side expansion devices 45 such that the amount of surplus refrigerant that stays in each of the accumulators 19 becomes less than or equal to the amount of refrigerant that is allowed to be accumulated in each accumulator 19 in capacity.

[0075] Refrigerating machine oil is discharged along with gas refrigerant from the compressor 10, and circulates through the refrigerant circuit. Such refrigerating machine oil is referred to as out-of-system oil. As described above, each accumulator 19 is provided with an oil return mechanism 20 (20a, 20b) that returns out-of-system oil to the compressor 10.

[0076] For example, when the amounts of surplus refrigerant that stays in the accumulators 19 of the outdoor units 1 are not equal to each other, a larger amount of refrigerating machine oil is returned from one of the accumulators 19 that stores a larger amount of surplus refrigerant than the other accumulators 19, to an associated compressor 10, by an associated oil return mechanism 20. In this case, the discharge temperature of the refrigerant in one of the compressors 10 that contains a large amount of refrigerating machine oil than the other compressor 10 is lower than the discharge temperature of the refrigerant in the other compressor 10, which contains a smaller amount of refrigerating machine oil.

[0077] Therefore, on a side where a larger amount of refrigerating machine oil is returned from the above accumulator 19 that stores a larger amount of surplus refrigerant, an associated controller 60 performs a control to reduce the opening degree of an associated outdoor-side expansion device 45. Therefore, the amount of liquid refrigerant that flows into the above accumulator 19 storing a larger amount of surplus refrigerant is reduced.

[0078] By contrast, on a side where a smaller amount of refrigerating machine oil is returned from the other ac-

cumulator 19 that stores a smaller amount of surplus refrigerant, an associated controller 60 performs a control to increase the opening degree of an associated outdoor-side expansion device 45 or maintain the opening degree thereof. Therefore, the amount of liquid refrigerant that flows into the above other accumulator 19 that stores a smaller amount of surplus refrigerant is increased. Because of the above controls, the amounts of refrigerant stored in the accumulators 19 of the two outdoor units 1 are equalized to each other. In such a manner, since the amounts of the refrigerant stored in the accumulators 19 of the two outdoor units 1 are equalized, it is possible to prevent the refrigerant from overflowing the accumulators 19.

(Liquid leveling Control in Case of Performing Injection)

[0079] It will be described how control is performed to equalize the amount of surplus refrigerant that stay in the accumulators 19, while the injection is being performed in the heating operation mode. In such a case, reduction of the discharge temperature of the compressor 10 that is caused by the injection and that of the discharge temperature that is caused by liquid backflow from the accumulator 19 are compared with each other. Then, it is determined which of the amounts of surplus refrigerant that stays in the accumulators 19 is larger.

[0080] The following description is made referring to by way of example the compressor 10a, etc., provided in the outdoor unit 1a. First, when determining that the discharge temperature or degree of discharge superheat of the compressor 10a is higher than a target discharge temperature threshold or a target superheat degree threshold, the controller 60a perform a control to increase the opening degree of the injection expansion device 42a. When the opening degree of the injection expansion device 42a is increased, the discharge temperature of the compressor is reduced.

[0081] At this time, based on the opening degree of the injection expansion device 42a, the pressure of the refrigerant that has not yet passed through the injection expansion device 42a, and the pressure of the refrigerant that has passed through the injection expansion device 42a, it is possible to estimate the flow rate and enthalpy of refrigerant that is injected. Furthermore, the discharge temperature of the compressor 10a in the case where the injection is not performed can be estimated from the discharge pressure and the efficiency of the compressor 10a, such as the driving frequency of the compressor 10a, and the pressure and temperature on the suction side of the compressor 10 in the case where the injection is not performed.

[0082] In the case where the injection is performed, the flow rate and enthalpy of the injected refrigerant and the flow rate and enthalpy of the refrigerant that is sucked into the compressor 10a in the case where the injection is not performed are added together. Because of this addition, the enthalpy of the refrigerant in the compressor

suction chamber can be calculated.

[0083] It should be noted that the refrigerant in the compressor suction chamber has a lower enthalpy and is a higher quality and two-phase refrigerant than in the case where the injection is not performed. The value by which the discharge temperature in the case where refrigerant is added by the injection is reduced can be estimated from the difference between a discharge temperature calculated from the enthalpy state of the refrigerant in the compressor suction chamber and the discharge temperature in the case where the injection is performed.

[0084] Furthermore, when the amount of surplus refrigerant in the accumulator 19a increases, the liquid level rises, and a liquid head that is the pressure of the liquid increases. As a result, the liquid backflow rate from the oil return mechanism 20 increases to a higher value than in the case where the liquid level is low. Therefore, the discharge temperature of the compressor 10a decreases. In such a manner, in the case where the liquid level of the accumulator 19a rises when refrigerant is added by the injection, the above liquid-level adjustment threshold is the discharge temperature of the compressor 10a that is decreased in accordance with an increase in the liquid backflow rate according to the liquid level of the accumulator 19a. The controller 60 adjusts the outdoor-side expansion device 45a in accordance with the estimated liquid level. When determining that the discharge temperature or the degree of discharge superheat of the compressor 10a is lower than the liquid-level adjustment threshold, the controller 60 performs a control to reduce the opening degree of the outdoor-side expansion device 45a. The amount of the refrigerant that flows into the accumulator 19a is reduced, whereby the amount of surplus refrigerant that stays in the accumulator 19a is reduced, and the liquid level is lowered.

[0085] As described above, in the case where the injection is not performed, the liquid-level adjustment threshold is the discharge temperature of the compressor 10 that is decreased in accordance with an increase in the liquid backflow rate according to the liquid level of the accumulator 19. In the case where the injection is performed, the liquid-level adjustment threshold is a value obtained by adding the value by which the discharge temperature in the case where the refrigerant is added by the injection is reduced, to the discharge temperature of the compressor 10 that is detected by the discharge temperature sensor 43.

[0086] The controller 60 controls the opening degree of the outdoor-side expansion device 45 such that the discharge temperature of the compressor 10 becomes higher than the liquid-level adjustment threshold, and the liquid level of the accumulator 19a becomes lower than or equal to the target liquid level.

[0087] Furthermore, in order to simplify the controls of the controllers 60, in the outdoor units 1, the difference between the opening degrees of the injection expansion devices 42 in the outdoor units 1 during the injection for decreasing the discharge temperatures of the compres-

sors 10 may be calculated. The difference between the amounts of surplus refrigerant in the accumulators 19 in the outdoor units 1 is estimated from the difference between the opening degrees of the injection expansion devices 42, and the opening degrees of the outdoor-side expansion devices 45 are adjusted.

[0088] For example, suppose the discharge temperatures of the compressors 10 are substantially equal to each other (for example, ± 1 degrees C), and the temperatures detected by the pressure detection sensors 44 are also substantially equal to each other. At this time, for example, in the case where the opening degree of the injection expansion device 42a is greater than that of the injection expansion device 42b, the amount of liquid backflow from the accumulator 19b is larger than that from the accumulator 19a. It can be therefore determined that the liquid level of the accumulator 19b is high. At this time, in the case where the discharge temperature of the compressor 10b is less than the liquid-level adjustment threshold, the liquid level of the accumulator 19b can be lowered by closing the opening degree of the outdoor-side expansion device 45b.

[0089] In such a case, in the case where one of the injection expansion devices 42 is opened to a greater degree than the other, for example, it is opened to 1/5 or more of its maximum opening degree at which it is fully opened, it is possible to more reliably prevent an erroneous detection which would be caused by variation of the opening degree. Therefore, the controllers 60 can more accurately estimate the difference between the liquid levels of the accumulators 19.

[0090] In Embodiment 2, each of the compressors 10 has a low-pressure shell structure and is configured to cause injected refrigerant to flow into an associated compressor suction chamber. Therefore, even if the amount of injection increases, the injected refrigerant can be made to flow into the scroll portion of the compressor 10. Thus, the liquid or two-phase refrigerant injected to the lower portion of the shell does not stay. Therefore, the refrigerating machine oil is not diluted with the liquid refrigerant. In addition, since the amount of injection can be increased, the opening degree of the outdoor-side expansion device 45a can be increased.

(Control Flowchart)

[0091] Fig. 7 is a diagram illustrating an example of control by each of the controllers 60 in the air-conditioning apparatus 100 of Embodiment 2 of the present disclosure. Fig. 7 illustrates an example of a flowchart related to the liquid leveling control by each controller 60 for the liquid level of an associated accumulator 19 during the injection. The processing operation of each controller 60 in the case where the injection is performed will be described with reference to Fig. 7. It is assumed that the controllers 60 in the outdoor units 1 both perform the processes of steps CT1 to CT7. Also, it is assumed that the process of step CT100 is performed by one of the

controllers 60 in the outdoor units 1 on the basis of data sent from the other controller 60. Furthermore, processes such as determination are performed based on the discharge temperature of each compressors 10; however, the processes may be performed based on the degree of discharge superheat instead of the discharge temperature, after calculation of the degree of discharge superheat.

(Step CT1)

[0092] When receiving an operation request for performing, for example, the cooling operation or the heating operation, from the indoor unit 2, each of the controllers 60 starts the operation of the air-conditioning apparatus 100. Then, the process proceeds to the process of step CT2.

(Step CT2)

[0093] Each controller 60 acquires the discharge temperature of an associated compressor 10 that is detected by an associated discharge temperature sensor 43, and then compares the discharge temperature of the compressor 10 with the discharge temperature threshold. The discharge temperature threshold is, for example, 110 degrees C. When it is determined from the result of the comparison that the discharge temperature of the compressor 10 is lower than or equal to the discharge temperature threshold, the process proceeds to the process of step CT4. It should be noted that the discharge temperature falls within a temperature range (for example, 110 degrees C $\pm$ 1 degree C) that covers the discharge temperature threshold, it is determined that the discharge temperature is equal to the discharge temperature threshold. When it is determined that the discharge temperature of the compressor 10 is higher than the discharge temperature threshold, the process proceeds to the process of step CT3.

(Steps CT3 and CT4)

[0094] Each controller 60 controls the opening degree of an associated injection expansion device 42 such that the discharge temperature of the associated compressor 10 detected by an associated discharge temperature sensor 43 approaches the discharge temperature threshold. For example, when determining that the discharge temperature of the compressor 10 is higher than the discharge temperature threshold, each controller 60 increases the opening degree of the injection expansion device 42 (step CT3). When determining that the discharge temperature of the compressor 10 is lower than the discharge temperature threshold, each controller 60 decreases the opening degree of the injection expansion device 42. When determining that the discharge temperature of the compressor 10 is equal to the discharge temperature threshold, each controller 60 maintains the

opening degree of the injection expansion device 42 (step CT4). After the controller 60 controls the opening degree of the injection expansion device 42, the process proceeds to the process of step CT5.

(Step CT5)

[0095] The controller 60 acquires a medium pressure that is the pressure of the refrigerant that passes through an associated injection pipe 41, which is detected by an associated pressure detection sensor 44, and compares the medium pressure with the medium pressure threshold. For example, in the case where the refrigerant is R410A, the medium pressure threshold is 1.1 MPa. In the process of step CT100, which will be described later, it is determined whether the control to increase the opening degree of an associated outdoor-side expansion device 45 is performed or not. When it is determined from the result of the comparison that the medium pressure is lower than or equal to the medium pressure threshold, or the control to increase the opening degree of the outdoor-side expansion device 45 is not performed, the process proceeds to the process of step CT7. It should be noted that when the medium pressure falls within a pressure range (for example, 1.1 MPa $\pm$ 0.05 MPa) that covers the medium pressure threshold, it is determined that the medium pressure is equal to the medium pressure threshold. When it is determined that the medium pressure is higher than the medium pressure threshold and the control to increase the opening degree of the outdoor-side expansion device 45 is performed, the process proceeds to the process of step CT6.

(Steps CT6 and CT7)

[0096] Each controller 60 controls the opening degree of the outdoor-side expansion device 45 such that the medium pressure detected by the pressure detection sensor 44 approaches the medium pressure threshold. For example, when determining that the medium pressure is higher than the medium pressure threshold and the controller 60 controls the opening degree of the outdoor-side expansion device 45 to be increased, the controller 60 increases the opening degree of the outdoor-side expansion device 45 (step CT6). When determining that the medium pressure is lower than the medium pressure threshold, the controller 60 decreases the opening degree of the outdoor-side expansion device 45. When determining that the discharge temperature of the compressor 10 is equal to the discharge temperature threshold, or the medium pressure is higher than the medium pressure threshold and the controller 60 does not increase the opening degree of the outdoor-side expansion device 45, the controller 60 maintains the opening degree of the injection expansion device 42 (step CT7). When control of the opening degree of the injection expansion device 42 is performed, the process of each controller 60 proceeds to the process of step CT100.

<Step CT100: Liquid Leveling Control for Accumulator 19 of Each Outdoor Unit 1>

[0097] Step CT100 is a step of performing a liquid leveling control to cause the amount of surplus refrigerant that stays in the accumulator 19 in each outdoor unit 1 to be less than or equal to a predetermined amount of surplus refrigerant. It should be noted that in the accumulator 19, the predetermined amount of surplus refrigerant corresponds to, for example, the level of surplus refrigerant that is less than or equal to a liquid level corresponding to 2/3 of the volume of the accumulator 19.

(Step CT101)

[0098] The controllers 60 acquire the discharge temperatures of the compressors 10a and 10b that are detected by the discharge temperature sensors 43a and 43b. Then, the controllers 60 determine whether the discharge temperature of the compressor 10a is lower than the above liquid-level adjustment threshold or not and whether the discharge temperature of the compressor 10b is higher than or equal to the liquid-level adjustment threshold or not. When the controllers 60 determine that the discharge temperature of the compressor 10a is lower than the above liquid-level adjustment threshold and the discharge temperature of the compressor 10b is higher than or equal to the liquid-level adjustment threshold, the process proceeds to step CT102. Otherwise, the process proceeds to the process of step CT103.

(Step CT102)

[0099] The controllers 60 control the opening degrees of the outdoor-side expansion devices 45a and 45b such that the discharge temperatures of the compressors 10a and 10b that are detected by the discharge temperature sensors 43a and 43b approach the liquid-level adjustment threshold. Since the discharge temperature of the compressor 10a is lower than the liquid-level adjustment threshold, the controller 60a decreases the opening degree of the outdoor-side expansion device 45a. Since the discharge temperature of the compressor 10b is higher than or equal to the liquid-level adjustment threshold, the controller 60b increases the opening degree of the outdoor-side expansion device 45b. However, in the case where the discharge temperature of the compressor 10b falls within a temperature range (for example, 100 degrees C $\pm$ 1 degree C) that covers the liquid-level adjustment threshold, the controller 60b assumes that the discharge temperature is equivalent to the liquid-level adjustment threshold, and maintains the opening degree of the outdoor-side expansion device 45b. The process then proceeds to the process of step CT2.

(Step CT103)

[0100] With respect to the discharge temperatures of

the compressors 10 that are detected by the discharge temperature sensors 43, the controllers 60 determine whether or not the discharge temperature of the compressor 10a is higher than or equal to the above liquid-level adjustment threshold and whether or not the discharge temperature of the compressor 10b is lower than the liquid-level adjustment threshold. When the controllers 60 determine that the discharge temperature of the compressor 10a is higher than or equal to the liquid-level adjustment threshold and the discharge temperature of the compressor 10b is lower than the liquid-level adjustment threshold, the process proceeds to the process of step CT104. Otherwise, the process proceeds to the process of step CT105.

(Step CT104)

[0101] Since the discharge temperature of the compressor 10a is higher than or equal to the liquid-level adjustment threshold, the controller 60a increases the opening degree of the outdoor-side expansion device 45a. However, in the case where the discharge temperature of the compressor 10a falls within the temperature range (for example, 100 degrees C $\pm$ 1 degree C) that covers the liquid-level adjustment threshold, the controller 60a assumes that the discharge temperature is equivalent to the liquid-level adjustment threshold, and maintains the opening degree of the outdoor-side expansion device 45a. Furthermore, since the discharge temperature of the compressor 10b is lower than the liquid-level adjustment threshold, the controller 60b decreases the opening degree of the outdoor-side expansion device 45b. The process then proceeds to the process of step CT2.

(Step CT105)

[0102] With respect to the discharge temperatures of the compressor 10a and 10b that are detected by the discharge temperature sensors 43a and 43b, the controllers 60 determine whether the discharge temperatures of the compressor 10a and the compressor 10b are lower than the above liquid-level adjustment threshold or not. When the controllers 60 determine that the discharge temperatures of the compressors 10a and 10b are lower than the liquid-level adjustment threshold, the process proceeds to the process of step CT106. Otherwise, the process proceeds to the process of step CT107.

(Step CT106)

[0103] Since the discharge temperatures of the compressors 10a and 10b are lower than the liquid-level adjustment threshold, the controllers 60a and 60b decrease the opening degrees of the outdoor-side expansion devices 45a and 45b. The process then proceeds to the process of step CT2.

(Step CT107)

[0104] Since the discharge temperatures of the compressors 10a and 10b are higher than or equal to the liquid-level adjustment threshold, the controllers 60a and 60b increase the opening degrees of the outdoor-side expansion devices 45a and 45b. In the case where the discharge temperature of the compressor 10a or 10b falls within the temperature range (for example, 100 degrees C $\pm$ 1 degree C) that covers the liquid-level adjustment threshold, it is determined that the discharge temperature is equivalent to the liquid-level adjustment threshold. In addition, the controller 60a or 60b maintains the opening degree of the outdoor-side expansion device 45a or 45b. The process then proceeds to the process of step CT2.

[0105] It should be noted that although the discharge temperature threshold and the liquid-level adjustment threshold are set at predetermined fixed values, this is not restrictive. For example, the set values may be changed to values according with the compression rate, which is a value obtained by dividing the discharge pressure by the suction pressure, the driving frequency of the compressor 10, and other values, on the basis of, for example, mathematical expressions and data expressed in a table format. By changing the thresholds, it is possible to increase the accuracy of detection of the liquid backflow from the accumulator 19, which depends on the operating state of the compressor 10.

[0106] In step CT100 described above, the magnitudes of the discharge temperature of the compressor 10a, the discharge temperature of the compressor 10b, and the liquid-level adjustment threshold were combined into four patterns, and the opening degrees of the outdoor-side expansion devices 45a and 45b are controlled. When the opening degrees of the outdoor-side expansion devices 45 are controlled based on such combinations as described above regarding step CT100, even in the case where the amounts of liquid refrigerant in the accumulators 19 are unbalanced, though the discharge temperature of each compressor 10 does not exceed the liquid-level adjustment threshold, the refrigerant can be distributed in such a manner to achieve liquid leveling. It is therefore possible to reduce the risk of the overflow of the refrigerant from the accumulators 19. However, the control is not limited to the above control. For example, the opening degree of the outdoor-side expansion device 45a may be controlled based on the comparison between the discharge temperature of the compressor 10a and the liquid-level adjustment threshold, and the opening degree of the outdoor-side expansion device 45b may be controlled based on the comparison between the discharge temperature of the compressor 10b and the liquid-level adjustment threshold. That is, the opening degrees of the outdoor-side expansion devices 45a and 45b may be controlled independently of each other.

[0107] In addition, although the above description is made by referring to by way of example the configuration of the air-conditioning apparatus 100 in which two out-

door units 1 are connected in parallel, also in the case where three or more outdoor units 1 are connected, it is possible to obtain the same advantages as in the above example.

[0108] As described above, according to Embodiment 2, by performing the injection, the controllers 60 can adjust the levels of the refrigerant in the accumulators 19 in the plurality of outdoor units 1, while maintaining a high performance. Therefore, while maintaining the comfortability for the user, it is possible to control the liquid levels of the accumulators 19 and prevent liquid backflow to the compressors 1 by preventing overflow from the accumulators 19. Thus, it is possible to prevent the compressors 10 from being damaged, and ensure the reliability of the entire air-conditioning apparatus 100.

Embodiment 3

[0109] Fig. 8 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 3 of the present disclosure. An air-conditioning apparatus according to Embodiment 3 of the present disclosure will be described. It should be noted that regarding Embodiment 3, components that have the same functions and the same advantages as those in Embodiments 1 and 2 will be denoted by the same reference signs.

[0110] As illustrated in Fig. 8, the air-conditioning apparatus 100 includes two outdoor units 1 (1a and 1b) that are heat source apparatuses, a plurality of indoor units 2 (2a, 2b, 2c and 2d), and a relay unit 3 that is provided between the outdoor units 1 and the indoor units 2a to 2d and includes an opening/closing device. The outdoor units 1 and the relay unit 3 are connected by a plurality of main pipes 5 that allow refrigerant to flow therethrough. The relay unit 3 and each of the indoor units 2a to 2d are connected by a plurality of branch pipes 8 that allow refrigerant to flow therethrough. The cooling energy or heating energy generated by each of the outdoor units 1 is supplied to the indoor units 2a to 2d through the relay unit 3.

[0111] To be more specific, in Embodiment 3, each of the outdoor units 1 and the relay unit 3 are connected by two main pipes 5, and the relay unit 3 and each of the indoor units 2a to 2d are connected by two branch pipes 8. In such a manner, since each of the outdoor units 1 and the relay unit 3 are connected by two pipe; and likewise, the relay unit 3 and each of the indoor units 2a to 2d are connected by two pipes, the air-conditioning apparatus 100 can be easily installed.

<Outdoor Unit 1>

[0112] As in Embodiment 1, the outdoor units 1 each include a compressor 10, a refrigerant flow switching device 11, a heat-source-side heat exchanger 12, a heat-source-side fan 18, and an accumulator 19. Also, each outdoor unit 1 includes an outdoor-side expansion device

45, an injection expansion device 42, an outdoor-side expansion device 45, an injection pipe 41, etc.

[0113] Also, each outdoor unit 1 of Embodiment 3 further includes a first connection pipe 6, a second connection pipe 7, and first backflow prevention devices 13, 14, 15 and 16. It should be noted that check valves are used as the first backflow prevention devices 13 to 16. The first backflow prevention device 13 prevents high-temperature, high-pressure gas refrigerant from flowing back from the first connection pipe 6 to the heat-source-side heat exchanger 12 in either the heating only operation mode or the heating main operation mode. The first backflow prevention device 14 prevents high-pressure liquid refrigerant or two-phase gas-liquid refrigerant from flowing back from the first connection pipe 6 to the accumulator 19 in either the cooling only operation mode or the cooling main operation mode. The first backflow prevention device 15 prevents high-pressure liquid refrigerant or two-phase gas-liquid refrigerant from flowing back from the second connection pipe 7 to the accumulator 19 in either the cooling only operation mode or the cooling main operation mode. The first backflow prevention device 16 prevents high-temperature, high-pressure gas refrigerant from flowing back from the flow passage on the discharge side of the compressor 10 to the second connection pipe 7 in either the heating only operation mode or the heating main operation mode.

[0114] In such a manner, because of provision of the first connection pipe 6, the second connection pipe 7, and the first backflow prevention devices 13 to 16, the flow direction of refrigerant that flows into the relay unit 3 can be set to a certain direction regardless of what operation is requested by each of the indoor units 2. It should be noted that although it is described above that check valves are used as the first backflow prevention devices 13 to 16, this is not restrictive. That is, the first backflow prevention devices 13 to 16 may be configured in any manner as long as they are made capable of preventing backflow of the refrigerant. For example, opening/closing devices or expansion devices having a fully closing function can be used as the first backflow prevention devices 13 to 16.

[0115] It should be noted that in the air-conditioning apparatus 100 of Embodiment 3, in either the heating only operation mode or the heating main operation mode, the refrigerant can pass through the injection expansion device 42 and the outdoor-side expansion device 45. Therefore, the injection, etc., are performed in neither the cooling only operation mode nor the cooling main operation mode.

<Indoor Units 2a to 2d>

[0116] The plurality of indoor units 2a to 2d have, for example, the same configuration. The indoor units 2a to 2d include load-side heat exchangers 26a, 26b, 26c, and 26d, and load-side expansion devices 25a, 25b, 25c, and 25d, respectively. Each of the load-side heat exchangers

26a to 26d is connected to the outdoor units 1 by branch pipes 8, the relay unit 3, and the main pipes 5. At each of the load-side heat exchangers 26a to 26d, heating air or cooling air to be supplied to an indoor space is generated through heat exchange between the refrigerant and air supplied by a load-side fan not illustrated. For example, the opening degrees of the load-side expansion devices 25a to 25d can be variably adjusted continuously or in multiple stages. As the load-side expansion devices 25a to 25d, for example, electronic expansion valves are used. The load-side expansion devices 25a to 25d each serve as a pressure reducing valve and an expansion valve, and reduce the pressure of the refrigerant to expand the refrigerant. The load-side expansion devices 25a to 25d are located upstream of the load-side heat exchangers 26a to 26d, respectively, in the flow of the refrigerant flow in the cooling operation mode (for example, the cooling only operation mode).

[0117] The indoor units 2 include inflow-side temperature sensors 31a to 31d that detect the temperatures of the refrigerant that flows into the load-side heat exchangers 26a to 26d, respectively. Also, the indoor units 2 include outflow-side temperature sensors 32a to 32d that detect the temperatures of the refrigerant that flows out of the load-side heat exchangers 26a to 26d, respectively. The inflow-side temperature sensors 31a to 31d and the outflow-side temperature sensors 32a to 32d are each, for example, a thermistor. The inflow-side temperature sensors 31a to 31d and the outflow-side temperature sensors 32a to 32d each output a detection signal to the controllers 60.

[0118] Although Fig. 8 illustrates four indoor units 2a to 2d, the number of indoor units may be two, three, or five or more.

<Relay unit 3>

[0119] The relay unit 3 includes a gas-liquid separator 29, a first relay-unit expansion device 30, and a second relay-unit expansion device 27. Also, the relay unit 3 includes a plurality of first opening/closing devices 23a to 23d, a plurality of second opening/closing devices 24a to 24d, second backflow prevention devices 21a to 21d (for example, check valves), and third backflow prevention devices 22a to 22d (for example, check valves).

[0120] The gas-liquid separator 29 separates high-pressure two-phase gas-liquid refrigerant obtained by the outdoor units 1 into liquid refrigerant and gas refrigerant, in a cooling and heating mixed operation mode in which a cooling load is great. The gas-liquid separator 29 causes the liquid refrigerant to flow into a pipe located on a lower side of the figure, and supplies cooling energy to one or more of the indoor units 2; and also causes the liquid refrigerant to flow into a pipe located on an upper side of the figure, and supplies heating energy to one of more of the other indoor units 2. The gas-liquid separator 29 is provided at an inlet portion of the relay unit 3 in the flow of the refrigerant.

[0121] The first relay-unit expansion device 30 serves as a pressure reducing valve and an open/close valve. The first relay-unit expansion device 30 reduces and adjusts the pressure of liquid refrigerant to a predetermined pressure, and opens and closes the flow passage for the liquid refrigerant. For example, the opening degree of the first relay-unit expansion device 30 can be variably adjusted continuously or in multiple stages. As the first relay-unit expansion device 30, for example, an electronic expansion valve is used. The first relay-unit expansion device 30 is provided at a pipe through which the liquid refrigerant flows out of the gas-liquid separator 29.

[0122] The second relay-unit expansion device 27 serves as a pressure reducing valve and an open/close valve. The second relay-unit expansion device 27 opens and closes the refrigerant flow passage in the heating only operation mode, and adjusts a bypass liquid flow rate in accordance with an indoor-side load in the heating main operation mode. For example, the opening degree of the second relay-unit expansion device 27 can be variably adjusted continuously or in multiple stages. As the second relay-unit expansion device 27, for example, an electronic expansion valve is used.

[0123] The plurality of first opening/closing devices 23a to 23d are provided for the plurality of indoor units 2a to 2d (four indoor units in this case), respectively. The first opening/closing devices 23a to 23d open and close respective flow passages for high-temperature, high-pressure gas refrigerant that are supplied to the indoor units 2a to 2d, respectively. The first opening/closing devices 23a to 23d are, for example, solenoid valves. The first opening/closing devices 23a to 23d are connected to a gas-side pipe extending from the gas-liquid separator 29. The first opening/closing devices 23a to 23d have only to be capable of opening and closing the respective flow passages, and may be expansion devices having a fully closing function.

[0124] The plurality of second opening/closing devices 24a to 24d are provided for the plurality of indoor units 2a to 2d (for indoor units in this case), respectively. The second opening/closing devices 24a and 24d open and close respective flow passages for low-pressure, low-temperature gas refrigerant that has flowed out of the indoor units 2a to 2d, respectively. The second opening/closing devices 24a to 24d are, for example, solenoid valves. The second opening/closing devices 24a to 24d are connected to respective low-pressure pipes that communicate with an outlet side of the relay unit 3. The second opening/closing devices 24a to 24d have only to be capable of opening and closing the respective flow passages, and may be expansion devices having a fully closing function.

[0125] The plurality of second backflow prevention devices 21a to 21d are provided for the plurality of indoor units 2a to 2d (four indoor units in Embodiment 3), respectively. The second backflow prevention devices 21a to 21d each cause high-pressure liquid refrigerant to flow into an associated one of the indoor units 2 when the

associated indoor unit 2 is in the cooling operation, and are connected to respective pipes on the outlet side of the first relay-unit expansion device 30. In the cooling main operation mode and the heating main operation mode, the medium-temperature, medium-pressure liquid or the two-phase gas-liquid refrigerant which flows from the load-side expansion device or devices 25 of the indoor unit or units 2 being in the heating operation and for which the degree of supercooling is not sufficiently secured can be prevented from flowing into the load-side expansion device or devices 25 of the indoor unit or units 2 being in the cooling operation. In Embodiment 3, check valves are used as the second backflow prevention devices 21a to 21d, but this is not restrictive. That is, the second backflow prevention devices 21a to 21d may be configured in any manner as long as they are made capable of preventing refrigerant backflow. For example, opening/closing devices or expansion devices having a fully closing function can be used as the second backflow prevention devices 21a to 21d.

[0126] The plurality of third backflow prevention devices 22a to 22d are provided for the plurality of indoor units 2a to 2d (four indoor units), respectively. Each of the third backflow prevention devices 22a to 22d causes high-pressure liquid refrigerant to flow into an associated one of the indoor units 2 in the case where the associated indoor unit 2 is in the cooling operation, and are connected to a pipe located on the outlet side of the first relay-unit expansion device 30. In the cooling main operation mode and the heating main operation mode, each of the third backflow prevention devices 22a to 22d prevents the medium-temperature, medium-pressure liquid or the two-phase refrigerant which flows from the first relay-unit expansion device 30 and the degree of supercooling of which is not sufficiently secured, from flowing into the load-side expansion device 25 of an associated one of the indoor units 2 in the case where the associated indoor unit is in the cooling operation. In Embodiment 3, check valves are used as the third backflow prevention devices 22a to 22d, but the third backflow prevention devices 22a to 22d may be configured in any manner as long as they are made capable of preventing refrigerant backflow. For example, opening/closing devices or expansion devices having a fully closing function can be used as the third backflow prevention devices 22a to 22d.

[0127] Furthermore, an expansion-device inlet-side pressure sensor 33 is provided on an inlet side of the first relay-unit expansion device 30 in the relay unit 3. The expansion-device inlet-side pressure sensor 33 detects the pressure of high-pressure refrigerant. On an outlet side of the first relay-unit expansion device 30, an expansion-device outlet-side pressure sensor 34 is provided. The expansion-device outlet-side pressure sensor 34 detects the medium pressure of liquid refrigerant on the outlet side of the first relay-unit expansion device 30 in the cooling main operation mode.

[0128] Also in the air-conditioning apparatus 100 as illustrated in Fig. 8, the controllers 60 (60a and 60b) con-

trol the operation of the overall air-conditioning apparatus 100 based on detection signals sent from various sensors and instructions from the remote control unit. For example, the controllers 60 control the driving frequencies of the compressors 10, and control the rotation speeds of the heat-source-side fans 18 and the load-side fans (including ON/OFF control). Furthermore, the controllers 60 control switching of respective flow passages to be set by the refrigerant flow switching devices 11, the opening degrees of the injection expansion devices 42, the opening degrees of the outdoor-side expansion devices 45, or opening and closing thereof. Also, the controllers 60 control the opening degrees of the load-side expansion devices 25, opening and closing of the first opening/closing devices 23a to 23d, opening and closing of the second opening/closing devices 24a to 24d, opening and closing of the first relay-unit expansion device 30, and opening and closing of the second relay-unit expansion device 27. Because of these controls, the controllers 60 cause the indoor units to enter any of the operation modes. It should be noted that the controllers 60 are provided in the outdoor units 1; however, the controllers 60 may be provided in the indoor units 2a to 2d or may be provided in the relay unit 3. Alternatively, in the above units (for example, the outdoor units 1, the indoor units 2a to 2d, and the relay unit 3), respective controllers 60 may be provided. In addition, the functions of the plurality of controllers 60 may be combined such that processes related to, for example, liquid backflow prevention are carried out using the combined functions.

[0129] Each of the operation modes of the air-conditioning apparatus 100 will be described. The controllers 60 of the air-conditioning apparatus 100 can cause the indoor units 2a to 2d to individually perform the cooling operation or the heating operation in response to instructions from the indoor units 2a to 2d, respectively. In other words, the air-conditioning apparatus 100 can cause all the indoor units 2a to 2d to perform the same operation (cooling operation or heating operation), and also cause the indoor units 2a to 2d to perform different operations.

[0130] The operation modes of the air-conditioning apparatus 100 are roughly classified into the cooling operation mode and the heating operation mode. The cooling operation mode includes the cooling only operation mode and the cooling main operation mode. The cooling only operation mode is an operation mode in which ones of the indoor units 2a to 2d that are not in the stopped state all perform the cooling operation. In other words, in the cooling only operation mode, the ones of the load-side heat exchangers 26a to 26d that are not in the stopped state all operate as evaporators. The cooling main operation mode is a cooling and heating mixed operation mode in which one or more of the indoor units 2a to 2d perform the cooling operation and the other or others of the indoor units 2a to 2d perform the heating operation, and the cooling load is greater than the heating load. In other words, in the cooling main operation mode, the one or more of the load-side heat exchangers 26a to 26d

operate as evaporators, and the other or others of the load-side heat exchangers 26a to 26d operate as condensers.

[0131] The heating operation mode includes the heating only operation mode and the heating main operation mode. The heating only operation mode is an operation mode in which ones of the indoor units 2a to 2d that are not in the stopped state all perform the heating operation. In other words, in the heating only operation mode, the one or more of the load-side heat exchangers 26a to 26d that are not in the stopped state all operate as condensers. The heating main operation mode is a cooling and heating mixed operation mode in which one or more of the indoor units 2a to 2d perform the cooling operation and the other or others of the indoor units 2a to 2d perform the heating operation, and the heating load is greater than the cooling load. Each of the operation modes will be described as follows.

<Cooling Operation Mode>

[0132] Fig. 9 is a diagram for explaining the flow of refrigerant in the cooling only operation mode of the air-conditioning apparatus 100 of Embodiment 3. In Fig. 9, the flow directions of refrigerant are indicated by solid arrows. In the following, it is assumed that a cooling load is applied only to the load-side heat exchanger 26a and the load-side heat exchanger 26b. In the cooling only operation mode, the controllers 60 each cause the refrigerant flow switching device 11 of an associated outdoor unit 1 to allow the refrigerant discharged from an associated compressor 10 to flow into an associated heat-source-side heat exchanger 12.

[0133] First, low-temperature, low-pressure refrigerant is compressed by the compressor 10 into high-temperature, high-pressure gas refrigerant, and the high-temperature, high-pressure gas refrigerant is then discharged. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flow into the heat-source-side heat exchanger 12 via the refrigerant flow switching device 11. At the heat-source-side heat exchanger 12, the high-temperature, high-pressure gas refrigerant change into high-pressure liquid refrigerant while transferring heat to outdoor air at the heat-source-side heat exchanger 12. The high-pressure liquid refrigerant that has flowed out of the heat-source-side heat exchanger 12 flows out of the outdoor unit 1 through the first backflow prevention device 13, and then flows into the relay unit 3 through the main pipes 5.

[0134] The high-pressure liquid refrigerant that has flowed into the relay unit 3 passes through the gas-liquid separator 29 and the first relay-unit expansion device 30, and most of the high-pressure liquid refrigerant passes through the second backflow prevention devices 21a and 21b and the branch pipes 8, is expanded by the load-side expansion devices 25, and changes into low-temperature, low-pressure two-phase gas-liquid refrigerant. The other part of the high-pressure refrigerant is expand-

ed by the second relay-unit expansion device 27 and changes into low-temperature, low-pressure gas refrigerant or two-phase gas-liquid refrigerant. Then, the refrigerant flows into the low-pressure pipe on the outlet side of the relay unit 3. At this time, the opening degree of the second relay-unit expansion device 27 is controlled such that the subcooling (the degree of subcooling) of the refrigerant becomes constant.

[0135] The two-phase gas-liquid refrigerant that has been expanded by the load-side expansion devices 25a and 25b flows into the load-side heat exchangers 26a and 26b, which operate as evaporators, respectively, and removes heat from indoor air, thereby changing into low-temperature, low-pressure gas refrigerant while cooling the indoor air. At this time, the opening degree of the load-side expansion device 25a is controlled such that the superheat (the degree of superheat) obtained as the difference between a temperature detected by the inflow-side temperature sensor 31a and a temperature detected by the outflow-side temperature sensor 32a becomes constant. Similarly, the opening degree of the load-side expansion device 25b is controlled such that the superheat obtained as the difference between a temperature detected by the inflow-side temperature sensor 31b and a temperature detected by the outflow-side temperature sensor 32b becomes constant.

[0136] The gas refrigerant that has flowed out of the load-side heat exchangers 26a and 26b flows out of the relay unit 3 through the branch pipes 8 and the second opening/closing devices 24a and 24b. The refrigerant that has flowed out of the relay unit 3 passes through the main pipes 5 and re-flows into the outdoor units 1. The refrigerant that has flowed into the outdoor units 1 passes through the first backflow prevention devices 16 and is re-sucked by the compressors 10 through the refrigerant flow switching devices 11 and the accumulators 19.

[0137] It should be noted that it is not necessary to cause refrigerant to flow in the load-side heat exchangers 26c and 26d to which no heating load is applied, and the load-side expansion devices 25c and 25d, which are associated with the load-side heat exchangers 26c and 26d, respectively, are thus closed. In the case where a cooling load is applied to the load-side heat exchanger 26c or 26d, the load-side expansion device 25c or 25d is opened and the refrigerant thus circulates. At this time, the opening degree of the load-side expansion device 25c or 25d is controlled as in the load-side expansion device 25a or 25b. At this time, the superheat (the degree of superheat) obtained as the difference between a temperature detected by the inflow-side temperature sensor 31c or 31d and a temperature detected by the outflow-side temperature sensor 32c or 32d is made constant.

<Cooling Operation Mode>

[0138] Fig. 10 is a diagram for explaining the flow of refrigerant in the cooling main operation mode of the air-conditioning apparatus 100 of Embodiment 3. In Fig. 10,

the flow directions of the refrigerant are indicated by solid arrows. It is assumed that a cooling load is applied only to the load-side heat exchanger 26a, and a heating load is applied only to the load-side heat exchanger 26b. In the cooling main operation mode, each of the controllers 60 causes an associated refrigerant flow switching device 11 to switch the flow passage to a flow passage in which the refrigerant discharged from an associated compressor 10 flows into an associated heat-source-side heat exchanger 12.

[0139] First, low-temperature, low-pressure refrigerant is compressed by the compressor 10 into high-temperature, high-pressure gas refrigerant, and the high-temperature, high-pressure gas refrigerant is then discharged from the compressor 10. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows into the heat-source-side heat exchanger 12 via the refrigerant flow switching device 11. Then, in the heat-source-side heat exchanger 12, the high-temperature, high-pressure gas refrigerant changes into two-phase gas-liquid refrigerant while transferring heat outdoor air in the heat-source-side heat exchanger 12. The refrigerant flows out of the heat-source-side heat exchanger 12, and then flows into the relay unit 3 through the first backflow prevention device 13 and the main pipes 5.

[0140] The two-phase gas-liquid refrigerant that has flowed into the relay unit 3 is separated into high-pressure gas refrigerant and high-pressure liquid refrigerant by the gas-liquid separator 29. The high-pressure gas refrigerant flows through the first opening/closing device 23b and the branch pipes 8, and then flows into the load-side heat exchanger 26b that operates as a condenser. The high-pressure gas refrigerant transfers heat to the indoor air and thus changes into liquid refrigerant while heating the indoor air. At this time, the opening degree of the load-side expansion device 25b is controlled such that the subcooling (the degree of subcooling) obtained as the difference between a saturated temperature into which a pressure detected by the expansion-device inlet-side pressure sensor 33 is converted and a temperature detected by the inflow-side temperature sensor 31b becomes constant. After flowing out of the load-side heat exchanger 26b, the liquid refrigerant is then expanded by the load-side expansion device 25b, and flows through the branch pipes 8 and the third backflow prevention device 22b.

[0141] Thereafter, the liquid refrigerant separated by the gas-liquid separator 29 is expanded by the first relay-unit expansion device 30 such that its pressure reaches a medium pressure and thus changes into medium-pressure liquid refrigerant. The medium-pressure liquid refrigerant joins the liquid refrigerant that has passed through the third backflow prevention device 22b. At this time, the opening degree of the first relay-unit expansion device 30 is controlled such that the difference between a pressure detected by the expansion-device inlet-side pressure sensor 33 and a pressure detected by the ex-

pansion-device outlet-side pressure sensor 34 reaches a predetermined difference (for example, 0.3MPa).

[0142] Most of the liquid refrigerant obtained by the above joining passes through the second backflow prevention device 21a and the branch pipes 8, is expanded by the load-side expansion device 25a, and changes into low-temperature, low-pressure two-phase gas-liquid refrigerant. The other part of the liquid refrigerant is expanded by the second relay-unit expansion device 27 and changes into low-temperature, low-pressure gas refrigerant or two-phase gas-liquid refrigerant. At this time, the opening degree of the second relay-unit expansion device 27 is controlled such that the subcooling (the degree of subcooling) of the refrigerant becomes constant. Then, the refrigerant flows into the low-pressure pipe on the outlet side of the relay unit 3.

[0143] On the other hand, the high-pressure liquid refrigerant separated by the gas-liquid separator 29 flows into the indoor unit 2a through the second backflow prevention device 21a. After expanded by the load-side expansion device 25a of the indoor unit 2a, the two-phase gas-liquid refrigerant flows into the load-side heat exchanger 26a, which operates as an evaporator, and removes heat from indoor air, thereby changing into low-temperature, low-pressure gas refrigerant while cooling the indoor air. At this time, the opening degree of the load-side expansion device 25a is controlled such that the superheat (the degree of superheat) obtained as the difference between a temperature detected by the inflow-side temperature sensor 31a and a temperature detected by the outflow-side temperature sensor 32b becomes constant. After flowing out of the load-side heat exchanger 26a, the gas refrigerant flows out of the relay unit 3 through the branch pipes 8 and the second opening/closing device 24a. The refrigerant that has flowed out of the relay unit 3 passes through the main pipes 5 and re-flows into the outdoor units 1. The refrigerant that has flowed into the outdoor units 1 passes through the first backflow prevention devices 16 and is re-sucked by the compressors 10 through the refrigerant flow switching devices 11 and the accumulators 19.

[0144] It should be noted that in the load-side heat exchangers 26c and 26d to which no heating load is applied, it is not necessary to cause the refrigerant to flow into the load-side heat exchangers 26c and 26d, and the load-side expansion devices 25c and 25d, are closed. In the case where a cooling load is applied to the load-side heat exchanger 26c or 26d, the load-side expansion device 25c or 25d is opened to allow the refrigerant to circulate. At this time, the opening degree of the load-side expansion device 25c or 25d is controlled such that the superheat (degree of superheat) becomes constant, as in the load-side expansion device 25a or the load-side expansion device 25b. Superheat is the difference between a temperature detected by the inflow-side temperature sensor 31c and a temperature detected by the outflow-side temperature sensor 32c and the difference between a temperature detected by the inflow-side temperature

sensor 31d and a temperature detected by the outflow-side temperature sensor 32d.

[0145] In the cooling main operation mode of the air-conditioning apparatus 100 of Embodiment 3, for example, in one of the outdoor units 1, the heat-source-side heat exchanger 12 may operate as an evaporator. In this outdoor unit 1, the operations of components, etc. in the case where the injection, the liquid backflow prevention, and the liquid leveling control are performed are the same as those of Embodiments 1 and 2.

<Heating Operation Mode>

[0146] Fig. 11 is a diagram for explaining the flow of refrigerant in the heating only operation mode of the air-conditioning apparatus 100 of Embodiment 3. In Fig. 11, the flow directions of the refrigerant are indicated by solid arrows. In the following, it is assumed that a heating load is applied only to the load-side heat exchangers 26a and 26b. In the heating only operation mode, each of the controllers 60 causes the associated refrigerant flow switching device 11 to switch the flow passage to a flow passage in which heat-source-side refrigerant discharged from the associated compressor 10 flows into the relay unit 3 without passing through the associated heat-source-side heat exchanger 12.

[0147] First, low-temperature, low-pressure refrigerant is compressed by the compressor 10 into high-temperature, high-pressure gas refrigerant, and the high-temperature, high-pressure gas refrigerant is then discharged from the compressor 10. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant flow switching device 11 and the first backflow prevention device 14. The high-temperature, high-pressure gas refrigerant that has flowed out of the outdoor unit 1 flows into the relay unit 3 through the main pipe 5.

[0148] The high-temperature, high-pressure gas refrigerant that has flowed into the relay unit 3 flows through the gas-liquid separator 29, the first opening/closing devices 23a and 23b, and the branch pipes 8, and then flows into the load-side heat exchangers 26a and 26b that operate as condensers. The refrigerant that has flowed into the load-side heat exchangers 26a and 26b transfers heat to the indoor air and thus changes into liquid refrigerant while heating the indoor air. After flowing out of the load-side heat exchangers 26a and 26b, the liquid refrigerant is expanded by the load-side expansion devices 25a and 25b. The refrigerant then re-flows into the outdoor units 1 through the branch pipes 8, the third backflow prevention devices 22a and 22b, the second relay-unit expansion device 27 that is controlled to be opened, and the main pipes 5. At this time, the opening degree of the load-side expansion device 25a is controlled such that subcooling (the degree of subcooling) obtained as the difference between a saturated temperature into which a pressure detected by the expansion-device inlet-side pressure sensor 33 is converted and a temper-

ature detected by the inflow-side temperature sensor 31a becomes constant. Similarly, the opening degree of the load-side expansion device 25b is controlled such that subcooling (the degree of subcooling) obtained as the difference between a saturated temperature into which a pressure detected by the expansion-device inlet-side pressure sensor 33 is converted and a temperature detected by the inflow-side temperature sensor 31b becomes constant.

[0149] The refrigerant that has flowed into each of the outdoor units 1 passes through the first backflow prevention device 15 and changes into low-temperature, low-pressure gas refrigerant while removing heat from the outdoor air in the heat-source-side heat exchanger 12, and is re-sucked into the compressor 10 through the refrigerant flow switching device 11 and the accumulator 19.

[0150] It should be noted that in the load-side heat exchangers 26c and 26d to which no heating load is applied, the refrigerant does not need to be made to flow in the load-side heat exchangers 26c and 26d, and the load-side expansion devices 25c and 25d are thus in the closed state. When a cooling load is applied to the load-side heat exchanger 26c or 26d, the load-side expansion device 25c or 25d is opened to allow the refrigerant to circulate. At this time, the opening degree of the load-side expansion device 25c or 25d, as well as that of the load-side expansion device 25a or 25b, is controlled such that the superheat (degree of superheat) becomes constant. Superheat is obtained as the difference between a temperature detected by the inflow-side temperature sensor 31c and a temperature detected by the outflow-side temperature sensor 32c and the difference between a temperature detected by the inflow-side temperature sensor 31d and a temperature detected by the outflow-side temperature sensor 32d.

[0151] In the air-conditioning apparatus 100 of Embodiment 3, the operations of components and the control by the controllers 60 in the case where the injection, the liquid backflow prevention and the liquid leveling control are performed in the heating main operation mode are the same as those of Embodiments 1 and 2.

<Heating Main Operation Mode>

[0152] Fig. 12 is a diagram for explaining the flow of refrigerant in the heating main operation mode of the air-conditioning apparatus 100 of Embodiment 3. In Fig. 12, the flow directions of the refrigerant are indicated by solid arrows. In the following, it is assumed that a cooling load is applied only to the load-side heat exchanger 26a, and a heating load is applied only to the load-side heat exchanger 26b. In the heating main operation mode, each of the controllers 60 causes the associated refrigerant flow switching device 11 to switch the flow passage to a flow passage in which the heat-source-side refrigerant discharged from the associated compressor 10 flows into the relay unit 3 without passing through the associated

heat-source-side heat exchanger 12.

[0153] The low-temperature, low-pressure refrigerant is compressed by the compressor 10 into high-temperature, high-pressure gas refrigerant, and the high-temperature, high-pressure gas refrigerant is discharged. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant flow switching device 11 and the first backflow prevention device 14. The high-temperature, high-pressure gas refrigerant that has flowed out of the outdoor unit 1 flows into the relay unit 3 through the main pipe 5.

[0154] The high-temperature, high-pressure gas refrigerant that has flowed into the relay unit 3 flows through the gas-liquid separator 29, the first opening/closing device 23b, and the branch pipe 8, and then flows into the load-side heat exchanger 26b that operates as a condenser. The refrigerant that has flowed into the load-side heat exchanger 26b transfers heat to the indoor air and thus changes into liquid refrigerant while heating the indoor air. After flowing out of the load-side heat exchanger 26b, the liquid refrigerant is expanded by the load-side expansion device 25b, and passes through the branch pipe 8 and the third backflow prevention device 22b. Subsequently, most of the liquid refrigerant passes through the second backflow prevention device 21a and the branch pipe 8, is then expanded by the load-side expansion device 25a, and changes into low-temperature, low-pressure two-phase gas-liquid refrigerant. The other part of the liquid refrigerant is expanded by the second relay-unit expansion device 27, which is also used as a bypass, and changes into medium-temperature, medium-pressure liquid or two-phase gas-liquid refrigerant. This liquid or two-phase gas-liquid refrigerant flows into the low-pressure pipe on the outlet side of the relay unit 3.

[0155] The two-phase gas-liquid refrigerant that has been expanded by the load-side expansion device 25a flows into the load-side heat exchanger 26a, which operates as an evaporator, and removes heat from the indoor air, thereby changing into low-temperature, medium-pressure two-phase gas-liquid refrigerant while cooling the indoor air. After flowing out of the load-side heat exchanger 26a, the two-phase gas-liquid refrigerant flows out of the relay unit 3 through the branch pipe 8 and the second opening/closing device 24a. The refrigerant that has flowed out of the relay unit 3 passes through the main pipes 5 and re-flows into the outdoor units 1. The refrigerant that has flowed into each of the outdoor units 1 passes through the associated first backflow prevention device 15, and changes into low-temperature, low-pressure gas refrigerant while removing heat from the outdoor air in the associated heat-source-side heat exchanger 12. This gas refrigerant is re-sucked into the associated compressor 10 through the associated refrigerant flow switching device 11 and accumulator 19.

[0156] At this time, the opening degree of the load-side expansion device 25b is controlled such that subcooling (the degree of subcooling) obtained as the difference be-

tween a saturated temperature into which a pressure detected by the expansion-device inlet-side pressure sensor 33 is converted and a temperature detected by the inflow-side temperature sensor 31b becomes constant. Also, the opening degree of the load-side expansion device 25a is controlled such that superheat (the degree of superheat) obtained as the difference between a temperature detected by the inflow-side temperature sensor 31a and a temperature detected by the outflow-side temperature sensor 32b becomes constant.

[0157] At this time, the opening degree of the second relay-unit expansion device 27 is controlled such that the subcooling (the degree of subcooling) of the refrigerant becomes constant. For example, the opening degree of the second relay-unit expansion device 27 is controlled such that the difference between a pressure detected by the pressure detected by the expansion-device inlet-side pressure sensor 33 and a pressure detected by the expansion-device outlet-side pressure sensor 34 is equalized to a predetermined difference (for example, 0.3 MPa).

[0158] It should be noted that in the load-side heat exchangers 26c and 26d to which no heating load is applied, the refrigerant does not need to be made to flow in the load-side heat exchangers 26c and 26d, and the load-side expansion devices 25c and 25d are thus in the closed state. In the case where a heating load is applied to the load-side heat exchanger 26c or 26d, the load-side expansion device 25c or 25d is opened to allow the refrigerant to circulate.

[0159] In the air-conditioning apparatus 100 of Embodiment 3, the operations of components and the control by the controllers 60 in the case where the injection, the liquid backflow prevention, and the liquid leveling control are performed in the heating main operation mode are the same as those of Embodiments 1 and 2.

[0160] As described above, in the air-conditioning apparatus 100 of Embodiment 3 in which a plurality of outdoor units 1 (1a and 1b) are connected in parallel such that a simultaneous operation of cooling and heating can be performed, excessive liquid backflow can be prevented by injection and liquid leveling control as in Embodiments 1 and 2.

Embodiment 4

[0161] Fig. 13 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 of Embodiment 4 of the present disclosure. In the air-conditioning apparatus 100 as illustrated in Fig. 13, the outdoor units 1 and the relay unit 3 are connected by main pipes 5 that allow the refrigerant to flow through the load-side heat exchangers 26a and 26b provided in the relay unit 3. In addition, the relay unit 3 and the indoor units 2 are connected by heat medium pipes 70 that allow a heat medium such as water or brine to flow through the load-side heat exchangers 26a and 26b. It should be noted that in Fig. 13, components denoted by the same refer-

ence numerals as those in Figs. 1, 6, and 8 operate in the same manners as the components denoted therein as described with respect to Embodiments 1 to 3.

[0162] Also, in the air-conditioning apparatus 100 of Embodiment 4, in the heating only operation mode and the heating main operation mode, the refrigerant can pass through the injection expansion devices 42 and the outdoor-side expansion devices 45. Therefore, in the cooling only operation mode and the cooling main operation mode, injection, etc., are not performed.

<Relay unit 3>

[0163] The relay unit 3 includes two load-side heat exchangers 26, two load-side expansion devices 25, two opening/closing devices 50, and two relay-unit refrigerant flow switching devices 51. Also, the relay unit 3 further includes two pumps 71, four first heat-medium flow switching devices 72, four second heat-medium flow switching devices 73, and four heat-medium flow adjusting devices 75.

[0164] The two load-side heat exchangers 26 (the load-side heat exchangers 26a and 26b) in Embodiment 4 operate as condensers (radiators) or evaporators. Each of the load-side heat exchangers 26 causes heat exchange to be performed between the heat-source-side refrigerant and the heat medium, and transfers to the heat medium, cooling energy or heating energy generated by the outdoor unit or units 1 and accumulated in the heat-source-side refrigerant. The load-side heat exchanger 26a is provided between the load-side expansion device 25a and the relay-unit refrigerant flow switching device 51a in the refrigerant circuit, and contributes to heating of the heat medium in the cooling and heating mixed operation mode. The load-side heat exchanger 26b is provided between the load-side expansion device 25b and the relay-unit refrigerant flow switching device 51b in the refrigerant circuit, and contributes to cooling of the heat medium in the cooling and heating mixed operation mode.

[0165] The two load-side expansion devices 25 (the load-side expansion devices 25a and 25b) each operate as a pressure reducing valve and an expansion valve, and reduce the heat-source-side refrigerant in pressure to expand the heat-source-side refrigerant. The load-side expansion device 25a is provided upstream of the load-side heat exchanger 26a in the flow of heat-source-side refrigerant flow during the cooling operation. The load-side expansion device 25b is provided upstream of the load-side heat exchanger 26b in the flow of heat-source-side refrigerant flow during the cooling operation. The two load-side expansion devices 25 are each a device whose opening degree can be variably controlled, for example, an electronic expansion valve.

[0166] The two opening/closing devices 50 (the opening/closing devices 50a and 50b) are, for example, two-way valves, and open/close refrigerant pipes 4. The opening/closing device 50a is provided at the refrigerant

pipe 4 on the inlet side for the heat-source-side refrigerant. The opening/closing device 50b is provided at a pipe connecting the refrigerant pipes 4 on the inlet side and the outlet side for the heat-source-side refrigerant. The two relay-unit refrigerant flow switching devices 51 (the relay-unit refrigerant flow switching devices 51a and 51b) are, for example, four-way valves, and switch the flow of the heat-source-side refrigerant in accordance with the operation mode. The relay-unit refrigerant flow switching device 51a is provided downstream of the load-side heat exchanger 26a in the flow of heat-source-side refrigerant during the cooling operation. The relay-unit refrigerant flow switching device 51b is provided downstream of the load-side heat exchanger 26b in the flow of heat-source-side refrigerant during the cooling only operation.

[0167] The two pumps 71 (the pumps 71a and 71b) each pressurize and circulate the heat medium that passes through an associated heat medium pipe 70. The pump 71a is provided in part of the heat medium pipe 70 that is located between the load-side heat exchanger 26a and the second heat-medium flow switching device 73. The pump 71b is provided in part of the heat medium pipe 70 between the load-side heat exchanger 26b and the second heat-medium flow switching device 73. The two pumps 71 are, for example, pumps whose capacities can be controlled.

[0168] The four first heat-medium flow switching devices 72 (the first heat-medium flow switching devices 72a to 72d) are, for example, three-way valves, and switch respective flow passages for the heat-medium. The number of first heat-medium flow switching devices 72 (four in this case) provided is determined in accordance with the number of indoor units 2 installed. One of three sides of each of the first heat-medium flow switching devices 72 is connected to the load-side heat exchanger 26a, another one of the three sides is connected to the load-side heat exchanger 26b, and the remaining one of the three sides is connected to the heat-medium flow adjusting device 75, and each first heat-medium flow switching device 72 is provided on the outlet side of the heat-medium flow passage of the use-side heat exchanger 76. The first heat-medium flow switching devices 72a, 72b, 72c, and 72d are arranged in association with the respective indoor units 2 and illustrated in this order from the lower side of the figure.

[0169] The four second heat-medium flow switching devices 73 (the second heat-medium flow switching devices 73a to 73d) are, for example, three-way valves, and switch respective medium flow passages for the heat medium. The number of second heat-medium flow switching devices 73 (four in this case) provided is determined in accordance with the number of indoor units 2 installed. One of three sides of each of the second heat-medium flow switching devices 73 is connected to the load-side heat exchanger 26a, another one of the three sides is connected to the load-side heat exchanger 26b, and the remaining one of the three sides is connected to the use-side heat exchanger 76, and each second heat-medium

flow switching device 73 is provided on the inlet side of the heat-medium flow passage of the use-side heat exchanger 76. It should be noted that the second heat-medium flow switching devices 73a, 73b, 73c, and 73d are arranged in association with the respective indoor units 2 and illustrated in this order from the lower side of the figure.

[0170] The four heat-medium flow adjusting devices 75 (the heat-medium flow adjusting devices 75a to 75d) are, for example, two-way valves that can be controlled in opening area, and control the flow rate of the refrigerant into the heat medium pipes 70. The number of heat-medium flow adjusting devices 75 (four in this case) provided is determined in accordance with the number of indoor units 2 installed. One of the sides of each heat-medium flow adjusting device 75 is connected to the use-side heat exchanger 76, and the other is connected to the first heat-medium flow switching device 72; and each heat-medium flow adjusting device 75 is provided on the outlet side of the heat-medium flow passage of the use-side heat exchanger 76. It should be noted that the heat-medium flow adjusting devices 75a, 75b, 75c, and 75d are arranged in association with the respective indoor units 2, and illustrated in this order from the lower side of the figure. Alternatively, each heat-medium flow adjusting device 75 may be provided on the inlet side of the heat-medium flow passage of an associated use-side heat exchanger 76.

[0171] The relay unit 3 is provided with various sensors. Signals related to detection by the sensors are sent to, for example, the controllers 60.

[0172] The two first heat-medium temperature sensors 37 (the first heat-medium temperature sensors 37a and 37b) each detect the temperature of the heat medium that has flowed out of an associated load-side heat exchangers 26, that is, the temperature of the heat medium at the outlet of the load-side heat exchanger 26. Each first heat-medium temperature sensor 37 is provided at part of the heat medium pipe 70 that is located on the inlet side of an associated pump 71.

[0173] The four second heat-medium temperature sensors 38 (the second heat-medium temperature sensors 38a to 38d) are each provided between the associated first heat-medium flow switching device 72 and heat-medium flow adjusting device 75 and each detect the temperature of the heat medium that has flowed out of the associated use-side heat exchanger 76. The number of second heat-medium temperature sensors 38 (four in this case) provided is determined in accordance with the number of indoor units 2 installed.

[0174] Each of the four heat exchanger temperature sensors 35 (the heat exchanger temperature sensors 35a to 35d) is provided on the inlet or outlet side of an associated load-side heat exchanger 26 for the heat-source-side refrigerant, and correspond to the inflow-side temperature sensor 31 or the outflow-side temperature sensor 32 in Embodiments 1 and 2.

[0175] The pressure sensors 36 (the pressure sensors

36a and 36b) detect the pressure of the heat-source-side refrigerant that flows between the load-side heat exchanger 26b and load-side expansion device 25b.

[0176] The operation modes of the air-conditioning apparatus 100 include the cooling only operation mode in which ones of the indoor units 2 that are in operation all perform the cooling operation and the heating only operation mode in which ones of the indoor units 2 that are in operation all perform the heating operation. The operation modes further include the cooling main operation mode that is applied in the case where the cooling load is greater than the heating load and the heating main operation mode which is applied in the case where the heating load is greater than the cooling load.

<Cooling Only Operation Mode>

[0177] In the cooling only operation mode, the high-temperature, high-pressure gas refrigerant that has been discharged from the compressors 10 flows into the heat-source-side heat exchangers 12 through the refrigerant flow switching devices 11, transfers heat to ambient air, and is condensed and liquified to change into high-pressure liquid refrigerant. The high-pressure liquid refrigerant flows out of the outdoor units 1 through the first backflow prevention devices 13, and then flows into the relay unit 3 through the main pipes 5. The refrigerant that has flowed into the relay unit 3 passes through the opening/closing device 50a, is expanded by the load-side expansion devices 25a and 25b, and changes into low-temperature, low-pressure two-phase refrigerant. The two-phase refrigerant flows into the load-side heat exchangers 26a and 26b that operate as evaporators, and removes heat from the heat medium that circulates in the heat medium circulation circuit, thereby changing into low-temperature, low-pressure gas refrigerant. The gas refrigerant flows out of the relay unit 3 through the relay-unit refrigerant flow switching devices 51a and 51b, and re-flows into the outdoor units 1 through the main pipes 5. The refrigerant that has flowed into the outdoor units 1 passes through the first backflow prevention devices 16 and is re-sucked by the compressors 10 through the refrigerant flow switching devices 11 and the accumulators 19.

[0178] In the heat medium circulation circuit, the heat medium is cooled by the refrigerant at each of both the load-side heat exchangers 26a and 26b. The cooled heat medium is made to flow through the heat medium pipes 70 by the pumps 71a and 71b. The heat mediums that have flowed into the use-side heat exchangers 76a to 76d through the second heat-medium flow switching devices 73a to 73d remove heat from the indoor air. The indoor air is cooled to cool the air-conditioned space. The refrigerant that has flowed out of the use-side heat exchangers 76a to 76d flows into the heat-medium flow adjusting devices 75a to 75d. The refrigerant then passes through the first heat-medium flow switching devices 72a to 72d, flows into the load-side heat exchangers 26a and

26b, is cooled and re-sucked into the pumps 71a and 71b. It should be noted that in the case where one or ones of the use-side heat exchangers 76a to 76d are not given a heating load, one or ones of the heat-medium flow adjusting devices 75a to 75d that are associated with the use-side heat exchanger or exchangers 76 not given the heating load are fully closed. By contrast, in the case where one or ones of the use-side heat exchangers 76a to 76d are given heating loads, one or ones of the heat-medium flow adjusting devices 75a to 75d that are associated with the use-side heat exchanger or exchangers 76 given the heating loads is adjusted in opening degree to adjust the heating load at the use-side heat exchanger or exchangers 76 given the heating loads.

<Cooling Main Operation Mode>

[0179] In the cooling main operation mode, the high-temperature, high-pressure gas refrigerant that has been discharged from the compressors 10 flows into the heat-source-side heat exchangers 12 through the refrigerant flow switching devices 11, transfers heat to ambient air, and is condensed and changes into two-phase refrigerant. The two-phase refrigerant flows out of the outdoor units 1 through the first backflow prevention devices 13, and then flows into the relay unit 3 through the main pipes 5. The refrigerant that has flowed into the relay unit 3 passes through the relay-unit refrigerant flow switching device 51b and flows into the load-side heat exchanger 26b that operates as a condenser, and transfers heat to the heat medium that circulates in the heat medium circulation circuit to change into high-pressure liquid refrigerant. The high-pressure liquid refrigerant is expanded by the load-side expansion device 25b and changes into low-temperature, low-pressure two-phase refrigerant. The two-phase refrigerant flows into the load-side heat exchanger 26a, which operates as an evaporator, through the load-side expansion device 25a, and removes heat from the heat medium that circulates in the heat medium circulation circuit, thereby changing into low-pressure gas refrigerant. The low-pressure gas refrigerant flows out of the relay unit 3 through the relay-unit refrigerant flow switching device 51a, and then re-flows into the outdoor units 1 through the main pipes 5. The refrigerant that has flowed into the outdoor units 1 passes through the first backflow prevention devices 16 and is re-sucked by the compressors 10 through the refrigerant flow switching devices 11 and the accumulators 19.

[0180] In the heat medium circulation circuit, the heat energy of the refrigerant is transferred to the heat medium by the load-side heat exchanger 26b. The heated heat medium is made to flow through the heat medium pipe 70 by the pump 71b. In the case where one or ones of the use-side heat exchangers 76a to 76d are given heating requests, the heat medium is made to flow into the use-side heat exchanger or exchangers 76 given the heating requests by operating an associated one or ones

of the first heat-medium flow switching devices 72a to 72d and an associated one or ones of the second heat-medium flow switching devices 73a to 73d, and transfer heat to the indoor air. The indoor air is heated to heat the air-conditioned space. By contrast, at the load-side heat exchanger 26a, the cooling energy of the refrigerant is transferred to the heat medium. The cooled heat medium is made to flow through the heat medium pipe 70 by the pump 71a. On the other hand, in the case where one or ones of the use-side heat exchangers 76a to 76d are given cooling requests, the heat medium flows into the user-side heat exchanger or exchangers 76 given the cooling requests, and remove heat from the indoor air by operating an associated one or associated ones of the first heat-medium flow switching devices 72a to 72d and an associated one or ones of the second heat-medium flow switching devices 73a to 73d. The indoor air is cooled to cool the air-conditioned space. It should be noted that in the case where one or ones of the user-side heat exchangers 76a to 76d are not given heating loads, one or ones of the heat-medium flow adjusting devices 75a to 75d that are associated with the use-side heat exchanger or exchangers 76 not given the heating loads are fully closed. By contrast, in the case where one or ones of the user-side heat exchangers 76a to 76d are given heating loads, one or ones of the heat-medium flow adjusting devices 75a to 75d that are associated with the use-side heat exchanger or exchangers 76 given the heating loads are adjusted in opening degree to adjust the heating load at the use-side heat exchanger or exchangers 76 given the heating loads.

[0181] In the cooling main operation mode of the air-conditioning apparatus 100 of Embodiment 4, for example, the heat-source-side heat exchanger 12 in a given outdoor unit 1 may operate as an evaporator. In this outdoor unit 1, the operations of components, etc., in the case where the injection, the liquid backflow prevention, and liquid levelling control are performed are the same as those of Embodiments 1 and 2.

<Heating Only Operation Mode>

[0182] In the heating only operation mode, the high-temperature, high-pressure gas refrigerant that has been discharged from the compressors 10 pass through the refrigerant flow switching devices 11, then the first connection pipes 6 and the first backflow prevention devices 14, and flows out of the outdoor units 1. The refrigerant then flows into the relay unit 3 through the main pipes 5. The refrigerant that has flowed into the relay unit 3 passes through the relay-unit refrigerant flow switching devices 51a and 51b and flows into the load-side heat exchangers 26a and 26b, and transfers heat to the heat medium that circulates in the heat medium circulation circuit, thereby changing into high-pressure liquid refrigerant. The high-pressure liquid refrigerant is expanded by the load-side expansion devices 25a and 25b to change into low-temperature, low-pressure two-phase refrigerant, and flows

out of the relay unit 3 through the opening/closing device 50b. The refrigerant then re-flows into the outdoor units 1 through the main pipes 5. The refrigerant that has flowed into the outdoor units 1 passes through the second connection pipes 7 and the first backflow prevention devices 15, flows into the heat-source-side heat exchangers 12 that operate as evaporators, and removes heat from ambient air to change into low-temperature, low-pressure gas refrigerant. The gas refrigerant is re-sucked into the compressors 10 through the refrigerant flow switching devices 11 and the accumulators 19. It should be noted that the flow of the heat medium in the heat medium circulation circuit is the same as that in the cooling only operation mode. In the heating only operation mode, the heat medium is heated with the refrigerant at the load-side heat exchangers 26a and 26b, and transfers heat to the indoor air at the use-side heat exchangers 76a and 76b, thereby heating the air-conditioned space.

[0183] In the air-conditioning apparatus 100 of Embodiment 4, the operations of components and the control by the controllers 60 in the case where the injection, the liquid backflow prevention and the liquid leveling control are performed in the heating only operation mode are the same as those of Embodiments 1 and 2.

<Heating Main Operation Mode>

[0184] In the heating main operation mode, the high-temperature, high-pressure gas refrigerant that has been discharged from the compressors 10 passes through the first connection pipes 6 and the first backflow prevention devices 14 via the refrigerant flow switching devices 11, and flows out of the outdoor units 1. The refrigerant then flows into the relay unit 3 through the main pipes 5. The refrigerant that has flowed into the relay unit 3 passes through the relay-unit refrigerant flow switching device 51b and flows into the load-side heat exchanger 26b that operates as a condenser, and transfers heat to the heat medium that circulates in the heat medium circulation circuit, thereby changing into high-pressure liquid refrigerant. The high-pressure liquid refrigerant is expanded by the load-side expansion device 25b and changes into low-temperature, low-pressure two-phase refrigerant. The two-phase refrigerant flows into the load-side heat exchanger 26a, which operates as an evaporator, through the load-side expansion device 25a, removes heat from the heat medium that circulates in the heat medium circulation circuit, and flows out of the relay unit 3 through the relay-unit refrigerant flow switching device 51a. The refrigerant then re-flows into the outdoor units 1 through the main pipes 5. The refrigerant that has flowed into the outdoor units 1 passes through the second connection pipes 7 and the first backflow prevention devices 15, flows into the heat-source-side heat exchangers 12 that operate as evaporators, and removes heat from ambient air to change into low-temperature, low-pressure gas refrigerant. The gas refrigerant is re-sucked into the compressors 10 through the refrigerant flow

switching devices 11 and the accumulators 19. It should be noted that the flow of the heat medium in the heat medium circulation circuit, and the operations of the first heat-medium flow switching devices 72a to 72d, the second heat-medium flow switching devices 73a to 73d, the heat-medium flow adjusting devices 75a to 75d, and the use-side heat exchangers 76a to 76d are the same as those in the cooling main operation mode.

[0185] In the air-conditioning apparatus 100 of Embodiment 4, the operations of components and the control by the controllers 60 in the case where the injection, the liquid backflow prevention and the liquid level control are performed in the heating main operation mode are the same as those of Embodiments 1 and 2.

<Main Pipes 5 and Heat Medium Pipes 70>

[0186] In each of the operation modes of the Embodiment 4, the refrigerant flows through the main pipes 5 that connect the outdoor units 1 and the relay unit 3, and a heat medium such as water or antifreeze liquid is supplied to the heat medium pipes 70 that connect the relay unit 3 and the indoor units 2.

[0187] In the case where heating and cooling loads are mixedly applied to the use-side heat exchangers 76, the first heat-medium flow switching device 72 and the second heat-medium flow switching device 73 that are associated with one or ones of the use-side heat exchangers 76 that are in the heating operation are caused to switch respective flow passages to flow passages connected to the heating load-side heat exchanger 26b. Furthermore, the first heat-medium flow switching device 72 and the second heat-medium flow switching device 73 that are associated with one or ones of the use-side heat exchangers 76 that are in the cooling operation are caused to switch respective flow passages to flow passages connected to the cooling load-side heat exchanger 26a. Because of this configuration, each of the indoor units 2 can be freely made to perform either the heating operation or the cooling operation.

[0188] As described above, as in Embodiments 1 and 2, in the air-conditioning apparatus 100 of Embodiment 4 which includes a heat medium circulation circuit and a refrigerant circuit and in which a plurality of outdoor units 1 provided with components included in the refrigerant circuit are connected in parallel to enable a simultaneous operation of cooling and heating to be performed, occurrence of excessive liquid backflow can be prevented by injection and liquid level control.

Embodiment 5

[0189] The air-conditioning apparatus 100 of the present disclosure is not limited to that of each of Embodiments 1 to 4, and various modifications can be made. For example, in the above embodiments, for example, the discharge temperature threshold is 110°C in the cooling operation mode and the heating operation mode;

however, the discharge temperature threshold may be set in accordance with the limit value of the discharge temperature of each compressor 10. For example, in the case where the limit value of the discharge temperature of the compressor 10 is 120°C, the operation of the compressor 10 is controlled by the controller 60 such that the discharge temperature does not exceed 120°C. To be more specific, when the discharge temperature exceeds 110°C, the controller 60 performs control such that the frequency of the compressor 10 is reduced to decrease the rotation speed of thereof.

[0190] Therefore, in the case where the discharge temperature of the compressor 10 is reduced by performing the injection as described above, it is appropriate that the target discharge temperature (liquid-level adjustment threshold) be set in advance to a temperature (for example, 100°C) between 90 to 105°C that are slightly lower than 110°C that is a temperature (discharge temperature threshold) at which the frequency of the compressor 10 is reduced. For example, in the case where the discharge temperature exceeds 110°C, and the driving frequency of the compressor 10 is not reduced, it suffices that the discharge temperature threshold be set to fall within the range of 90°C to 120°C (for example, 110°C).

[0191] Regarding Embodiments 1 to 4, although the R410A refrigerant and the R32 refrigerant are mentioned as examples of the refrigerant, other types of refrigerant are also applicable. For example, a mixed refrigerant (non-azeotropic refrigerant mixture) containing the R32 refrigerant and a tetrafluoropropene refrigerant (for example, HFO1234yf or HFO1234ze) that has a small global warming potential and is expressed by the chemical formula " $\text{CF}_3\text{CF}=\text{CH}_2$ " may be used. In particular, in the case where the R32 refrigerant is used as the refrigerant, the discharge temperature is raised by approximately 20°C than in the case of using the R410A refrigerant on the premise that they are used under the same operation state. Thus, in the case where the R32 refrigerant is used, it is necessary to reduce the discharge temperature. It can be therefore understood that by the injection as described regarding Embodiment 1, etc., a great advantage can be obtained, especially, in the case of using refrigerant for which the discharge temperature is increased.

[0192] In the mixed refrigerant of the R32 refrigerant and HFO1234yf, in the case where the mass ratio of R32 is 62% (62 wt%) or more, the discharge temperature is at least 3°C higher than in the case of using the R410A refrigerant. Therefore, the advantage obtained because of reduction of the discharge temperature that is effected by performing the injection is great. In the mixed refrigerant of R32 and HFO1234ze, in the case where the mass ratio of R32 is 43% (43 wt%) or more, the discharge temperature is at least 3°C higher than in the case where the R410A refrigerant is used. Therefore, the advantage obtained because of reduction of the discharge temperature that is effected by the above injection is great. The type of refrigerant in the mixed refrigerant is not limited to the above type. Even in the case where a mixed re-

frigerant containing a small amount of other refrigerant components is used, the discharge temperature is not greatly affected, and the same advantage as described above is obtained. Furthermore, for example, even in the case where when a mixed refrigerant containing a small amount of R32, HFO1234yf, and other types of refrigerant is used, the same advantage as described above is obtained.

[0193] Moreover, refrigerant that acts in a supercritical state on the high-pressure side, such as CO₂ (R744), can also be used as the refrigerant in the above embodiments. Also in this case, since it is necessary to lower the discharge temperature, the discharge temperature can be reduced by applying the refrigerant circuit configuration of each of the above embodiments to the air-conditioning apparatus 100.

[0194] For example, as an example of the configuration of the air-conditioning apparatus according to each of Embodiments 3 and 4, which can perform the simultaneous operation of cooling and heating, it is described above that the outdoor units 1 and the relay unit 3 are connected by the two main pipes 5; however, the configuration of the air-conditioning apparatus is not limited to the above, and various known methods can be applied to the air-conditioning apparatus. For example, the air-conditioning apparatus may be configured such that the outdoor units 1 and the relay unit 3 are connected by three main pipes 5 to enable the simultaneous operation of cooling and heating to be performed. Also, in such an air-conditioning apparatus, it is possible to prevent the temperature of the high-pressure and high-temperature gas refrigerant that is discharged from the compressors 10 from being excessively raised, as in the above embodiments.

[0195] Further, regarding, for example, Embodiment 1, although it is described above that the compressor 10 is of a low-pressure shell type, for example, a high-pressure shell-type compressor can also be used. In the case where the injection is performed on the compressor suction chamber, it is advantageous that a low-pressure shell type compressor is used. However, also in the case where the high-pressure shell type compressor is used, the same advantages as described above can be obtained.

[0196] Furthermore, with respect to, for example, Embodiment 1, it is described above that the outdoor unit 1 includes the heat-source-side fan 18, and the indoor unit 2 includes the load-side fan 28. This, however is not limitative. For example, in the case where a device similar to a panel heater is used as the load-side heat exchanger 26, the load-side fan 28 does not need to be provided.

[0197] Fig. 14 is a diagram illustrating an example of the configuration of an air-conditioning apparatus 100 according to Embodiment 5 of the present disclosure. In this example, as the heat-source-side heat exchanger 12, a water-refrigerant heat exchanger that causes heat exchange to be performed between refrigerant and a liquid such as water or antifreeze liquid, which has passed

through water pipes 80, can be used. Any object can be used as an object to be subjected to heat exchange at each of the heat-source-side heat exchanger 12 and the load-side heat exchanger 26 as long as it can transfer heat and remove heat to and from the refrigerant.

[0198] Regarding the above embodiments, in the case where an air-conditioning apparatus dedicated to cooling or heating is applied, the refrigerant flow switching devices 11 can be omitted.

Reference Signs List

[0199] 1, 1a, 1b outdoor unit, 2, 2a, 2b, 2c, 2d indoor unit, 3 relay unit, 4, 4a, 4b refrigerant pipe, 5 main pipe, 6 first connection pipe, 7 second connection pipe, 8 branch pipe, 10, 10a, 10b compressor, 11, 11a, 11b refrigerant flow switching device, 12, 12a, 12b heat-source-side heat exchanger, 13, 14, 15, 16 first backflow prevention device, 17, 17a, 17b injection port, 18, 18a, 18b heat-source-side fan, 19, 19a, 19b accumulator, 20, 20a, 20b oil return mechanism, 21a, 21b, 21c, 21d second backflow prevention device, 22a, 22b, 22c, 22d third backflow prevention device, 23a, 23b, 23c, 23d first opening/closing device, 24a, 24b, 24c, 24d second opening/closing device, 25, 25a, 25b, 25c, 25d load-side expansion device, 26, 26a, 26b, 26c, 26d load-side heat exchanger, 27 second relay-unit expansion device, 28 load-side fan, 29 gas-liquid separator, 30 first relay-unit expansion device, 31, 31a, 31b, 31c, 31d inflow-side temperature sensor, 32, 32a, 32b, 32c, 32d outflow-side temperature sensor, 33 expansion-device inlet-side pressure sensor, 34 expansion-device outlet-side pressure sensor, 35, 35a, 35b, 35c, 35d heat exchanger temperature sensor, 36, 36a, 36b pressure sensor, 37, 37a, 37b first heat-medium temperature sensor, 38, 38a, 38b second heat-medium temperature sensor, 40, 40a, 40b discharge pressure sensor, 41, 41a, 41b injection pipe, 42, 42a, 42b injection expansion device, 43, 43a, 43b discharge temperature sensor, 44, 44a, 44b pressure detection sensor, 45, 45a, 45b outdoor-side expansion device, 46, 46a, 46b outside-air temperature sensor, 50, 50a, 50b opening/closing device, 51, 51a, 51b relay-unit refrigerant flow switching device, 60, 60a, 60b controller, 61, 61a, 61b storage device, 70 heat medium pipe, 71, 71a, 71b pump, 72, 72a, 72b, 72c, 72d first heat-medium flow switching device, 73, 73a, 73b, 73c, 73d second heat-medium flow switching device, 75, 75a, 75b, 75c, 75d heat-medium flow adjusting device, 76, 76a, 76b, 76c, 76d use-side heat exchanger, 80 water pipe, 100 air-conditioning apparatus

Claims

1. An air-conditioning apparatus comprising:

an outdoor unit including a compressor, a heat-source-side heat exchanger, and an accumula-

tor, the compressor including a suction chamber having an injection port that allows refrigerant to flow into the suction chamber, the compressor being configured to compress and discharge the refrigerant, the heat-source-side heat exchanger being configured to cause heat exchange for the refrigerant to be performed, the accumulator being configured to accumulate the refrigerant; at least one load-side expansion device configured to reduce a pressure of the refrigerant; and at least one load-side heat exchanger configured to cause heat exchange to be performed between a load and the refrigerant, the outdoor unit, the at least one load-side expansion device, and the at least one load-side heat exchanger being connected by pipes, whereby a refrigerant circuit is formed to circulate the refrigerant, the outdoor unit including:

an injection pipe having one end connected between the heat-source-side heat exchanger and the load-side expansion device and an other end connected to the injection port, the injection pipe being configured to allow part of the refrigerant in the refrigerant circuit to flow toward the injection port;

an outdoor-side expansion device located downstream of the one end of the injection pipe in a flow of the refrigerant in a case where the refrigerant flows from the load-side expansion device to the heat-source-side heat exchanger in the refrigerant circuit, the outdoor-side expansion device being configured to reduce the pressure of the refrigerant to adjust a flow rate thereof; and an injection expansion device configured to adjust an amount of the refrigerant that flows in the injection pipe,

the air-conditioning apparatus further comprising a controller configured to control an opening degree of the outdoor-side expansion device and an opening degree of the injection expansion device.

2. The air-conditioning apparatus of claim 1, wherein a plurality of the outdoor units are connected in parallel by pipes, whereby the refrigerant circuit is formed.
3. The air-conditioning apparatus of claim 1 or 2, wherein when determining that a discharge temperature of the refrigerant that is discharged from the compressor is higher than or equal to a predetermined discharge temperature threshold, the controller controls the opening degree of the injection ex-

pansion device such that the discharge temperature becomes lower than the discharge temperature threshold.

4. The air-conditioning apparatus of claim 1 or 2, wherein the controller controls the opening degree of the injection expansion device such that a discharge temperature of the refrigerant that is discharged from the compressor approaches a predetermined discharge temperature threshold.
5. The air-conditioning apparatus of any one of claims 1 to 3, wherein when determining a discharge temperature of the compressor that is reduced because of a return liquid from the accumulator is lower than or equal to a predetermined liquid-level adjustment threshold, the controller controls the opening degree of the outdoor-side expansion device such that the discharge temperature of the compressor becomes higher than the liquid-level adjustment threshold.
6. The air-conditioning apparatus of claim 5, wherein the liquid-level adjustment threshold is a value obtained by adding a temperature value by which the discharge temperature is reduced in accordance with the opening degree of the injection expansion device, to the discharge temperature that is reduced because of the return liquid from the accumulator, when the injection expansion device is in an opened state.
7. The air-conditioning apparatus of any one of claims 3 to 6, wherein the controller calculates a degree of discharge superheat of the refrigerant that is discharged from the compressor, and performs processing based on the degree of discharge superheat instead of the discharge temperature.
8. The air-conditioning apparatus of any one of claims 1 to 7, wherein the outdoor unit further includes a refrigerant flow switching device configured to switch a flow passage for the refrigerant between a flow passage for a cooling operation mode and a flow passage for a heating operation mode, and the controller controls the opening degree of the injection expansion device in the heating operation mode.
9. The air-conditioning apparatus of claim 8, wherein the heating operation mode includes a heating only operation mode in which ones of the load-side heat exchangers that are not in a stopped state all operate as condensers, and a heating main operation mode in which one or ones of the load-side heat exchangers not being in the stopped state operate as condensers, and a remaining one or ones of the load-side heat exchangers not being in the stopped state

operate as evaporators.

10. The air-conditioning apparatus of any one of claims 1 to 9, further comprising:

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a plurality of indoor units each including the load-side expansion device and the load-side heat exchanger; and

a relay unit configured to operate as a relay between the outdoor unit and the plurality of indoor units,

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wherein the outdoor unit, the plurality of indoor units, and the relay unit are connected by pipes such that the refrigerant circulates between components included in the outdoor unit and components included in the plurality of indoor units, through the relay unit, whereby the refrigerant circuit is formed.

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11. The air-conditioning apparatus of any one of claims 1 to 9, comprising:

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the refrigerant circuit including the load-side heat exchanger, the load-side heat exchanger being configured to cause heat exchange to be performed between the refrigerant and a heat medium that is applied as the load and different from the refrigerant; and

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a heat-medium circulation circuit in which a pump, the load-side heat exchanger, a use-side heat exchanger, and a heat-medium flow adjusting device are connected by pipes to circulate the heat medium, the pump being configured to pressurize the heat medium, the use-side heat exchanger being configured to cause heat exchange for air to be conditioned to be performed, the heat-medium flow adjusting device being configured to adjust a flow rate of the heat medium that flows into and out of the use-side heat exchanger.

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12. The air-conditioning apparatus of any one of claims 1 to 11, wherein the heat-source-side heat exchanger is a water-refrigerant heat exchanger configured to cause heat exchange to be performed between water and the refrigerant.

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FIG. 1

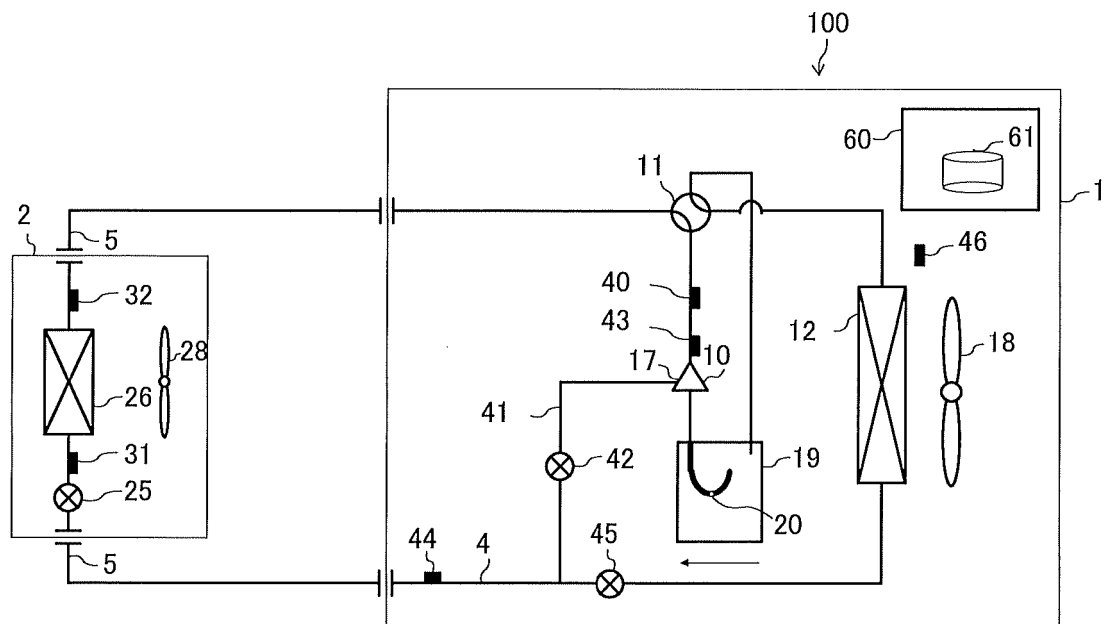


FIG. 2

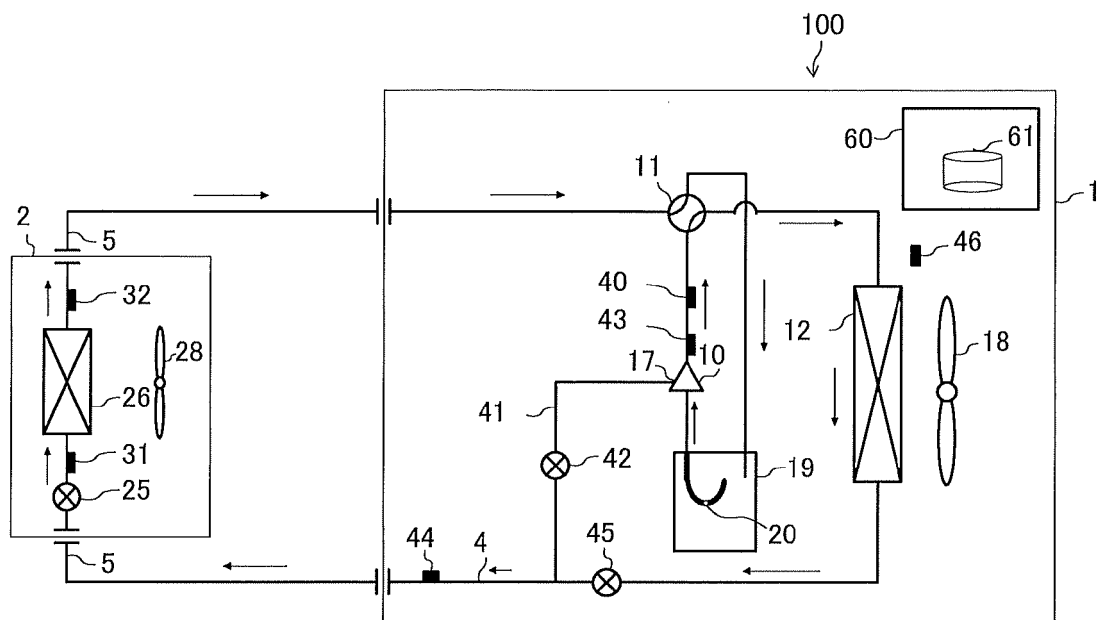


FIG. 3

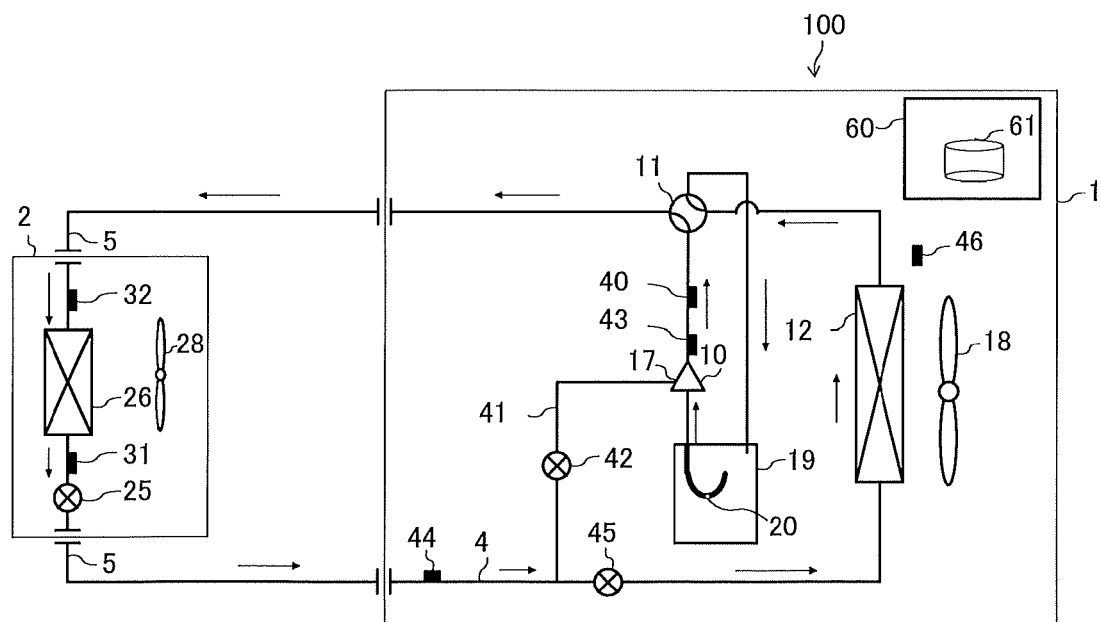


FIG. 4

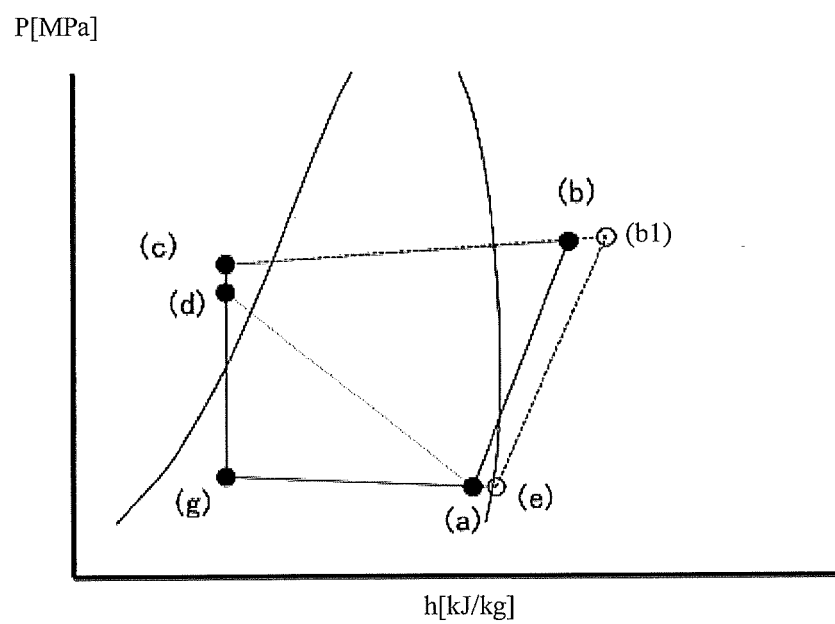


FIG. 5

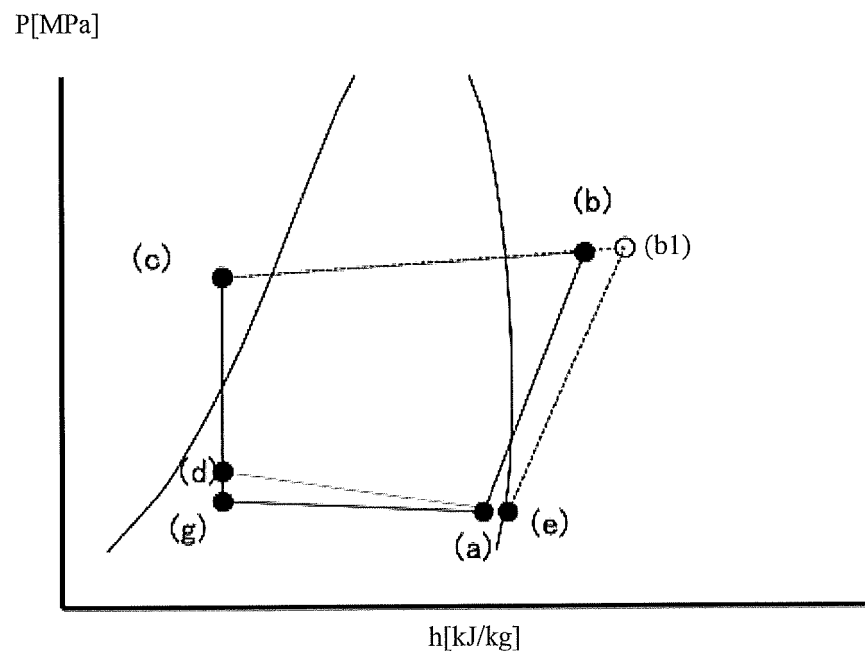


FIG. 6

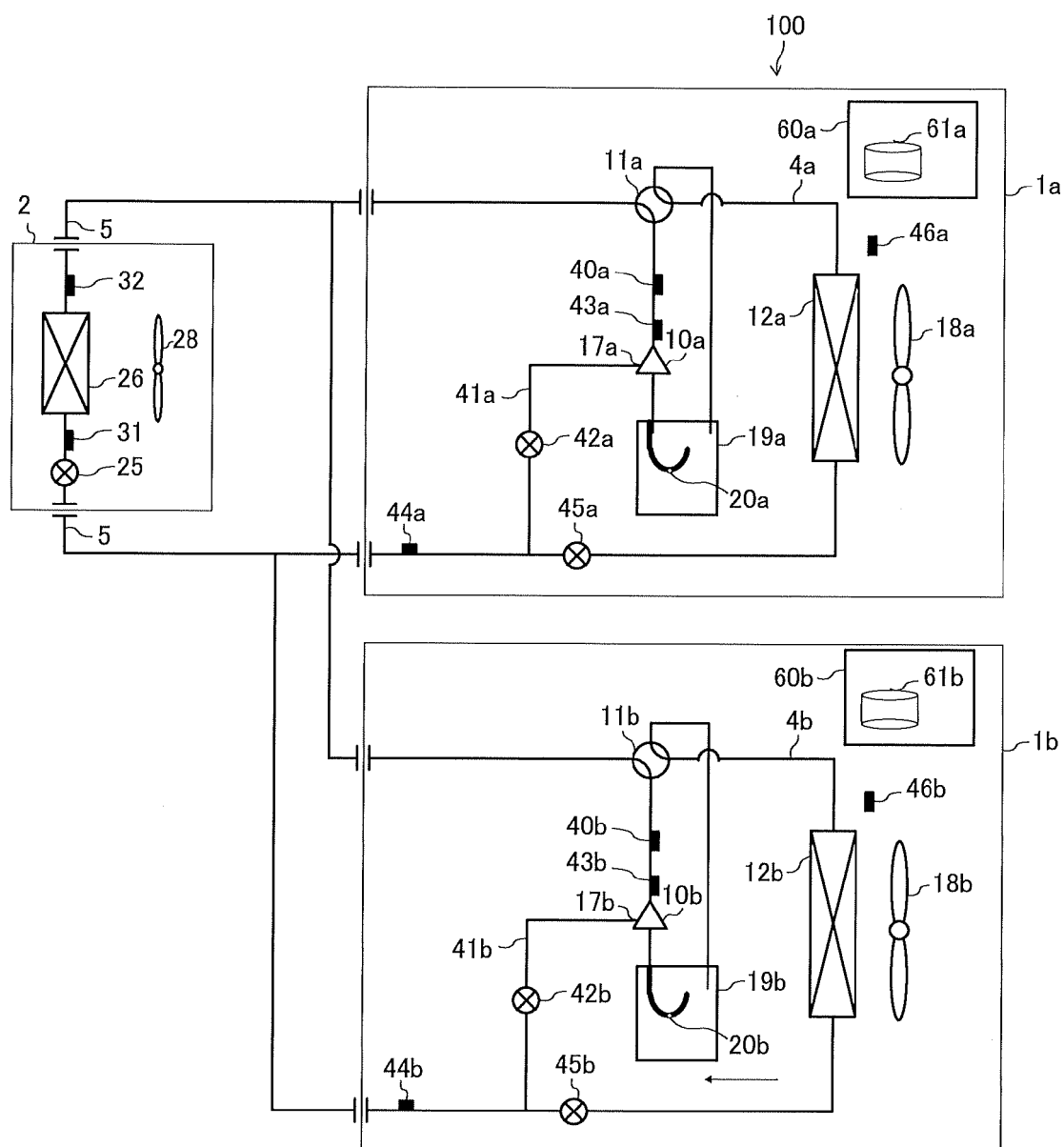


FIG. 7

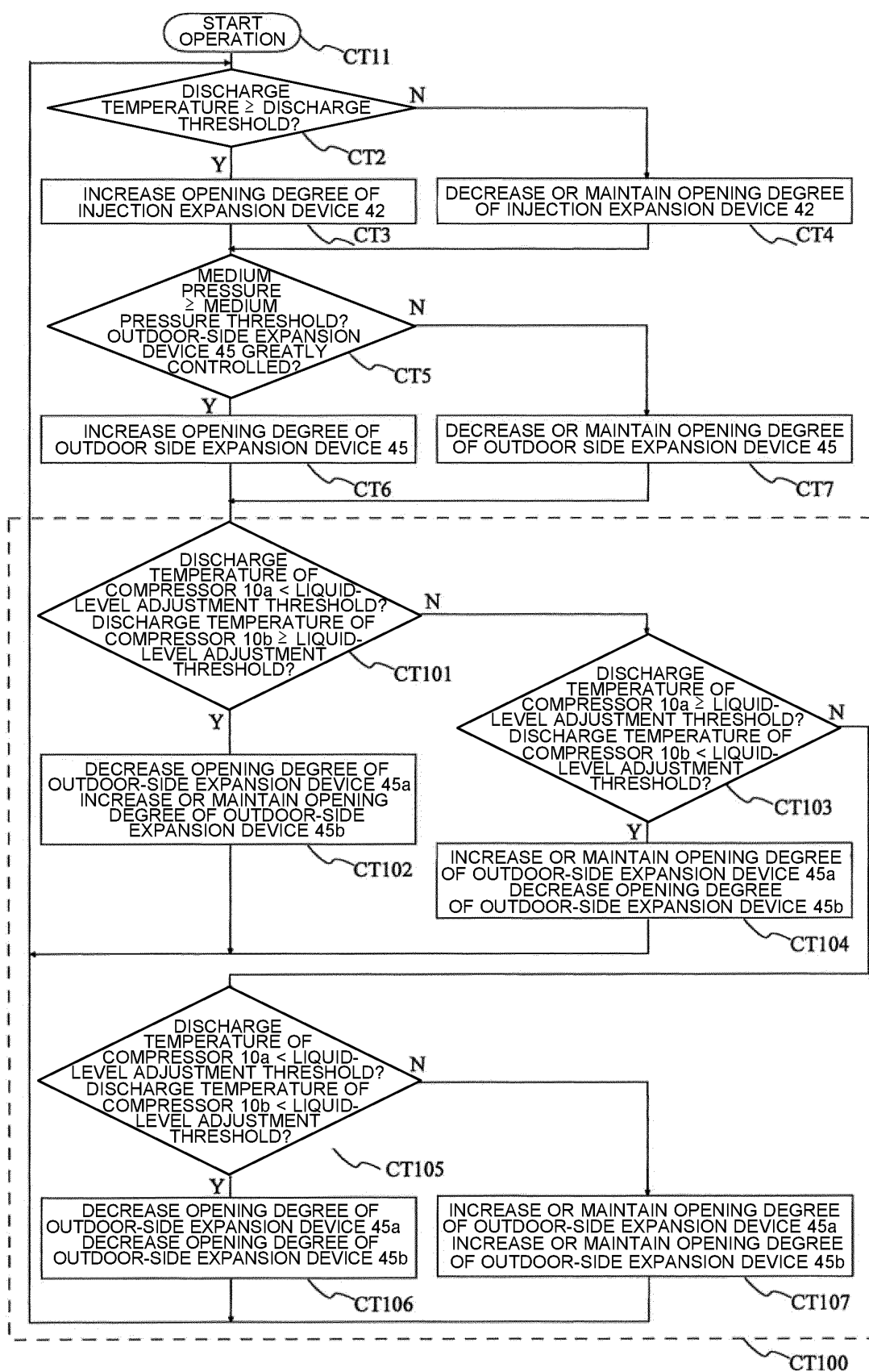


FIG. 8

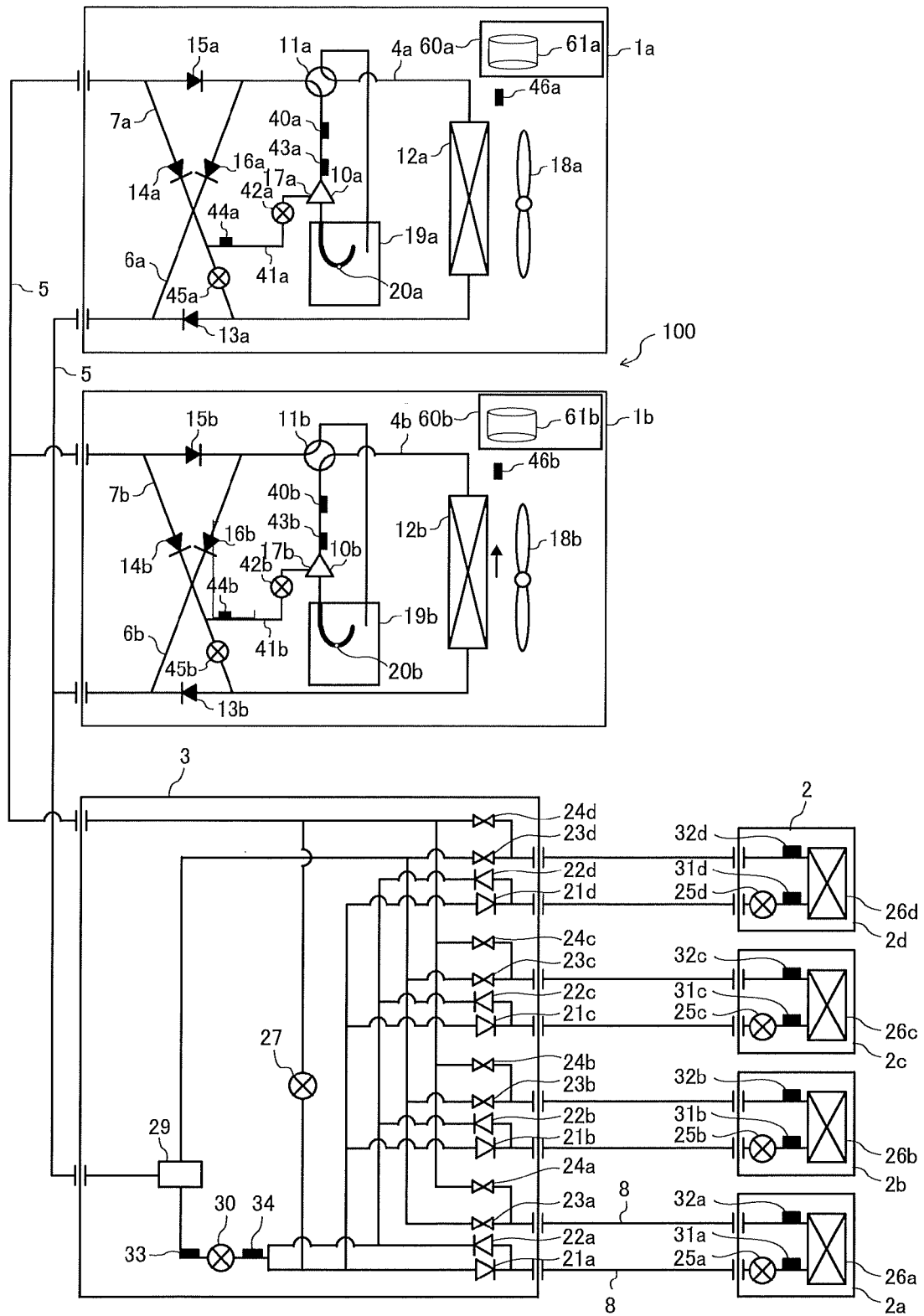


FIG. 9

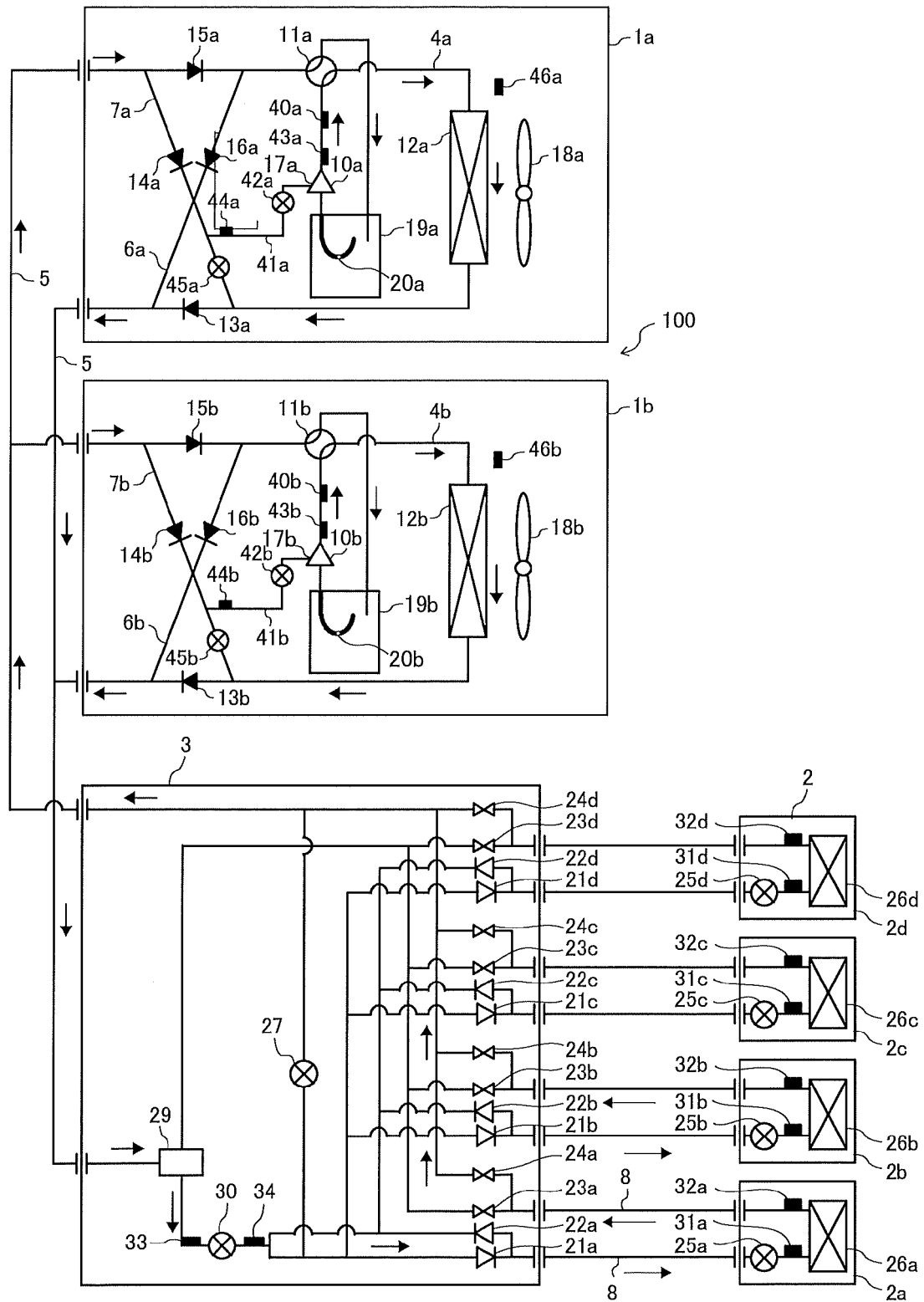


FIG. 10

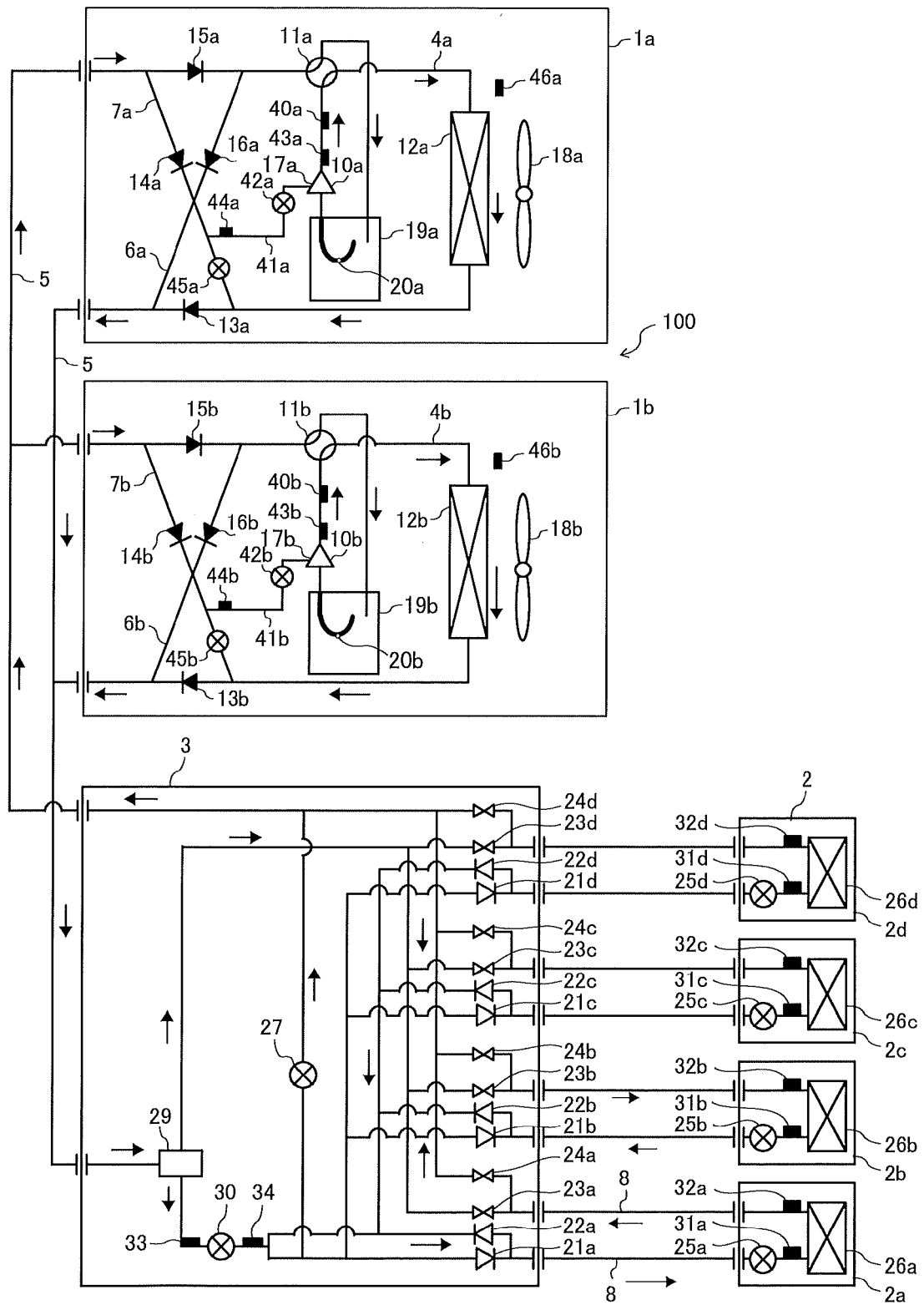


FIG. 11

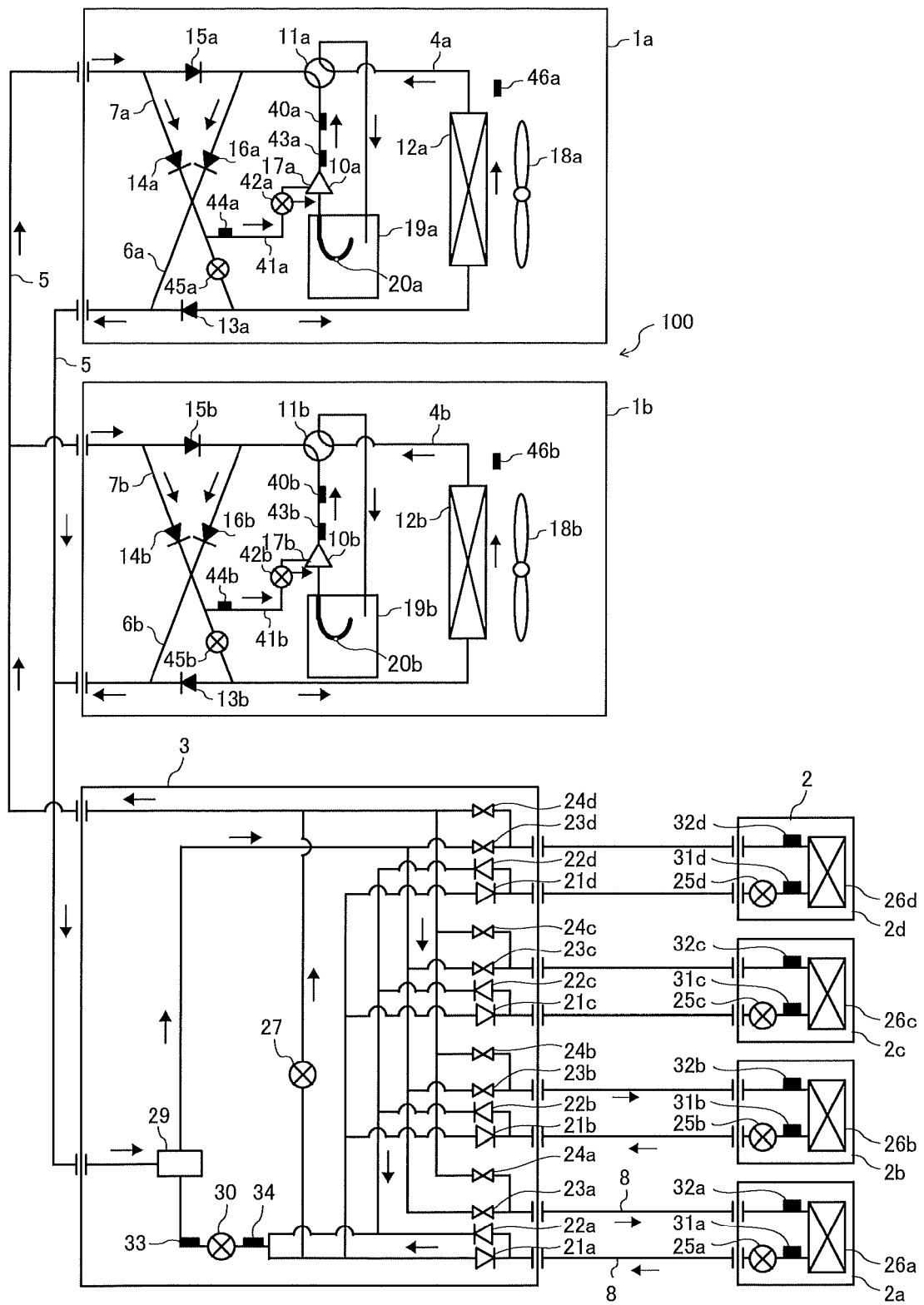


FIG. 12

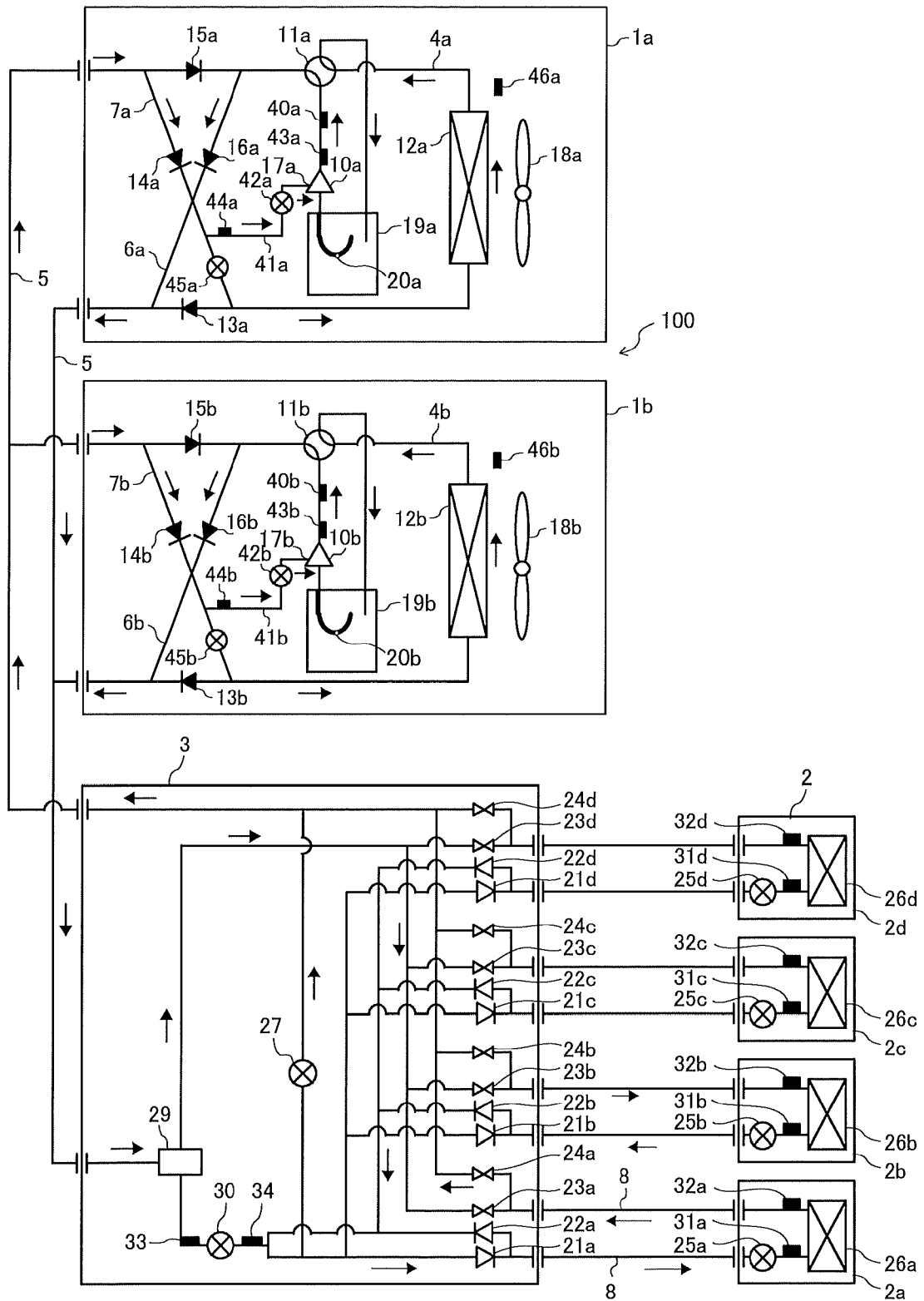


FIG. 13

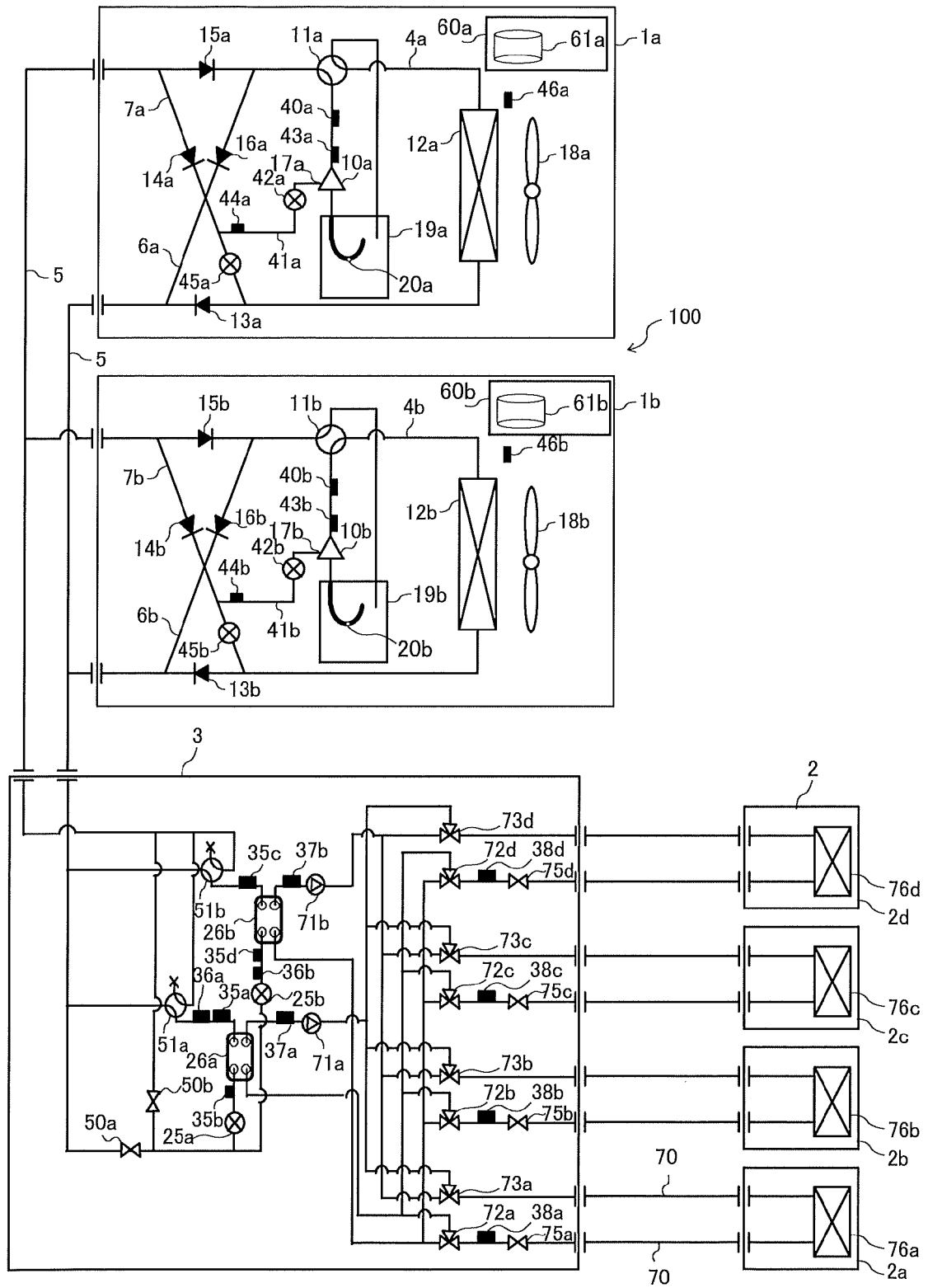
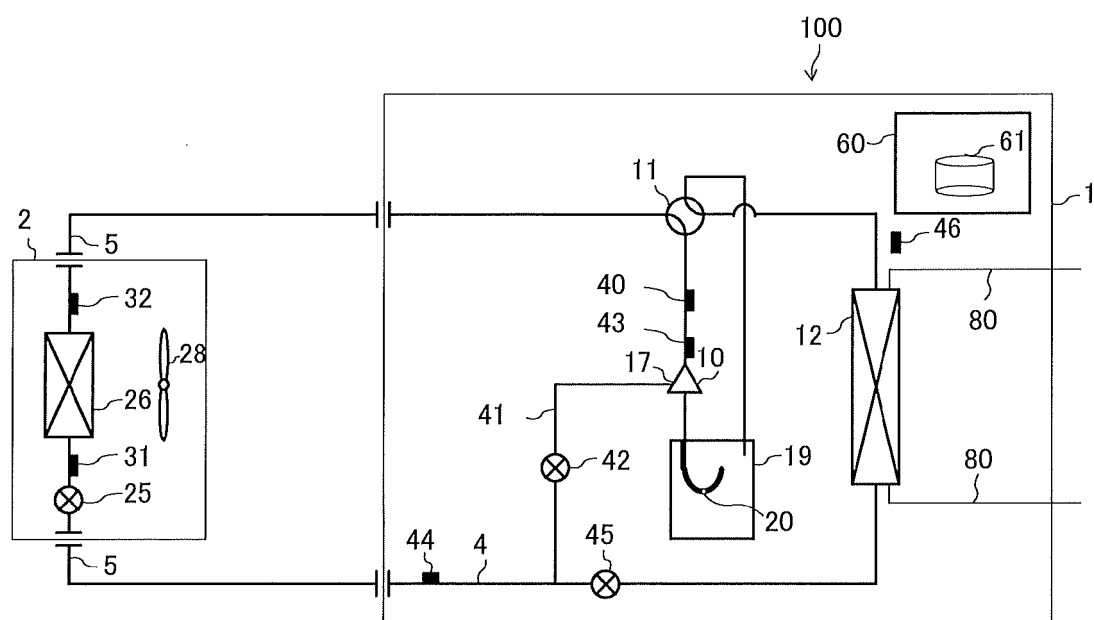


FIG. 14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/035261

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. F25B1/00 (2006.01) i, F24F11/02 (2006.01) i, F25B13/00 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. F25B1/00, F24F11/02, F25B13/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2017

Registered utility model specifications of Japan 1996-2017

Published registered utility model applications of Japan 1994-2017

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2014/080464 A1 (MITSUBISHI ELECTRIC CORP.) 30 May 2014, paragraphs [0001]-[0280], fig. 1-21 & US 2015/0300714 A1, paragraphs [0002]-[0508], fig. 1- 21 & EP 2924366 A1 & CN 104797893 A	1-4, 7-12 5-6
Y	US 2015/0267957 A1 (LG ELECTRONICS INC.) 24 September 2015, paragraphs [0002]-[0111], fig. 1-7 & EP 2924370 A1 & KR 10-2015-0109749 A	1-4, 7-12
Y A	WO 2013/160966 A1 (MITSUBISHI ELECTRIC CORP.) 31 October 2013, paragraphs [0001]-[0118], fig. 1-8 & US 2015/0107290 A1, paragraphs [0002]-[0174], fig. 1-8 & EP 2863147 A1 & CN 104350338 A	1-4, 7-12 5-6



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search
28.11.2017Date of mailing of the international search report
05.12.2017Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2017/035261
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/105262 A1 (FLAKT WOODS AB) 30 June 2016, page 1, line 3 to page 10, line 11, fig. 1-4 & SE 1451659 A1	1-12
A	WO 2014/141374 A1 (MITSUBISHI ELECTRIC CORP.) 18 September 2014, paragraphs [0001]-[0125], fig. 1-7 & US 2015/0362235 A1 & EP 2975335 A1 & CN 105008820 A	1-12

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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