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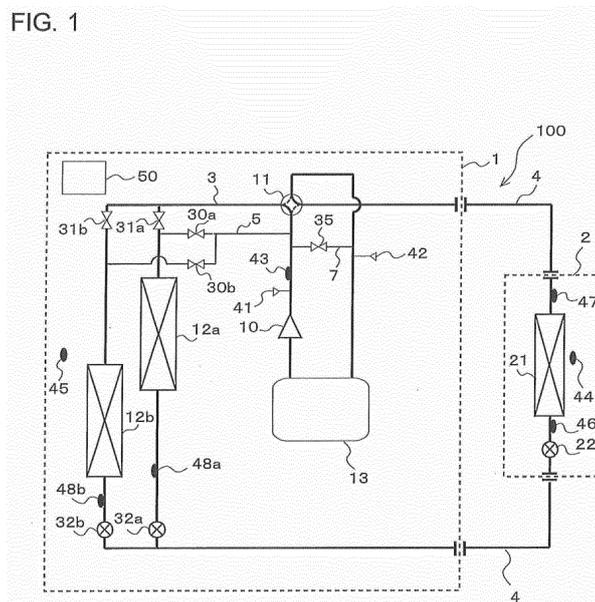
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(54) **AIR CONDITIONER**

(57) An air-conditioning apparatus 100 includes a first gas bypass pipe 5 branching off from a pipe on a discharge side of a compressor 10 and allowing refrigerant to flow into a defrosting-target heat source side heat exchanger 12 of a plurality of heat source side heat exchangers 12, a second gas bypass pipe 7 branching off from the pipe on the discharge side of the compressor 10 and allowing the refrigerant to flow into an accumulator

13, a plurality of first opening and closing devices 30, arranged in the first gas bypass pipe 5, permitting or stopping the flow of the refrigerant through the first gas bypass pipe 5, and at least one second opening and closing device 35, disposed in the second gas bypass pipe 7, permitting or stopping the flow of the refrigerant through the second gas bypass pipe 7.

FIG. 1



**Description**

## Technical Field

**[0001]** The present invention relates to an air-conditioning apparatus.

## Background Art

**[0002]** In a typical air-conditioning apparatus, such as a multi-air-conditioning apparatus for a building, an outdoor unit, functioning as a heat source device, disposed outside a structure, for example, is connected to an indoor unit disposed in the structure by pipes to form a refrigerant circuit through which refrigerant is circulated. The refrigerant is used to transfer heat to or remove heat from air in order to heat or cool the air, thereby heating or cooling an air-conditioned space.

**[0003]** In a heating operation of such a multi-air-conditioning apparatus for a building, a heat exchanger included in the outdoor unit functions as an evaporator and exchanges heat between low temperature refrigerant and the air. This causes moisture in the air to condense on fins and heat transfer tubes of the heat exchanger, thus forming frost on the heat exchanger. The frost on the heat exchanger will block air passages in the heat exchanger, resulting in a decrease in heat transfer area for heat exchange with air. This will lead to poor heating capacity.

**[0004]** Typically, the heating operation is stopped, a refrigerant flow direction is changed by a refrigerant flow switching device, and the heat exchanger in the outdoor unit is allowed to function as a condenser, thus achieving a defrosting operation. Performing such a defrosting operation can prevent a decrease in heating capacity. In the defrosting operation, however, the heating operation for an indoor space is stopped. Disadvantageously, an indoor air temperature will fall, thus reducing comfort of an indoor environment.

**[0005]** To solve the above-described disadvantage, related-art apparatuses are configured such that an outdoor unit includes a plurality of heat exchangers and gas discharged from a compressor is allowed to flow into the heat exchangers. Specifically, bypass pipes for bypassing the heat exchangers through on-off valves are arranged, and each of the heat exchangers is allowed to function as an evaporator or a condenser such that the evaporator and the condenser are driven simultaneously, thus achieving the defrosting operation and the heating operation simultaneously (refer to Patent Literature 1 to 3, for example).

## Citation List

## Patent Literature

**[0006]**

Patent Literature 1: International Publication No. WO 2010/082325 (Figs. 7 and 8, for example)

Patent Literature 2: U.S. Patent Application Publication No. 2010/0170270 (Fig. 2, for example)

Patent Literature 3: International Publication No. WO 2012/014345 (paragraph [0006], Fig. 1, for example)

## Summary of Invention

## 10 Technical Problem

**[0007]** In an air-conditioning apparatus disclosed in each of Patent Literature 1 and Patent Literature 2, a plurality of outdoor heat exchangers are used such that an outdoor heat exchanger is operated as an evaporator for the heating operation and another outdoor heat exchanger is operated as a condenser for the defrosting operation, and the heating operation and the defrosting operation are simultaneously performed. While the defrosting operation is performed such that one outdoor heat exchanger is operated as a condenser, part of gas refrigerant discharged from a compressor flows into the condenser and only sensible heat of the gas refrigerant is used to perform the defrosting operation. The difference in enthalpy between a point prior to the condenser and a point after the condenser is accordingly insufficient. To achieve sufficient defrosting capacity, a circulation amount of part of the gas refrigerant discharged from the compressor has to be increased. This increase causes a decrease in the amount of refrigerant supplied to the evaporator, resulting in a decrease in indoor heating capacity. This leads to a reduction in comfort of an indoor environment.

**[0008]** In an air-conditioning apparatus disclosed in Patent Literature 3, while the defrosting operation is performed such that an outdoor heat exchanger is operated as a condenser, an expansion device having a variable opening degree disposed in a passage on a refrigerant outlet side of the condenser is controlled to accumulate the refrigerant in the condenser. This enables intermediate pressure defrosting. Consequently, the pressure of the refrigerant in the condenser is increased to allow a saturation temperature of the refrigerant to be slightly higher than 0 degrees C (in a range from above approximately 0 to approximately 10 degrees C), such that the saturation temperature is higher than the temperature of frost. Thus, latent heat of two-phase part of the refrigerant can be used and a sufficient difference in enthalpy between a point prior to the condenser and a point after the condenser can be ensured, so that sufficient defrosting capacity can be achieved with a smaller amount of refrigerant than that in the above-described defrosting operation.

**[0009]** The term "intermediate pressure defrosting" as used herein refers to a defrosting operation performed under conditions where the refrigerant in the condenser, serving as a defrosting target, has a pressure that is lower than a discharge pressure of a compressor and is higher

than a suction pressure of the compressor (or has a pressure equivalent to a temperature slightly higher than 0 degrees C in terms of saturation temperature).

**[0010]** It is, however, necessary to accumulate the refrigerant in the condenser so that latent heat of two-phase part of the refrigerant can be used. In other words, accumulating the refrigerant in the condenser reduces the total amount of refrigerant in a refrigeration cycle, resulting in a decrease in the amount of refrigerant supplied to an evaporator. This results in a decrease in indoor heating capacity, leading to a reduction in comfort of an indoor environment. Additionally, sufficient defrosting capacity is not achieved until the refrigerant is accumulated in the condenser, because latent heat of two-phase part of the refrigerant cannot be used. Disadvantageously, the time required for defrosting is increased, resulting in a decrease in indoor heating capacity. This leads to a reduction in comfort of the indoor environment.

**[0011]** The present invention has been made in consideration of the above-described problems and is intended to provide an air-conditioning apparatus in which, while a heating operation for an indoor space and a defrosting operation are simultaneously performed such that an outdoor heat exchanger is operated as a condenser, a decrease in indoor heating capacity and a decrease in defrosting capacity can be eliminated or reduced.

#### Solution to Problem

**[0012]** The present invention provides an air-conditioning apparatus (100, 200) capable of simultaneously performing a heating operation and a defrosting operation. The apparatus includes a main circuit including a compressor (10), a load side heat exchanger (21), a load side expansion device (22), a plurality of heat source side heat exchangers (12) connected in parallel, and an accumulator (13) that are connected by refrigerant pipes to form at least a heating circuit, a first gas bypass pipe (5) branching off from the refrigerant pipe on a discharge side of the compressor (10) and allowing refrigerant to flow into a defrosting-target heat source side heat exchanger (12) of the heat source side heat exchangers (12), a second gas bypass pipe (7) branching off from the refrigerant pipe on the discharge side of the compressor (10) and allowing the refrigerant to flow into the accumulator (13), a plurality of first opening and closing devices (30), arranged in the first gas bypass pipe (5), permitting or stopping the flow of the refrigerant through the first gas bypass pipe (5), and at least one second opening and closing device (35), disposed in the second gas bypass pipe (7), permitting or stopping the flow of the refrigerant through the second gas bypass pipe (7).

#### Advantageous Effects of Invention

**[0013]** In the air-conditioning apparatus according to the present invention, while the defrosting operation in

which at least one of the heat source side heat exchangers is operated as a condenser is performed simultaneously with the heating operation in which the load side heat exchanger is operated as a condenser and at least one of the other heat source side heat exchangers is operated as an evaporator, the refrigerant accumulating in the accumulator can be supplied to the evaporator and the condensers. In the air-conditioning apparatus according to the present invention, a decrease in the total amount of refrigerant in a refrigeration cycle can be eliminated or reduced, thus eliminating or reducing a decrease in heating capacity and defrosting capacity. Consequently, in the air-conditioning apparatus according to the present invention, the time required for defrosting is shortened and a decrease in heating capacity is eliminated or reduced, thus achieving comfort of an indoor environment.

#### Brief Description of Drawings

#### **[0014]**

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

[Fig. 2] Fig. 2 is a schematic diagram illustrating an example of the configuration of heat source side heat exchangers of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a refrigerant circuit diagram illustrating the flow of refrigerant in a cooling only operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a refrigerant circuit diagram illustrating the flow of the refrigerant in a heating only operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a refrigerant circuit diagram illustrating the flow of the refrigerant in a defrosting operation mode, in which the heat source side heat exchanger is defrosted, of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a graph illustrating a change in enthalpy difference, available for defrosting, caused by a change in saturation temperature in the heat source side heat exchanger, serving as a defrosting-target heat exchanger, of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 7] Fig. 7 is a graph illustrating the rate of heating capacity in the defrosting mode with respect to a saturation temperature in the heat source side heat exchanger, serving as a defrosting-target heat exchanger, of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 8] Fig. 8 is a flowchart illustrating control for operating a second opening and closing device in

the defrosting operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 9] Fig. 9 is a graph illustrating a change in saturation temperature converted from a pressure in a load side heat exchanger with respect to a change in flow rate of high temperature, high pressure gas refrigerant flowing into an accumulator in the defrosting operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 10] Fig. 10 is a schematic circuit diagram illustrating another example of the circuit configuration of the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 11] Fig. 11 is a schematic circuit diagram illustrating an example of the circuit configuration of an air-conditioning apparatus according to Embodiment 2 of the present invention.

#### Description of Embodiments

**[0015]** Embodiments of the present invention will be described with reference to the drawings. Note that the dimensional relationship among components in Fig. 1 and subsequent figures may be different from the actual one. Furthermore, note that components designated by the same reference numerals in Fig. 1 and the subsequent figures are the same components or equivalents. The above notes are intended to be common throughout this specification. Furthermore, note that the forms of components described in the specification are intended to be illustrative only and are not intended to be limited to the descriptions.

#### Embodiment 1

**[0016]** Fig. 1 is a schematic circuit diagram illustrating an example of the circuit configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present invention.

**[0017]** The configuration of the air-conditioning apparatus 100 will now be described in detail with reference to Fig. 1.

**[0018]** The air-conditioning apparatus 100 conditions air using a refrigeration cycle through which refrigerant is circulated. The air-conditioning apparatus 100 permits selection of any one of a cooling only operation mode in which all of operating indoor units 2 perform cooling, a heating only operation mode in which all of the operating indoor units 2 perform heating, and a defrosting operation mode in which the indoor units 2 continuously perform a heating operation and heat exchangers (a heat source side heat exchanger 12a and a heat source side heat exchanger 12b) in an outdoor unit 1 are defrosted.

**[0019]** As illustrated in Fig. 1, the air-conditioning apparatus 100 includes the outdoor unit 1 and the indoor unit 2 such that the outdoor unit 1 and the indoor unit 2 are connected by refrigerant main pipes 4. In the following

description, the heat source side heat exchanger 12a and the heat source side heat exchanger 12b may be collectively referred to as heat source side heat exchangers 12 or a heat source side heat exchanger 12.

[Outdoor Unit 1]

**[0020]** The outdoor unit 1 includes a compressor 10, a refrigerant flow switching device 11, such as a four-way valve, the heat source side heat exchanger 12a, the heat source side heat exchanger 12b, an accumulator 13, a first opening and closing device 30a, a first opening and closing device 30b, a second opening and closing device 35, a third opening and closing device 31 a, a third opening and closing device 31 b, a flow control device 32a, and a flow control device 32b. These components are connected by refrigerant pipes 3, a first gas bypass pipe 5, and a second gas bypass pipe 7 in the outdoor unit 1.

**[0021]** The refrigerant pipes 3 connect the compressor 10, the refrigerant flow switching device 11, the heat source side heat exchanger 12a, the heat source side heat exchanger 12b, the flow control device 32a, the flow control device 32b, and the accumulator 13. The heat source side heat exchanger 12a and the heat source side heat exchanger 12b are connected in parallel by the refrigerant pipes 3.

**[0022]** The first gas bypass pipe 5 is connected at a first end to the refrigerant pipe 3 between a discharge outlet of the compressor 10 and the refrigerant flow switching device 11. The first gas bypass pipe 5 branches into two pipes at a second end. At the second end of the first gas bypass pipe 5, one of the two pipes is connected to the refrigerant pipe 3 between the heat source side heat exchanger 12a and the third opening and closing device 31 a, and the other one of the two pipes is connected to the refrigerant pipe 3 between the heat source side heat exchanger 12b and the third opening and closing device 31 b.

**[0023]** The first opening and closing device 30a is disposed in the first gas bypass pipe 5 connected to the heat source side heat exchanger 12a.

**[0024]** The first opening and closing device 30b is disposed in the first gas bypass pipe 5 connected to the heat source side heat exchanger 12b.

**[0025]** The second gas bypass pipe 7 is connected at a first end to the refrigerant pipe 3 between the discharge outlet of the compressor 10 and the refrigerant flow switching device 11. The second gas bypass pipe 7 is connected at a second end to the refrigerant pipe 3 between the refrigerant flow switching device 11 and the accumulator 13.

**[0026]** The second opening and closing device 35 is disposed in the second gas bypass pipe 7.

**[0027]** The third opening and closing device 31 a for stopping the flow of the refrigerant into the heat source side heat exchanger 12a is disposed in the refrigerant pipe 3 between the heat source side heat exchanger 12a

and the refrigerant flow switching device 11.

**[0028]** The third opening and closing device 31 b for stopping the flow of the refrigerant into the heat source side heat exchanger 12b is disposed in the refrigerant pipe 3 between the heat source side heat exchanger 12b and the refrigerant flow switching device 11.

**[0029]** Each of the heat source side heat exchangers 12a and 12b is a finned tube heat exchanger including a plurality of plate-shaped fins (fins 51 in Fig. 2) and heat transfer tubes (heat transfer tubes 52 in Fig. 2) extending through and orthogonal to the fins. An example of the configuration of the heat source side heat exchangers 12 will now be described with reference to Fig. 2. Fig. 2 is a schematic diagram illustrating an example of the configuration of the heat source side heat exchangers 12 of the air-conditioning apparatus 100.

**[0030]** As illustrated in Fig. 2, the heat source side heat exchanger 12 is divided into a plurality of heat exchangers. A configuration in which the heat source side heat exchanger 12 is divided into the two heat source side heat exchangers 12a and 12b will be described as an example. The heat source side heat exchangers 12a and 12b each include two adjacent sets of fins 51 arranged in a set arrangement direction (or a left-right direction along the width of the fins aligned so as to face in the same direction). The heat source side heat exchangers 12a and 12b are arranged at two levels in a level arrangement direction (or a top-bottom direction along the length of the fins aligned so as to face in the same direction) in which the heat transfer tubes 52 are arranged at different levels.

**[0031]** In other words, the heat source side heat exchanger 12 is divided into the heat source side heat exchangers 12a and 12b in a housing of the outdoor unit 1 such that the heat source side heat exchangers 12a and 12b are arranged in the top-bottom direction along the length of the fins 51 aligned so as to face in the same direction. For example, as illustrated in Fig. 2, the heat source side heat exchanger 12a is disposed at an upper level, the heat source side heat exchanger 12b is disposed at a lower level, and each of the fins 51 extending in the level arrangement direction is a one-piece member (shared by the heat source side heat exchangers).

**[0032]** As illustrated in Fig. 2, a refrigerant passage to the heat source side heat exchanger 12a may be divided by a distributor 12a-1 and a header 12a-2. Similarly, a refrigerant passage to the heat source side heat exchanger 12b may be divided by a distributor 12b-1 and a header 12b-2 as illustrated in Fig. 2.

**[0033]** In the above-described configuration of Fig. 2, the two adjacent sets of fins are arranged in the set arrangement direction (or the left-right direction along the width of the fins aligned so as to face in the same direction). In addition, one set, three sets, or more sets may be arranged. Another pass pattern different from that in Fig. 2 may be used. As regards the heat source side heat exchangers 12, a plurality of heat source side heat exchangers may be arranged at three or more levels in the

level arrangement direction (or the top-bottom direction along the length of the fins aligned so as to face in the same direction) and each of the fins extending in the level arrangement direction may be a one-piece member (shared by the heat source side heat exchangers). The number of levels for arrangement of the heat source side heat exchangers is not limited to that illustrated in Fig. 2. More or less than two levels may be arranged.

**[0034]** The heat transfer tubes 52, through which the refrigerant passes, are arranged at multiple levels in the level arrangement direction perpendicular to an air passing direction such that multiple columns of heat transfer tubes are arranged in the set arrangement direction identical to the air passing direction.

**[0035]** The fins 51 are spaced apart such that the air passes through the fins in the air passing direction.

**[0036]** Although the heat source side heat exchanger 12 may be divided into two heat exchangers arranged in the left-right direction, pipe connection would be complicated in such arrangement, because a refrigerant inlet of the heat source side heat exchanger 12a and a refrigerant inlet of the heat source side heat exchanger 12b would be arranged at opposite ends of the outdoor unit 1 in the left-right direction. It is therefore preferred that the heat source side heat exchanger 12 be divided into two heat exchangers arranged in the top-bottom direction, as illustrated in Fig. 2.

**[0037]** As regards the fins 51 of the heat source side heat exchangers 12a and 12b, each fin 51 may be a one-piece member as illustrated in Fig. 2 or may be divided into two segments corresponding to the heat exchangers. The number of heat exchangers obtained by dividing the heat source side heat exchanger 12 is not limited to two. The heat source side heat exchanger 12 may be divided into any number of heat exchangers.

**[0038]** Furthermore, outdoor air is sent to the heat source side heat exchangers 12a and 12b by an air-sending device (not illustrated), such as a fan.

**[0039]** The air-sending devices may be arranged in one-to-one correspondence to the heat source side heat exchangers 12a and 12b. Alternatively, a single air-sending device may be shared by the heat source side heat exchangers 12a and 12b.

**[0040]** The flow control device 32a has a variable opening degree. The flow control device 32a is disposed in the refrigerant pipe 3 extending from the heat source side heat exchanger 12a toward a load side expansion device 22.

**[0041]** The flow control device 32b has a variable opening degree. The flow control device 32b is disposed in the refrigerant pipe 3 extending from the heat source side heat exchanger 12b toward the load side expansion device 22.

**[0042]** The compressor 10 sucks the refrigerant and compresses the refrigerant into a high temperature, high pressure state. The compressor 10 is, for example, a capacity-controllable inverter compressor.

**[0043]** The refrigerant flow switching device 11 switch-

es a refrigerant flow direction in the heating only operation mode and a refrigerant flow direction in the cooling only operation mode.

**[0044]** The heat source side heat exchangers 12a and 12b function as evaporators in the heating only operation mode and function as condensers in the cooling only operation mode. In the defrosting operation, one of the heat source side heat exchangers 12a and 12b functions as an evaporator and the other one of them functions as a condenser.

**[0045]** The accumulator 13, which is disposed on a suction side of the compressor 10, stores an excess of refrigerant caused by the difference between an operation state in the heating only operation mode and that in the cooling only operation mode or an excess of refrigerant caused by a transient change in operation.

**[0046]** The first opening and closing device 30a permits high temperature refrigerant flowing through the first gas bypass pipe 5 to flow into the heat source side heat exchanger 12a when the heat source side heat exchanger 12a operates as a condenser in the defrosting operation mode.

**[0047]** The first opening and closing device 30b permits high temperature refrigerant flowing through the first gas bypass pipe 5 to flow into the heat source side heat exchanger 12b when the heat source side heat exchanger 12b operates as a condenser in the defrosting operation mode.

**[0048]** Each of the first opening and closing devices 30a and 30b may be a component capable of opening and closing a refrigerant passage, for example, a two-way valve, a solenoid valve, or an electronic expansion valve.

**[0049]** In the following description, the first opening and closing devices 30a and 30b may be collectively referred to as first opening and closing devices 30.

**[0050]** The third opening and closing device 31 a closes a refrigerant passage to prevent low temperature two-phase refrigerant, flowing from the indoor unit 2 through the refrigerant main pipe 4 to the outdoor unit 1, from flowing into the heat source side heat exchanger 12a when the heat source side heat exchanger 12a operates as a condenser in the defrosting operation mode.

**[0051]** The third opening and closing device 31 b closes a refrigerant passage to prevent low temperature two-phase refrigerant, flowing from the indoor unit 2 through the refrigerant main pipe 4 to the outdoor unit 1, from flowing into the heat source side heat exchanger 12b when the heat source side heat exchanger 12b operates as a condenser in the defrosting operation mode.

**[0052]** Each of the third opening and closing devices 31 a and 31 b may be a component capable of opening and closing the refrigerant passage, for example, a two-way valve, a solenoid valve, or an electronic expansion valve.

**[0053]** In the following description, the third opening and closing devices 31 a and 31 b may be collectively referred to as third opening and closing devices 31.

**[0054]** Each of the flow control devices 32a and 32b is an expansion device whose opening degree (opening area) is variable to control a pressure in the heat source side heat exchanger 12 functioning as a condenser.

**[0055]** Each of the flow control devices 32a and 32b may be, for example, an electronic expansion valve that is driven by a stepping motor or may include a plurality of small solenoid valves arranged in parallel such that the opening area is changed by switching the valves.

**[0056]** In the following description, the flow control devices 32a and 32b may be collectively referred to as flow control devices 32.

**[0057]** The second opening and closing device 35 permits part of high temperature, high pressure gas refrigerant discharged from the compressor 10 in the defrosting operation mode to flow into the accumulator 13.

**[0058]** The second opening and closing device 35 may be a component capable of opening and closing the refrigerant passage, for example, a two-way valve, a solenoid valve, or an electronic expansion valve.

**[0059]** The outdoor unit 1 includes, as pressure detecting units, a first pressure sensor 41 and a second pressure sensor 42.

**[0060]** The first pressure sensor 41 is disposed in the refrigerant pipe 3 between the compressor 10 and the refrigerant flow switching device 11. The first pressure sensor 41 detects a pressure of high temperature, high pressure refrigerant discharged from the compressor 10.

**[0061]** The second pressure sensor 42 is disposed in the refrigerant pipe 3 between the refrigerant flow switching device 11 and the accumulator 13. The second pressure sensor 42 detects a pressure of low pressure refrigerant to be sucked into the compressor 10.

**[0062]** The outdoor unit 1 includes, as temperature detecting units, a first temperature sensor 43, a second temperature sensor 45, a third temperature sensor 48a, and a third temperature sensor 48b. Each of the first temperature sensor 43, the second temperature sensor 45, and the third temperature sensors 48a and 48b may be, for example, a thermistor.

**[0063]** The first temperature sensor 43 is disposed in the refrigerant pipe 3 between the compressor 10 and the refrigerant flow switching device 11. The first temperature sensor 43 measures a temperature of the refrigerant discharged from the compressor 10.

**[0064]** The second temperature sensor 45 is disposed in an air inlet of either the heat source side heat exchanger 12a or the heat source side heat exchanger 12b. The second temperature sensor 45 measures a temperature of ambient air around the outdoor unit 1.

**[0065]** The third temperature sensor 48a is disposed in the refrigerant pipe 3 between the heat source side heat exchanger 12a and the refrigerant flow switching device 11. The third temperature sensor 48a measures a temperature of the refrigerant flowing into the heat source side heat exchanger 12a operating as an evaporator or a temperature of the refrigerant flowing out of the heat source side heat exchanger 12a operating as a

condenser.

**[0066]** The third temperature sensor 48b is disposed in the refrigerant pipe 3 between the heat source side heat exchanger 12b and the refrigerant flow switching device 11. The third temperature sensor 48b measures a temperature of the refrigerant flowing into the heat source side heat exchanger 12b operating as an evaporator or a temperature of the refrigerant flowing out of the heat source side heat exchanger 12b operating as a condenser.

**[0067]** The outdoor unit 1 further includes a controller 50. Information about the pressures detected by the first pressure sensor 41 and the second pressure sensor 42 and information about the temperatures detected by the first temperature sensor 43, the second temperature sensor 45, and the third temperature sensors 48a and 48b are input to the controller 50.

[Indoor Unit 2]

**[0068]** The indoor unit 2 includes a load side heat exchanger 21 and the load side expansion device 22 connected in series.

**[0069]** The load side heat exchanger 21 is connected to the outdoor unit 1 by the refrigerant main pipes 4 such that the refrigerant flows into and out of the load side heat exchanger 21. The load side heat exchanger 21 exchanges heat between the refrigerant and air supplied from an air-sending device (not illustrated), such as a fan. The load side heat exchanger 21 produces heating air or cooling air to be supplied to an indoor space. A heat medium for heat exchange with the refrigerant in the load side heat exchanger 21 is not limited to the air. The heat medium may be, for example, water or brine.

**[0070]** The load side expansion device 22 functions as a pressure reducing valve or an expansion valve to depressurize the refrigerant such that the refrigerant is expanded. The load side expansion device 22 is disposed upstream of the load side heat exchanger 21 in the refrigerant flow direction in the cooling only operation mode. The load side expansion device 22 includes a component having a variably controllable opening degree. The load side expansion device 22 may be, for example, an electronic expansion valve.

**[0071]** The indoor unit 2 includes, as temperature detecting units, a fourth temperature sensor 46, a fifth temperature sensor 47, and a sixth temperature sensor 44. Each of the fourth temperature sensor 46, the fifth temperature sensor 47, and the sixth temperature sensor 44 may be, for example, a thermistor.

**[0072]** The fourth temperature sensor 46 is disposed in the refrigerant pipe 3 between the load side expansion device 22 and the load side heat exchanger 21. The fourth temperature sensor 46 detects a temperature of the refrigerant flowing into the load side heat exchanger 21 or a temperature of the refrigerant flowing out of the load side heat exchanger 21.

**[0073]** The fifth temperature sensor 47 is disposed in

the refrigerant pipe 3 between the load side heat exchanger 21 and the refrigerant flow switching device 11 of the outdoor unit 1. The fifth temperature sensor 47 detects a temperature of the refrigerant flowing into the load side heat exchanger 21 or a temperature of the refrigerant flowing out of the load side heat exchanger 21.

**[0074]** The sixth temperature sensor 44 is disposed in an air inlet of the load side heat exchanger 21. The sixth temperature sensor 44 detects a temperature of ambient air in the indoor space.

**[0075]** Information about the temperatures detected by the fourth temperature sensor 46, the fifth temperature sensor 47, and the sixth temperature sensor 44 is input to the controller 50 disposed in the outdoor unit 1.

**[0076]** In the air-conditioning apparatus 100 with the above-described configuration, the compressor 10, the refrigerant flow switching device 11, the load side heat exchanger 21, the load side expansion device 22, and the heat source side heat exchangers 12a and 12b connected in parallel are connected in sequence by the pipes to form a main circuit through which the refrigerant is circulated and a bypass through which part of the refrigerant discharged from the compressor 10 is allowed to flow to the heat source side heat exchanger 12, serving as a defrosting target, that is, either the heat source side heat exchanger 12a or the heat source side heat exchanger 12b.

**[0077]** Although the case where, as illustrated in Fig. 1, one indoor unit 2 is connected to one outdoor unit 1 by the refrigerant main pipes 4 is illustrated as an exemplary configuration in Embodiment 1, the present invention is not limited to this configuration. The air-conditioning apparatus 100 may include a plurality of indoor units 2. The indoor units 2 may be connected in parallel with one outdoor unit 1. In addition, two or more outdoor units may be connected in parallel. Furthermore, the air-conditioning apparatus 100 may include a refrigerant circuit that enables a cooling and heating mixed operation, in which the cooling operation or the heating operation can be selected in each indoor unit, by connecting three extension pipes in parallel or disposing a switching valve in each indoor unit.

**[0078]** The air-conditioning apparatus 100 includes the controller 50, which includes a microcomputer. The controller 50 controls, for example, driving frequency of the compressor 10, a rotation speed (including ON/OFF) of each air-sending device, switching of the refrigerant flow switching device 11, opening and closing of the first opening and closing devices 30a and 30b, opening and closing of the third opening and closing devices 31, and the opening degree of the load side expansion device 22 on the basis of information about detection results of the individual detecting units and an instruction from a remote control, thus performing any of the operation modes, which will be described later.

**[0079]** Although Fig. 1 illustrates the case where the controller 50 is installed in the outdoor unit 1, another configuration may be used. For example, the controller

50 may be disposed in each unit or may be disposed in the indoor unit 2. If the controller 50 is disposed in each unit, the controllers 50 may be connected in a wired or wireless manner to achieve communication and cooperative control.

**[0080]** The operation modes performed by the air-conditioning apparatus 100 will now be described.

**[0081]** The operation modes will be described in accordance with the flow of the refrigerant.

[Cooling Only Operation Mode]

**[0082]** Fig. 3 is a refrigerant circuit diagram illustrating the flow of the refrigerant in the cooling only operation mode of the air-conditioning apparatus 100. The cooling only operation mode performed by the air-conditioning apparatus 100 will now be described with reference to Fig. 3. The cooling only operation mode will be described on the assumption that, for example, a cooling load is generated in the load side heat exchanger 21 in Fig. 3. In Fig. 3, solid-line arrows indicate the refrigerant flow direction.

**[0083]** In the cooling only operation mode, the refrigerant flow switching device 11 is switched to a state illustrated by solid lines in Fig. 2. Each of the first opening and closing devices 30a and 30b and the second opening and closing device 35 is switched to a closed state, thus stopping the flow of the refrigerant. Each of the third opening and closing devices 31 a and 31 b and the flow control devices 32a and 32b is switched to an open state, thus permitting the flow of the refrigerant.

**[0084]** When the compressor 10 is driven, low temperature, low pressure refrigerant is compressed into high temperature, high pressure gas refrigerant and is then discharged. The high temperature, high pressure gas refrigerant discharged from the compressor 10 flows through the refrigerant flow switching device 11 and divides into two refrigerant streams, which flow into the heat source side heat exchangers 12a and 12b. In the heat source side heat exchangers 12a and 12b, the high temperature, high pressure gas refrigerant streams that have flowed into the heat source side heat exchangers 12a and 12b transfer heat to outdoor air, so that the refrigerant turns into high pressure liquid refrigerant. The high pressure liquid refrigerant streams flow out of the heat source side heat exchangers 12a and 12b, pass through the flow control devices 32a and 32b, and then merge together. The refrigerant flows out of the outdoor unit 1.

**[0085]** The high pressure liquid refrigerant leaving the outdoor unit 1 passes through the refrigerant main pipe 4, flows into the indoor unit 2, and is expanded by the load side expansion device 22, so that the refrigerant turns into low temperature, low pressure two-phase refrigerant. The two-phase refrigerant flows into the load side heat exchanger 21 operating as an evaporator and removes heat from indoor air to cool the indoor air, so that the refrigerant turns into low temperature, low pres-

sure gas refrigerant. The gas refrigerant flows out of the load side heat exchanger 21, passes through the refrigerant main pipe 4, and again flows into the outdoor unit 1. The refrigerant that has flowed into the outdoor unit 1 passes through the refrigerant flow switching device 11 and the accumulator 13 and is again sucked into the compressor 10.

**[0086]** The controller 50 controls the opening degree of the load side expansion device 22 to provide a constant superheat (degree of superheat). The degree of superheat is obtained as the difference between a temperature detected by the fourth temperature sensor 46 and a temperature detected by the fifth temperature sensor 47.

[Heating Only Operation Mode]

**[0087]** Fig. 4 is a refrigerant circuit diagram illustrating the flow of the refrigerant in the heating only operation mode of the air-conditioning apparatus 100. The heating only operation mode performed by the air-conditioning apparatus 100 will now be described with reference to Fig. 4. The heating only operation mode will be described on the assumption that a heating load is generated in the load side heat exchanger 21 in Fig. 4. In Fig. 4, solid-line arrows indicate the refrigerant flow direction.

**[0088]** In the heating only operation mode, the refrigerant flow switching device 11 is switched to a state indicated by solid lines in Fig. 3. Each of the first opening and closing devices 30a and 30b and the second opening and closing device 35 is switched to the closed state, thus stopping the flow of the refrigerant. Each of the third opening and closing devices 31 a and 31 b and the flow control devices 32a and 32b is switched to the open state, thus permitting the flow of the refrigerant.

**[0089]** When the compressor 10 is driven, low temperature, low pressure refrigerant is compressed into high temperature, high pressure gas refrigerant and is then discharged. The high temperature, high pressure gas refrigerant discharged from the compressor 10 passes through the refrigerant flow switching device 11 and flows out of the outdoor unit 1.

**[0090]** The high temperature, high pressure gas refrigerant leaving the outdoor unit 1 passes through the refrigerant main pipe 4 and flows into the indoor unit 2. The refrigerant transfers heat to indoor air in the load side heat exchanger 21 to heat the indoor air, so that the refrigerant turns into liquid refrigerant. The liquid refrigerant flows out of the load side heat exchanger 21 and is then expanded by the load side expansion device 22, so that the refrigerant turns into low temperature, intermediate pressure two-phase refrigerant or liquid refrigerant. The refrigerant passes through the refrigerant main pipe 4 and again flows into the outdoor unit 1.

**[0091]** The low temperature, intermediate pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 passes through the flow control devices 32a and 32b and flows into the heat source side heat exchangers 12a and 12b. The refrigerant that has

flowed into the heat source side heat exchangers 12a and 12b removes heat from outdoor air, so that the refrigerant turns into low temperature, low pressure gas refrigerant. The refrigerant passes through the refrigerant flow switching device 11 and the accumulator 13 and is again sucked into the compressor 10.

**[0092]** The controller 50 controls the opening degree of the load side expansion device 22 to provide a constant subcooling (degree of subcooling). The degree of subcooling is obtained as the difference between a saturation temperature converted from a pressure detected by the first pressure sensor 41 and a temperature detected by the fourth temperature sensor 46.

[Defrosting Operation Mode]

**[0093]** The defrosting operation mode is performed when a detection result of each of the third temperature sensors 48a and 48b arranged on outlet sides of the heat source side heat exchangers 12a and 12b is less than or equal to a predetermined value. Specifically, when a detection result of each of the third temperature sensors 48a and 48b is less than or equal to the predetermined value (for example, less than or equal to approximately -10 degrees C) in the heating only operation mode, the controller 50 determines that the fins of the heat source side heat exchangers 12a and 12b have a predetermined amount of frost, and then performs the defrosting operation mode.

**[0094]** Another method may be used for frost formation determination. For example, when a saturation temperature converted from a suction pressure of the compressor 10 significantly falls as compared with a preset outdoor air temperature, or alternatively, when the difference between an outdoor air temperature and an evaporating temperature is greater than or equal to a preset value for a certain period of time, it may be determined that frost is formed.

**[0095]** In the defrosting operation mode of the air-conditioning apparatus 100, the heat source side heat exchanger 12b at the lower level is defrosted and, after that, the heat source side heat exchanger 12a at the upper level is defrosted. In addition, the heat source side heat exchanger 12 that is not a defrosting target of the heat source side heat exchangers 12a and 12b is allowed to operate as an evaporator, and the load side heat exchanger 21 of the indoor unit 2 is allowed to operate as a condenser, thus continuing the heating operation.

(Defrosting of Heat Source Side Heat Exchanger 12b)

**[0096]** Fig. 5 is a refrigerant circuit diagram illustrating the flow of the refrigerant in the defrosting operation mode of the air-conditioning apparatus 100 in which the heat source side heat exchanger 12b is defrosted. In Fig. 4, solid-line arrows indicate the refrigerant flow direction.

**[0097]** In the defrosting operation mode, the refrigerant flow switching device 11 is maintained in the state indi-

cated by solid lines in Fig. 5.

**[0098]** In the defrosting operation mode in which the heat source side heat exchanger 12b is a defrosting target, the first opening and closing devices 30, the second opening and closing device 35, the third opening and closing devices 31, and the flow control devices 32 have the following states.

**[0099]** The controller 50 controls the states of those devices.

**[0100]** The first opening and closing device 30b is switched to the open state, thus permitting the flow of the refrigerant.

**[0101]** The third opening and closing device 31 b is switched to the closed state, thus stopping the flow of the refrigerant.

**[0102]** The first opening and closing device 30a is maintained in the closed state to stop the flow of the refrigerant.

**[0103]** The third opening and closing device 31 a is maintained in the open state to permit the flow of the refrigerant.

**[0104]** The flow control device 32a is set to a fully open state to permit the flow of the refrigerant.

**[0105]** The opening degree of the flow control device 32b is controlled so that a preset pressure (for example, approximately 0.8 MPa for R410A refrigerant) remains constant. At the preset pressure, a saturation temperature converted from a saturation pressure of two-phase refrigerant calculated based on a detection result of the third temperature sensor 48b is greater than 0 degrees C.

**[0106]** When either one of a condition that an outdoor air temperature detected by the second temperature sensor 45 is less than or equal to a second predetermined value (for example, less than or equal to 0 degrees C) and a condition that a pressure at a suction inlet of the compressor 10 detected by the second pressure sensor 42 is less than or equal to a first predetermined value (for example, less than or equal to approximately 0.3 MPa for R410A refrigerant) is satisfied, or alternatively, when both the conditions are satisfied, the second opening and closing device 35 is maintained in the open state to permit the flow of the refrigerant.

**[0107]** The second temperature sensor 45 and the second pressure sensor 42 correspond to a defrosting mode refrigerant decrease detecting unit in the present invention.

**[0108]** If either the condition associated with the second temperature sensor 45 or the condition associated with the second pressure sensor 42 is satisfied in the defrosting operation mode, a shortage of refrigerant circulated through the main circuit may be determined. If either one of the sensors breaks down, functions of the defrosting mode refrigerant decrease detecting unit can be reliably achieved by making the above determination based on both the conditions.

**[0109]** Fig. 6 is a graph illustrating a change in enthalpy difference, available for defrosting, caused by a change in saturation temperature in the heat source side heat

exchanger 12 that serves as a defrosting-target heat exchanger in the air-conditioning apparatus 100. In Fig. 6, the horizontal axis represents the saturation temperature in the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger. The left vertical axis represents an average refrigerant density ( $\text{kg/m}^3$ ) in the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger. The right vertical axis represents the difference in enthalpy ( $\text{kJ/kg}$ ) between an inlet and an outlet of the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger. In Fig. 6, a solid line represents an average refrigerant density necessary for the saturation temperature in the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger. In Fig. 6, a dashed line represents the difference in enthalpy, or enthalpy difference that is caused by a change in saturation temperature in the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger, and that is available for defrosting.

**[0110]** In Fig. 6, as indicated by the dashed line, it can be seen that the enthalpy difference available for defrosting increases at saturation temperatures ranging from above 0 degrees C and to approximately 1 degree C in the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger, latent heat of two-phase part of the refrigerant can be used more effectively, and the necessary average refrigerant density in the heat source side heat exchanger 12 at that time is approximately  $600 \text{ (kg/m}^3\text{)}$  or greater. In other words, when the defrosting operation is performed such that latent heat of two-phase part of the refrigerant is effectively used, the refrigerant having an average refrigerant density of approximately  $600 \text{ (kg/m}^3\text{)}$  or greater has to be accumulated in the heat source side heat exchanger 12.

**[0111]** When the refrigerant having an average refrigerant density of approximately  $600 \text{ (kg/m}^3\text{)}$  or greater is supplied to the heat source side heat exchanger 12 in the defrosting operation mode, the refrigerant in the load side heat exchanger 21 used as a condenser for the heating operation moves into the heat source side heat exchanger 12. Consequently, the amount of refrigerant in the load side heat exchanger 21 decreases, leading to a decrease in pressure (high pressure) in the load side heat exchanger 21. In addition, a decrease in the amount of gas refrigerant in the whole cycle results in a decrease in low pressure. While the load side heat exchanger 21 is used as a condenser, air supplied to the indoor space has to be at such a temperature that cold air does not cause user discomfort.

**[0112]** The indoor air temperature and the saturation temperature converted from the pressure in the load side heat exchanger 21 have to have a temperature difference of a predetermined value or greater (for example, 10 degrees C or greater) therebetween. For example, according to Japanese Industrial Standards JIS B 8616, serving as the standards for performance evaluation of package air conditioners, when a set temperature of an indoor

environment in the heating operation is 20 degrees C, the saturation temperature converted from the pressure in the load side heat exchanger 21 has to be at or above 30 degrees C. In the defrosting operation mode, therefore, a pressure on a low-pressure side under circumstances where the saturation temperature converted from the pressure in the load side heat exchanger 21 can be at or above 30 degrees C is approximately 0.3 MPa, which is the first predetermined value.

**[0113]** Furthermore, in the defrosting operation under conditions where the outdoor air temperature is at or below approximately 0 degrees C, which is the second predetermined value, the operation is in a state where the pressure on the low-pressure side is below approximately 0.3 MPa. To accumulate the refrigerant in the heat source side heat exchanger 12 while a decrease in pressure on the low-pressure side is eliminated or reduced, the refrigerant that is not used for the heating operation and the defrosting operation has to be supplied to the heat source side heat exchanger 12.

**[0114]** The flow of the refrigerant in the defrosting operation mode will now be described in detail.

**[0115]** When the compressor 10 is driven, low temperature, low pressure refrigerant is compressed into high temperature, high pressure gas refrigerant and is then discharged.

**[0116]** Part of the high temperature, high pressure gas refrigerant discharged from the compressor 10 flows through the first gas bypass pipe 5 and is then depressurized to a pressure equivalent to greater than 0 degrees C in terms of saturation temperature by the first opening and closing device 30b, so that the refrigerant turns into intermediate pressure, high temperature gas refrigerant. The refrigerant flows into the heat source side heat exchanger 12b. The intermediate pressure, high temperature gas refrigerant that has flowed into the heat source side heat exchanger 12b turns into intermediate pressure, low quality two-phase refrigerant or intermediate pressure liquid refrigerant while melting frost on the heat source side heat exchanger 12b. The refrigerant then passes through the flow control device 32b. The refrigerant leaving the flow control device 32b merges with intermediate pressure, low temperature, low quality two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 from the indoor unit 2 at a point upstream of the flow control device 32a.

**[0117]** The other part of the high temperature, high pressure gas refrigerant discharged from the compressor 10 passes through the refrigerant flow switching device 11 and flows out of the outdoor unit 1. The high temperature, high pressure gas refrigerant leaving the outdoor unit 1 passes through the refrigerant main pipe 4, flows into the indoor unit 2, and transfers heat to indoor air in the load side heat exchanger 21, so that the refrigerant turns into liquid refrigerant while heating the indoor air. The liquid refrigerant flows out of the load side heat exchanger 21 and is expanded by the load side expansion device 22, so that the refrigerant turns into low temper-

ature, intermediate pressure two-phase refrigerant or liquid refrigerant. The refrigerant passes through the refrigerant main pipe 4 and again flows into the outdoor unit 1.

**[0118]** The low temperature, intermediate pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 merges with the refrigerant leaving the flow control device 32b at the point upstream of the flow control device 32a. The refrigerant then flows into the heat source side heat exchanger 12a. The refrigerant that has flowed into the heat source side heat exchanger 12a removes heat from outdoor air, so that the refrigerant turns into low temperature, low pressure gas refrigerant. The gas refrigerant flows out of the heat source side heat exchanger 12a, passes through the refrigerant flow switching device 11 and the accumulator 13, and is again sucked into the compressor 10.

**[0119]** The controller 50 controls the opening degree of the flow control device 32b so that the preset pressure (for example, approximately 0.8 MPa for R410A refrigerant), at which a saturation temperature converted from a saturation pressure of two-phase refrigerant calculated based on a detection result of the third temperature sensor 48b is greater than 0 degrees C, remains constant. In other words, the controller 50 controls the opening degree of the flow control device 32b so that the saturation pressure of the two-phase refrigerant calculated based on the detection result of the third temperature sensor 48b is greater than a pressure (for example, approximately 0.8 MPa for R410A refrigerant) equivalent to greater than 0 degrees C in terms of saturation temperature.

**[0120]** As regards the completion of defrosting of the heat source side heat exchanger 12b, the completion of defrosting may be determined, for example, after a lapse of a predetermined period of time, or alternatively, when a temperature detected by the third temperature sensor 48b is greater than or equal to a predetermined value (e.g., 5 degrees C). Assuming that the heat source side heat exchanger 12b is fully covered with frost, the predetermined period of time may be set longer than or equal to the time required to completely defrost the heat source side heat exchanger 12b by allowing part of high temperature, high pressure refrigerant to flow into the heat source side heat exchanger 12b.

**[0121]** While the second opening and closing device 35 is maintained in the open state by the controller 50, a branch flow of the high temperature, high pressure gas refrigerant from a discharge side of the compressor 10 flows through the second gas bypass pipe 7, passes through the second opening and closing device 35, and merges with the low temperature, low pressure gas refrigerant leaving the heat source side heat exchanger 12a. The refrigerant then flows into the accumulator 13. The refrigerant that has flowed into the accumulator 13 causes liquid refrigerant accumulating in the accumulator 13 to evaporate. This evaporation increases the amount of gas refrigerant flowing out of the accumulator 13, thus achieving an increase in density of low pressure gas re-

frigerant. Consequently, the pressure of the low pressure gas refrigerant increases, so that the pressure of the low pressure gas refrigerant can be maintained at a value (for example, approximately 0.3 MPa for R410A refrigerant) greater than the first predetermined value.

**[0122]** If the pressure of the low pressure gas refrigerant is less than or equal to the first predetermined value (for example, less than or equal to approximately 0.3 MPa for R410A refrigerant), the density of the low pressure gas refrigerant would decrease and the amount of refrigerant discharged from the compressor 10 would decrease, leading to a decrease in heating capacity and defrosting capacity. In the air-conditioning apparatus 100, however, the second gas bypass pipe 7 is used to increase the amount of gas refrigerant flowing out of the accumulator 13, so that the pressure of the low pressure gas refrigerant can be increased. This can eliminate or reduce a decrease in the amount of refrigerant discharged from the compressor 10, thus eliminating or reducing a decrease in heating capacity and defrosting capacity.

**[0123]** In the defrosting operation mode, if the outdoor air temperature detected by the second temperature sensor 45 is at or below the second predetermined value (e.g., at or below 0 degrees C), the pressure of the refrigerant in the heat source side heat exchanger 12a used as an evaporator would decrease due to a decrease in outdoor air temperature and frost on the heat source side heat exchanger 12a. The temperature of the refrigerant in the heat source side heat exchanger 12a may reach approximately -27 degrees C in terms of saturation temperature (approximately 0.3 MPa as a saturation pressure) and the pressure of low pressure gas refrigerant at the suction inlet of the compressor 10 may reach the first predetermined value (e.g., approximately 0.3 MPa for R410A refrigerant). If the outdoor air temperature is at or below the second predetermined value (e.g., at or below 0 degrees C), therefore, the second opening and closing device 35 is maintained in the open state by the controller 50, so that a decrease in the amount of refrigerant discharged from the compressor 10 can be eliminated or reduced. Thus, a decrease in heating capacity and defrosting capacity can be eliminated or reduced.

**[0124]** In addition, since the refrigerant accumulating in the accumulator 13 is supplied to the suction inlet of the compressor 10, gas refrigerant having a density higher than that before the second opening and closing device 35 is opened can be sucked into the compressor 10. This can increase the circulation amount of refrigerant discharged from the compressor 10.

**[0125]** As described above, increasing the circulation amount of refrigerant discharged from the compressor 10 enables much refrigerant to be supplied to the heat source side heat exchanger 12b while a sufficient amount of gas refrigerant is supplied from the second gas bypass pipe 7 to the accumulator 13. Consequently, the saturation pressure of two-phase refrigerant in the heat source side heat exchanger 12b can be increased to a value

equivalent to greater than 0 degrees C in terms of saturation temperature more rapidly than in a case where high temperature, high pressure gas refrigerant is not allowed to flow into the accumulator 13 through the second gas bypass pipe 7 and the second opening and closing device 35. Thus, the air-conditioning apparatus 100 can rapidly increase the temperature difference between the frost and the refrigerant necessary for defrosting, thus shortening the time required for defrosting.

**[0126]** To defrost the heat source side heat exchanger 12a after the heat source side heat exchanger 12b is completely defrosted, an operation is performed in a manner obtained by interchanging the letters "a" and "b" added to the reference numerals in the above description about the defrosting operation for the heat source side heat exchanger 12b. Specifically, the open and closed states of the first opening and closing devices 30a and 30b and the third opening and closing devices 31 a and 31 b are the opposite of the above-described states and the refrigerant flow direction in each of the heat source side heat exchangers 12a and 12b is reversed. In addition, the flow control device 32b is fully opened and the opening degree of the flow control device 32a is controlled.

**[0127]** As described above, the saturation temperature of the refrigerant in the heat source side heat exchanger 12 functioning as a condenser in the defrosting operation mode for the heat source side heat exchanger 12 is set at an intermediate pressure (for example, at or above approximately 0.8 MPa for R410A refrigerant) equivalent to a temperature greater than the temperature of frost, that is, 0 degrees C. In the air-conditioning apparatus 100, therefore, a two-phase region (latent heat) of the refrigerant can be used, so that efficient defrosting can be achieved with a small circulation amount of refrigerant, a decrease in indoor heating capacity can be eliminated or reduced, and the indoor space can be kept comfortable.

**[0128]** The air-conditioning apparatus 100 can defrost the heat source side heat exchangers 12a and 12b while continuing the heating operation by performing the above-described defrosting operation mode. The heat source side heat exchanger 12b at the lower level in the housing of the outdoor unit 1 is defrosted and, after that, the heat source side heat exchanger 12a at the upper level is defrosted. This can eliminate a likelihood that water produced by defrosting the heat source side heat exchanger 12a may freeze in the lower heat source side heat exchanger 12b to be defrosted. Efficient defrosting can be achieved.

**[0129]** Fig. 7 illustrates a change in heating capacity relative to the saturation temperature in the heat source side heat exchanger 12 that serves as a defrosting-target heat exchanger. In Fig. 7, the refrigerant excessively accumulates in the heat source side heat exchanger 12 at saturation temperatures greater than 10 degrees C. In such a state, there is no liquid refrigerant accumulating in the accumulator 13, thus causing a shortage of refrigerant

in the whole refrigeration cycle. This leads to a decrease in heating capacity. To solve such a shortage of refrigerant caused by excessive accumulation of the refrigerant in the heat source side heat exchanger 12, the saturation temperature in the heat source side heat exchanger 12 may be in the range from above 0 to 10 degrees C.

**[0130]** Fig. 8 is a flowchart of control for operating the second opening and closing device 35 in the defrosting operation mode of the air-conditioning apparatus 100. An operation of the controller 50 operating the second opening and closing device 35 in the defrosting operation mode will now be described with reference to Fig. 8.

(CT1)

**[0131]** When a detection result of each of the third temperature sensors 48a and 48b is less than or equal to a predetermined value (for example, less than or equal to approximately -10 degrees C) in the heating operation mode, the controller 50 determines that the fins of the heat source side heat exchangers 12a and 12b are covered with a predetermined amount of frost, executes the defrosting operation mode, and proceeds to CT2.

(CT2)

**[0132]** The controller 50 determines whether an outdoor air temperature detected by the second temperature sensor 45 is greater than or equal to a predetermined value (e.g., 0 degrees C). This predetermined value corresponds to the second predetermined value.

**[0133]** If the value detected by the second temperature sensor 45 is greater than or equal to the predetermined value, the controller 50 proceeds to CT3.

**[0134]** If the value detected by the second temperature sensor 45 is not greater than or equal to the predetermined value, the controller 50 proceeds to CT4.

(CT3)

**[0135]** The controller 50 determines whether a pressure substantially equal to the refrigerant pressure at the suction inlet of the compressor 10 detected by the second pressure sensor 42 is greater than or equal to a predetermined value (for example, greater than or equal to 0.3 MPa for R410A refrigerant). This predetermined value corresponds to the first predetermined value.

**[0136]** If the value detected by the second pressure sensor 42 is greater than or equal to the predetermined value, the controller 50 proceeds to CT5.

**[0137]** If the value detected by the second pressure sensor 42 is not greater than or equal to the predetermined value, the controller 50 proceeds to CT4.

(CT4)

**[0138]** The controller 50 opens the second opening

and closing device 35 to cause a branch flow of high temperature, high pressure gas refrigerant discharged from the compressor 10 to flow through the second gas bypass pipe 7 and the second opening and closing device 35 into the accumulator 13. Consequently, liquid refrigerant accumulating in the accumulator 13 is evaporated to increase the amount of gas refrigerant flowing out of the accumulator 13, thus achieving an increase in pressure of low pressure gas refrigerant.

**[0139]** After opening the second opening and closing device 35, the controller 50 proceeds to CT6.

(CT5)

**[0140]** The controller 50 closes the second opening and closing device 35 to close the passage of the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 to the accumulator 13 through the second gas bypass pipe 7 and the second opening and closing device 35.

**[0141]** After closing the second opening and closing device 35, the controller 50 proceeds to CT6.

(CT6)

**[0142]** The controller 50 determines whether the defrosting operation mode is completed.

**[0143]** If the defrosting operation mode is not completed, the controller 50 proceeds to CT2.

**[0144]** If the defrosting operation mode is completed, the controller 50 proceeds to CT7.

(CT7)

**[0145]** If the defrosting operation mode is completed, the controller 50 closes the second opening and closing device 35 to close the passage of the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 to the accumulator 13 through the second gas bypass pipe 7 and the second opening and closing device 35.

**[0146]** After closing the second opening and closing device 35, the controller 50 shifts to the heating only operation mode.

**[0147]** Although the pressure substantially equal to the refrigerant pressure at the suction inlet of the compressor 10 detected by the second pressure sensor 42 is set at approximately 0.3 MPa for R410A refrigerant in CT3 in Fig. 8, another value may be used. Specifically, the first predetermined value may be set to a value less than 0.3 MPa, as long as the difference between an indoor air temperature and a saturation temperature converted from a pressure in the load side heat exchanger 21 can be provided to the extent that cold air caused by an operation state does not cause user discomfort, that is, the temperature difference can be greater than or equal to a predetermined value (for example, greater than or equal to 10 degrees C). As regards the second pressure sensor

42, a temperature sensor, such as a thermistor, may be used instead of the pressure sensor. The controller 50 may calculate a saturation pressure based on a value detected by the temperature sensor and the saturation pressure may be used.

**[0148]** Although the second opening and closing device 35 is opened in accordance with the detection result of the defrosting mode refrigerant decrease detecting unit in the above-described case, the second opening and closing device 35 may be opened at the time when the opening and closing devices and the flow control devices are switched between the states upon start of the defrosting operation mode, because a refrigerant shortage in the refrigerant circuit is expected at this switching time. Consequently, the refrigerant can be more rapidly supplied to the defrosting-target heat source side heat exchanger 12, thus shortening the time required for defrosting.

**[0149]** In the above-described case, when a pressure substantially equal to the refrigerant pressure at the suction inlet of the compressor 10 detected by the second pressure sensor 42 is greater than or equal to the first predetermined value (for example, greater than or equal to 0.3 MPa for R410A refrigerant), the second opening and closing device 35 is closed. In addition, for example, an increase in refrigerant pressure at the suction inlet of the compressor 10 in the defrosting operation mode may be estimated in advance based on examinations and the second opening and closing device 35 may be closed after a lapse of a predetermined period of time. This can prevent the refrigerant accumulating in the accumulator 13 from being excessively supplied to the refrigerant circuit if the second pressure sensor 42 breaks down. In other words, the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 can be prevented from being wastefully introduced into the bypass pipe, thus eliminating or reducing a decrease in heating capacity.

**[0150]** A duration during which the second opening and closing device 35 is kept opened may be changed in accordance with an outdoor air temperature. At high outdoor air temperatures, when the heat source side heat exchanger 12 used as an evaporator is allowed to achieve a heat exchange amount greater than or equal to that at low outdoor air temperatures on the assumption that the difference in temperature between the outdoor air and the refrigerant in the heat source side heat exchanger 12 at high outdoor air temperatures is substantially equivalent to that at low outdoor air temperatures, the refrigerant pressure in the heat source side heat exchanger 12 rises and the refrigerant pressure at the suction inlet of the compressor 10 also rises. Consequently, a large amount of refrigerant is circulated through the refrigerant circuit. If a small amount of the refrigerant accumulating in the accumulator 13 is supplied to the refrigerant circuit by opening the second opening and closing device 35, the defrosting operation and the heating operation can be adequately performed. At high outdoor

air temperatures, therefore, a short duration during which the second opening and closing device 35 is opened can be set.

[0151] On the other hand, at low outdoor air temperatures, the refrigerant pressure in the heat source side heat exchanger 12 falls and the refrigerant pressure at the suction inlet of the compressor 10 also falls. Consequently, a small amount of refrigerant is circulated through the refrigerant circuit. A large amount of the refrigerant accumulating in the accumulator 13 has to be supplied to the refrigerant circuit. A long duration during which the second opening and closing device 35 is opened has to be set.

[0152] In other words, setting the duration during which the second opening and closing device 35 is opened in accordance with a change in outdoor air temperature prevents the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 from being wastefully introduced into the bypass pipe, particularly, at high outdoor air temperatures, thus eliminating or reducing a decrease in heating capacity.

[0153] Fig. 9 is a graph illustrating a change in saturation temperature converted from a pressure in the load side heat exchanger 21 caused by changing the flow rate of high temperature, high pressure gas refrigerant flowing into the accumulator 13 in the defrosting mode of the air-conditioning apparatus 100. Fig. 9 illustrates the change in saturation temperature converted from the pressure in the load side heat exchanger 21 caused by changing the flow rate of high temperature, high pressure gas refrigerant flowing into the accumulator 13 in the defrosting operation mode at an outdoor air temperature of approximately 0 degrees C and an indoor air temperature of approximately 20 degrees C. In Fig. 9, the horizontal axis represents a value (hereinafter, "gas refrigerant flow rate ratio") obtained by dividing the flow rate of high temperature, high pressure gas refrigerant flowing from the pipe disposed at the discharge outlet of the compressor 10 through the second gas bypass pipe 7 into the accumulator 13 by the flow rate of the whole of high temperature, high pressure gas refrigerant discharged from the compressor 10, and the vertical axis represents the saturation temperature converted from the pressure in the load side heat exchanger 21.

[0154] In Fig. 9, it can be seen that the flow rate of the high temperature, high pressure gas refrigerant flowing into the accumulator 13 should be increased (shifted to the right of the horizontal axis in Fig. 9) to more rapidly supply the refrigerant having an average density of approximately 600 (kg/m<sup>3</sup>) or greater from the accumulator 13 to the defrosting-target heat source side heat exchanger 12. Furthermore, in Fig. 9, it can be seen that the saturation temperature converted from the pressure in the load side heat exchanger 21 accordingly decreases (shifts to the bottom of the vertical axis in Fig. 9). To maintain the saturation temperature converted from the pressure in the load side heat exchanger 21 at or above

30 degrees C so that the difference between the saturation temperature and an indoor air temperature of approximately 20 degrees C is greater than or equal to 10 degrees C, the gas refrigerant flow rate ratio has to be set below 0.65. As regards the second opening and closing device 35, a valve having a size that satisfies the condition where the gas refrigerant flow rate ratio is less than 0.65 may be used.

(Modified Manner of Gas Supply to Accumulator 13)

[0155] Fig. 10 is a schematic circuit diagram illustrating another example of the circuit configuration of the air-conditioning apparatus 100. As illustrated in Fig. 10, the second end of the second gas bypass pipe 7 may be connected to the accumulator 13. Such a configuration enables the branch flow of the high temperature, high pressure gas refrigerant discharged from the compressor 10 to directly flow into the accumulator 13 through the second gas bypass pipe 7 and the second opening and closing device 35.

[0156] In the configuration in which the second end of the second gas bypass pipe 7 is connected to the refrigerant pipe 3 between the refrigerant flow switching device 11 and the accumulator 13, the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 transfers heat to low temperature, low pressure gas or two-phase refrigerant flowing from the heat source side heat exchanger 12 functioning as an evaporator, so that heat energy decreases. In addition, when flowing into the accumulator 13, the refrigerant exchanges heat with only upper part of liquid refrigerant accumulating in the accumulator 13.

[0157] The circuit configuration as illustrated in Fig. 10 enables the gas refrigerant flowing into the accumulator 13 to efficiently exchange heat with the liquid refrigerant accumulating in the accumulator 13. Consequently, the refrigerant accumulating in the accumulator 13 can be more rapidly supplied to the defrosting-target heat source side heat exchanger 12 than that in the configuration in which the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 flows into the pipe at an inlet of the accumulator 13, thus achieving defrosting more rapidly. A decrease in indoor heating capacity can be further eliminated or reduced and the indoor space can be kept comfortable.

Embodiment 2

[0158] Fig. 11 is a schematic circuit diagram illustrating an example of the circuit configuration of an air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

[0159] The configuration of the air-conditioning apparatus 200 will now be described in detail with reference to Fig. 11.

[0160] The following description of Embodiment 2 will

be focused on differences from Embodiment 1. The same components as those in Embodiment 1 are designated by the same reference numerals and an explanation of these components is omitted in the description of Embodiment 2. In Fig. 11, solid-line arrows indicate a refrigerant flow direction in a state where the heat source side heat exchanger 12b is defrosted.

**[0161]** As illustrated in Fig. 11, the air-conditioning apparatus 200 further includes a fourth opening and closing device 33a for closing the refrigerant passage to the heat source side heat exchanger 12a. The fourth opening and closing device 33a is disposed in the pipe extending from the heat source side heat exchanger 12a toward the load side expansion device 22. The air-conditioning apparatus 200 further includes a fourth opening and closing device 33b for closing the refrigerant passage to the heat source side heat exchanger 12b. The fourth opening and closing device 33b is similarly disposed in the pipe extending from the heat source side heat exchanger 12b toward the load side expansion device 22.

**[0162]** The air-conditioning apparatus 200 further includes a refrigerant bypass pipe 6. The refrigerant bypass pipe 6 is connected at a first end to each of the refrigerant pipe 3 between the heat source side heat exchangers 12a and the third opening and closing device 31 a and the refrigerant pipe 3 between the heat source side heat exchanger 12b and the third opening and closing device 31 b. The refrigerant bypass pipe 6 is connected at a second end to the passage between the load side expansion device 22 and the fourth opening and closing devices 33a and 33b. The refrigerant bypass pipe 6 allows the refrigerant in the heat source side heat exchanger 12 functioning as a condenser in the defrosting operation mode to flow into the refrigerant pipe 3.

**[0163]** In addition, a fifth opening and closing device 34a and a fifth opening and closing device 34b for switching between refrigerant passages of the refrigerant bypass pipe 6 are arranged in the first end of the refrigerant bypass pipe 6 connected to the pipes between the heat source side heat exchangers 12 and the third opening and closing devices 31. At the second end of the refrigerant bypass pipe 6, the one flow control device 32b (or flow control device 32a), serving as an expansion device having a variable opening degree (opening area), for controlling a refrigerant pressure in the heat source side heat exchanger 12 is disposed.

**[0164]** The fourth opening and closing device 33a closes the refrigerant passage in the defrosting operation mode in which the heat source side heat exchanger 12a operates as a condenser so that low temperature two-phase refrigerant flowing from the indoor unit 2 through the refrigerant main pipe 4 into the outdoor unit 1 does not flow into the heat source side heat exchanger 12a.

**[0165]** The fourth opening and closing device 33b closes the refrigerant passage in the defrosting operation mode in which the heat source side heat exchanger 12b operates as a condenser so that low temperature two-phase refrigerant flowing from the indoor unit 2 through

the refrigerant main pipe 4 into the outdoor unit 1 does not flow into the heat source side heat exchanger 12b.

**[0166]** Each of the fourth opening and closing devices 33a and 33b may be a component capable of opening and closing the refrigerant passage, for example, a two-way valve, a solenoid valve, or an electronic expansion valve.

**[0167]** In the following description, the fourth opening and closing devices 33a and 33b may be collectively referred to as fourth opening and closing devices 33.

**[0168]** The fifth opening and closing device 34a allows the refrigerant flowing from the heat source side heat exchanger 12a operating as a condenser in the defrosting operation mode to flow into the refrigerant pipe 3 through the flow control device 32b (or the flow control device 32a).

**[0169]** The fifth opening and closing device 34b allows the refrigerant flowing from the heat source side heat exchanger 12a to flow into the refrigerant pipe 3 through the flow control device 32b (or the flow control device 32a) while the heat source side heat exchanger 12b is operating as a condenser in the defrosting operation mode.

**[0170]** Each of the fifth opening and closing devices 34a and 34b may be a component capable of opening and closing the refrigerant passage, for example, a two-way valve, a solenoid valve, or an electronic expansion valve.

**[0171]** In the following description, the fifth opening and closing devices 34a and 34b may be collectively referred to as fifth opening and closing devices 34.

**[0172]** One of the two pipes constituting the second end of the first gas bypass pipe 5 is connected to the refrigerant pipe 3 between the heat source side heat exchanger 12a and the fourth opening and closing device 33a, and the other one of them is connected to the refrigerant pipe 3 between the heat source side heat exchanger 12b and the fourth opening and closing device 33b.

**[0173]** The third temperature sensor 48a is disposed in the refrigerant pipe 3 between the heat source side heat exchanger 12a and the third opening and closing device 31 a. The third temperature sensor 48b is disposed in the refrigerant pipe 3 between the heat source side heat exchanger 12b and the third opening and closing device 31 b.

**[0174]** The third temperature sensor 48a measures a temperature of the refrigerant flowing from the heat source side heat exchanger 12a operating as an evaporator or the refrigerant flowing from the heat source side heat exchanger 12a operating as a condenser. The third temperature sensor 48b measures a temperature of the refrigerant flowing from the heat source side heat exchanger 12b operating as an evaporator or the refrigerant flowing from the heat source side heat exchanger 12b operating as a condenser.

**[0175]** Since the rest of the configuration is the same as that of the air-conditioning apparatus 100 according

to Embodiment 1, an explanation of the rest of the configuration is omitted. As regards Figs. 6 to 9 in the description of Embodiment 1, the same applies to the air-conditioning apparatus 200.

**[0176]** In the cooling only operation mode and the heating only operation mode of the air-conditioning apparatus 200, the fourth opening and closing devices 33a and 33b are opened and the fifth opening and closing devices 34a and 34b are closed. Since the operations of the other opening and closing devices and the refrigerant flows are the same as those in the air-conditioning apparatus 100 according to Embodiment 1, an explanation of the operations and the refrigerant flows is omitted.

[Defrosting Operation Mode]

**[0177]** In the defrosting operation mode of the air-conditioning apparatus 200, similarly, the heat source side heat exchanger 12b disposed at the lower level in the housing of the outdoor unit 1 is defrosted and, after that, the heat source side heat exchanger 12a disposed at the upper level in the housing of the outdoor unit 1 is defrosted.

**[0178]** Conditions for starting the defrosting operation mode are the same as those in the air-conditioning apparatus 100 according to Embodiment 1.

(Defrosting of Heat Source Side Heat Exchanger 12b)

**[0179]** In the defrosting operation mode, the refrigerant flow switching device 11 is maintained in the state indicated by solid lines in Fig. 11.

**[0180]** Additionally, in the defrosting operation mode in which the heat source side heat exchanger 12b is a defrosting target, the states of the first opening and closing devices 30, the second opening and closing device 35, the third opening and closing devices 31, the fourth opening and closing devices 33, the fifth opening and closing devices 34, and the flow control device 32 are as follows.

**[0181]** The controller 50 controls the states of those devices.

**[0182]** The first opening and closing device 30b is switched to the open state, thus permitting the flow of the refrigerant.

**[0183]** The third opening and closing device 31 b is switched to the closed state, thus stopping the flow of the refrigerant.

**[0184]** The fourth opening and closing device 33b is switched to the closed state, thus stopping the flow of the refrigerant.

**[0185]** The fifth opening and closing device 34b is switched to the open state, thus permitting the flow of the refrigerant.

**[0186]** The first opening and closing device 30a is maintained in the closed state to stop the flow of the refrigerant.

**[0187]** The third opening and closing device 31 a is

maintained in the open state to permit the flow of the refrigerant.

**[0188]** The fourth opening and closing device 33a is switched to the open state, thus permitting the flow of the refrigerant.

**[0189]** The fifth opening and closing device 34a is switched to the closed state, thus stopping the flow of the refrigerant.

**[0190]** The opening degree of the flow control device 32b (or the flow control device 32a) is controlled so that a preset pressure (e.g., approximately 0.8 MPa for R410A refrigerant) remains constant. At the preset pressure, a saturation temperature converted from a saturation pressure of two-phase refrigerant calculated based on a detection result of the third temperature sensor 48b, serving as the "defrosting mode refrigerant decrease detecting unit", is greater than 0 degrees C.

**[0191]** When either one of the condition that an outdoor air temperature detected by the second temperature sensor 45 is less than or equal to the second predetermined value (for example, less than or equal to 0 degrees C) and the condition that a pressure at the suction inlet of the compressor 10 detected by the second pressure sensor 42 is less than or equal to the first predetermined value (for example, less than or equal to approximately 0.3 MPa for R410A refrigerant) is satisfied, or alternatively, when both the conditions are satisfied, the second opening and closing device 35 is maintained in the open state to permit the flow of the refrigerant.

**[0192]** The second temperature sensor 45, the second pressure sensor 42, and the third temperature sensor 48b correspond to the defrosting mode refrigerant decrease detecting unit in the present invention.

**[0193]** The flow of the refrigerant in the defrosting operation mode will now be described in detail.

**[0194]** When the compressor 10 is driven, low temperature, low pressure refrigerant is compressed into high temperature, high pressure gas refrigerant and is then discharged.

**[0195]** Part of the high temperature, high pressure gas refrigerant discharged from the compressor 10 flows through the first gas bypass pipe 5. In the first opening and closing device 30b, the refrigerant is depressurized to a pressure equivalent to greater than 0 degrees C in terms of saturation temperature, so that the refrigerant turns into intermediate pressure, high temperature gas refrigerant. The refrigerant flows into the heat source side heat exchanger 12b. The intermediate pressure, high temperature gas refrigerant that has flowed into the heat source side heat exchanger 12b turns into intermediate pressure, low quality two-phase refrigerant or intermediate pressure refrigerant while melting frost on the heat source side heat exchanger 12b. The refrigerant then passes through the fifth opening and closing device 34b. The refrigerant leaving the fifth opening and closing device 34b is depressurized by the flow control device 32b (or the flow control device 32a) and then merges with intermediate pressure, low temperature, low quality two-

phase refrigerant or liquid refrigerant that has flowed from the indoor unit 2 into the outdoor unit 1 at a point upstream of the fourth opening and closing device 33a.

**[0196]** Most of the high temperature, high pressure gas refrigerant discharged from the compressor 10 passes through the refrigerant flow switching device 11 and flows out of the outdoor unit 1. The high temperature, high pressure gas refrigerant leaving the outdoor unit 1 passes through the refrigerant main pipe 4, flows into the indoor unit 2, and transfers heat to indoor air in the load side heat exchanger 21, so that the refrigerant turns into liquid refrigerant while heating the indoor air. The liquid refrigerant flows out of the load side heat exchanger 21 and is then expanded by the load side expansion device 22, so that the refrigerant turns into low temperature, intermediate pressure two-phase refrigerant or liquid refrigerant. The refrigerant passes through the refrigerant main pipe 4 and again flows into the outdoor unit 1.

**[0197]** The low temperature, intermediate pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 merges with the refrigerant flowing from the flow control device 32b (or the flow control device 32a) at the point upstream of the fourth opening and closing device 33a. The refrigerant then flows into the heat source side heat exchanger 12a. The refrigerant that has flowed into the heat source side heat exchanger 12a removes heat from outdoor air, so that the refrigerant turns into low temperature, low pressure gas refrigerant. The gas refrigerant flows out of the heat source side heat exchanger 12a, passes through the third opening and closing device 31 a, the refrigerant flow switching device 11, and the accumulator 13, and is again sucked into the compressor 10.

**[0198]** The controller 50 controls the opening degree of the flow control device 32b (or the flow control device 32a) so that the preset pressure (for example, approximately 0.8 MPa for R410A refrigerant), at which a saturation temperature converted from a saturation pressure of two-phase refrigerant calculated based on a detection result of the third temperature sensor 48b is greater than 0 degrees C, remains constant. In other words, the controller 50 controls the opening degree of the flow control device 32b (or the flow control device 32a) so that the saturation temperature converted from the saturation pressure of the two-phase refrigerant calculated based on the detection result of the third temperature sensor 48b is greater than 0 degrees C.

**[0199]** As regards the completion of defrosting of the heat source side heat exchanger 12b, the completion of defrosting may be determined, for example, after a lapse of a predetermined period of time, or alternatively, when a temperature detected by the third temperature sensor 48b is greater than or equal to a predetermined temperature (e.g., 5 degrees C). Assuming that the heat source side heat exchanger 12b is fully covered with frost, the predetermined period of time may be set longer than or equal to the time required to completely defrost the heat source side heat exchanger 12b by allowing part of high

temperature, high pressure refrigerant to flow into the heat source side heat exchanger 12b.

**[0200]** The rest of the operation in the defrosting operation mode is the same as that of the air-conditioning apparatus 100 according to Embodiment 1. Specifically, while the second opening and closing device 35 is maintained in the open state by the controller 50, a branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 is allowed to flow into the accumulator 13, so that the refrigerant accumulating in the accumulator 13 is supplied to the suction inlet of the compressor 10. Consequently, the air-conditioning apparatus 200 achieves the same advantages as those of the air-conditioning apparatus 100 according to Embodiment 1. A decrease in indoor heating capacity and defrosting capacity can be eliminated or reduced.

**[0201]** Since the controller 50 controls the second opening and closing device 35 in the same manner as that in the air-conditioning apparatus 100 according to Embodiment 1, a description of the operation of the controller 50 is omitted.

**[0202]** For example, if the heat source side heat exchanger 12b includes a first heat exchanger element and a second heat exchanger element and is used as an evaporator, most of outdoor air will be dehumidified by the fins of the first heat exchanger element disposed on an outdoor air inlet side of the heat source side heat exchanger 12b, or the fins of the first heat exchanger element disposed on the air inlet side of the heat source side heat exchanger 12b. In other words, the fins of the first heat exchanger element on the air inlet side of the heat source side heat exchanger 12b will be covered with a large amount of frost and the fins of the second heat exchanger element will be covered with a small amount of frost.

**[0203]** Unlike the air-conditioning apparatus 100 according to Embodiment 1, the air-conditioning apparatus 200 allows part of the high temperature, high pressure gas refrigerant discharged from the compressor 10 to flow into the heat source side heat exchanger 12b functioning as a condenser in the same direction as that in the passage of the heat source side heat exchanger 12b used as an evaporator. Consequently, two-phase refrigerant having higher heat energy is allowed to flow into the first heat exchanger element covered with the large amount of frost. Thus, the air-conditioning apparatus 200 achieves defrosting with higher efficiency than the air-conditioning apparatus 100 according to Embodiment 1, so that the time required for defrosting can be shortened and a decrease in indoor heating capacity can be further eliminated or reduced.

**[0204]** To defrost the heat source side heat exchanger 12a after the heat source side heat exchanger 12b is completely defrosted, an operation may be performed in a manner obtained by interchanging the letters "a" and "b" added to the reference numerals in the above description about the defrosting operation for the heat

source side heat exchanger 12b. Specifically, the open and closed states of the first opening and closing devices 30a and 30b, the third opening and closing devices 31 a and 31 b, the fourth opening and closing devices 33a and 33b, and the fifth opening and closing devices 34a and 34b are the opposite of the above-described states and the refrigerant flow direction in each of the heat source side heat exchangers 12a and 12b is reversed.

**[0205]** As described above, the saturation temperature of the refrigerant in the heat source side heat exchanger 12 functioning as a condenser in the defrosting operation mode for the heat source side heat exchanger 12 is set at an intermediate pressure (for example, at or above approximately 0.8 MPa for R410A refrigerant) equivalent to a temperature greater than the temperature of frost, that is, 0 degrees C. In the air-conditioning apparatus 200, therefore, a two-phase region (latent heat) of the refrigerant can be used, so that efficient defrosting can be achieved with a small circulation amount of refrigerant, a decrease in indoor heating capacity can be eliminated or reduced, and the indoor space can be kept comfortable.

**[0206]** The air-conditioning apparatus 200 can defrost the heat source side heat exchangers 12a and 12b while continuing the heating operation by performing the above-described defrosting operation mode. The heat source side heat exchanger 12b at the lower level in the housing of the outdoor unit 1 is defrosted and, after that, the heat source side heat exchanger 12a at the upper level is defrosted. This can eliminate a likelihood that water produced by defrosting the heat source side heat exchanger 12a may freeze in the lower heat source side heat exchanger 12b to be defrosted. Efficient defrosting can be achieved.

**[0207]** In the above description, the air-conditioning apparatus 200 according to Embodiment 2 is configured such that the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 flows into the pipe at the inlet of the accumulator 13. In addition, for example, the air-conditioning apparatus 200 may have such a circuit configuration that the branch flow of the high temperature, high pressure gas refrigerant from the discharge side of the compressor 10 directly flows into the accumulator 13 through the second gas bypass pipe 7 and the second opening and closing device 35 in a manner similar to the configuration of Fig. 10 of the air-conditioning apparatus 100 according to Embodiment 1. Such a configuration achieves the same advantages as those of the air-conditioning apparatus 100 according to Embodiment 1. Efficient defrosting can be performed, a decrease in indoor heating capacity can be eliminated or reduced, and the indoor space can be kept comfortable.

[Refrigerant]

**[0208]** As regards the heat source side refrigerant for the air-conditioning apparatus 100 according to Embod-

iment 1 and the air-conditioning apparatus 200 according to Embodiment 2, a nonflammable refrigerant, such as R410A, R407C, or R22, a refrigerant mixture containing HFO1234yf, HFO1234ze(E), R32, HC, or R32 and HFO1234yf, a slightly flammable refrigerant, such as a refrigerant mixture containing any of the above-described refrigerants as at least one component, a highly flammable refrigerant, such as propane (R290), or a refrigerant that operates in a supercritical state on a high-pressure side, for example, CO<sub>2</sub> (R744), can be used as a heat source side refrigerant.

[First Opening and Closing Devices]

**[0209]** As regards the first opening and closing devices 30a and 30b of each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, the solenoid valves are used in the above-described case. In addition, a valve having a variable opening degree, for example, an electronic expansion valve, may be used as each of the first opening and closing devices 30a and 30b.

[Second Opening and Closing Device]

**[0210]** As regards the second opening and closing device 35 of each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, the solenoid valve is used in the above-described case. In addition, a valve having a variable opening degree, for example, an electronic expansion valve, may be used as the second opening and closing device 35. Furthermore, the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2 each include the single second opening and closing device 35 in the above-described case. In addition, a plurality of solenoid valves arranged in parallel may be used. Such a configuration achieves the same advantages as those of Embodiments 1 and 2.

[Third Opening and Closing Devices]

**[0211]** As regards the third opening and closing devices 31 a and 31 b of each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, the solenoid valves are used in the above-described case. In addition, a valve having a variable opening degree, for example, an electronic expansion valve, may be used as each of the third opening and closing devices 31 a and 31 b.

[Flow Control Devices]

**[0212]** As regards the flow control devices 32a and 32b of each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, the expansion device having

a variable opening degree (opening area) is used as each flow control device in the above description. Any device having a variable passage opening area may be used. For example, the expansion device may be an electronic expansion valve that is driven by a stepping motor or may include a plurality of small solenoid valves arranged in parallel such that the opening degree is changed by switching the solenoid valves.

**[0213]** In each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, each of the flow control devices 32a and 32b is the device having a variable passage opening area. In addition, for example, the flow control device 32a may be a device having a variable passage opening area and the flow control device 32b may include a plurality of small solenoid valves arranged in parallel. Such a configuration achieves the same advantages as those of Embodiments 1 and 2.

#### [Fourth Opening and Closing Devices]

**[0214]** As regards the fourth opening and closing devices 33 of the air-conditioning apparatus 200 according to Embodiment 2, the solenoid valves are used in the above-described case. In addition, a valve having a variable opening degree, for example, an electronic expansion valve, may be used as each of the fourth opening and closing devices 33.

#### [Fifth Opening and Closing Devices]

**[0215]** As regards the fifth opening and closing devices 34 of the air-conditioning apparatus 200 according to Embodiment 2, the solenoid valves are used in the above-described case. In addition, a valve having a variable opening degree, for example, an electronic expansion valve, may be used as each of the fifth opening and closing devices.

**[0216]** Assuming that a component having a variable opening degree (opening area), for example, an electronic expansion valve, is used as each of the opening and closing devices, the term "opening the opening and closing device" refers to changing the opening degree to fully or substantially fully open the opening and closing device, and the term "closing the opening and closing device" refers to changing the opening degree to fully or substantially fully close the opening and closing device. The same applies to each of the flow control devices. The term "opening" refers to changing the opening degree to fully or substantially fully open the flow control device, and the term "closing the flow control device" refers to changing the opening degree to fully or substantially fully close the flow control device, that is, changing the opening degree to a state where little or no refrigerant flows through the device.

#### [Heat Source Side Heat Exchangers]

**[0217]** As regards the heat source side heat exchangers 12a and 12b of each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, the heat source side heat exchangers are arranged at two levels in the level arrangement direction (or the top-bottom direction along the length of the fins aligned so as to face in the same direction) in the above-described case. The present invention is not limited to such a configuration. For example, as described above, a plurality of heat source side heat exchangers 12 may be arranged at, for example, three or more levels in the level arrangement direction (or the top-bottom direction along the length of the fins aligned so as to face in the same direction). Furthermore, the arrangement is not limited to that in the top-bottom direction. A plurality of heat source side heat exchangers 12 may be arranged in the left-right direction or a front-rear direction.

**[0218]** As regards each of the air-conditioning apparatus 100 according to Embodiment 1 and the air-conditioning apparatus 200 according to Embodiment 2, the air-conditioning apparatus capable of switching between the cooling operation and the heating operation has been described as an example. In addition, the present invention can be applied to an air-conditioning apparatus having a circuit configuration that enables the cooling and heating mixed operation. Furthermore, the present invention can be applied to an air-conditioning apparatus that does not include the refrigerant flow switching device 11 and performs only the heating only operation mode and the defrosting operation mode. The term "heating circuit" refers to the refrigerant circuit configuration formed in the heating operation mode of each of the air-conditioning apparatus 100 and the air-conditioning apparatus 200. Reference Signs List

**[0219]** 1: outdoor unit; 2: indoor unit; 3: refrigerant pipe; 4: refrigerant main pipe; 5: first gas bypass pipe; 6: refrigerant bypass pipe; 7: second gas bypass pipe; 10: compressor; 11: refrigerant flow switching device; 12: heat source side heat exchanger; 12a: heat source side heat exchanger; 12b: heat source side heat exchanger; 13: accumulator; 21: load side heat exchanger; 22: load side expansion device; 30: first opening and closing device; 30a: first opening and closing device; 30b: first opening and closing device; 31: third opening and closing device; 31 a: third opening and closing device; 31b: third opening and closing device; 32: flow control device; 32a: flow control device; 32b: flow control device; 33: fourth opening and closing device; 33a: fourth opening and closing device; 33b: fourth opening and closing device; 34: fifth opening and closing device; 34a: fifth opening and closing device; 34b: fifth opening and closing device; 35: second opening and closing device; 41: first pressure sensor; 42: second pressure sensor; 43: first temperature sensor; 44: sixth temperature sensor; 45: second temperature sensor; 46: fourth temperature sensor; 47: fifth

temperature sensor; 48a: third temperature sensor; 48b: third temperature sensor; 50: controller; 51: fin; 52: heat transfer tube; 100: air-conditioning apparatus; and 200: air-conditioning apparatus.

### Claims

1. An air-conditioning apparatus capable of simultaneously performing a heating operation and a defrosting operation, the apparatus comprising:

a main circuit including a compressor, a load side heat exchanger, a load side expansion device, a plurality of heat source side heat exchangers connected in parallel one another, and an accumulator that are connected by refrigerant pipes to form at least a heating circuit;

a first gas bypass pipe branching off from the refrigerant pipe on a discharge side of the compressor and allowing refrigerant to flow into a defrosting-target heat source side heat exchanger of the heat source side heat exchangers;

a second gas bypass pipe branching off from the refrigerant pipe on the discharge side of the compressor and allowing the refrigerant to flow into the accumulator;

a plurality of first opening and closing devices arranged in the first gas bypass pipe, the first opening and closing devices each permitting or stopping a flow of the refrigerant through the first gas bypass pipe; and

at least one second opening and closing device disposed in the second gas bypass pipe, the second opening and closing device permitting or stopping the flow of the refrigerant through the second gas bypass pipe.

2. The air-conditioning apparatus of claim 1, wherein while the heating operation and the defrosting operation are simultaneously performed, the first opening and closing devices allow part of the refrigerant discharged from the compressor to flow into the defrosting-target heat source side heat exchanger, thereby causing the defrosting-target heat source side heat exchanger to function as a condenser, the heat source side heat exchangers other than the defrosting-target heat source side heat exchanger are allowed to function as an evaporator, and the second opening and closing device allows part of the refrigerant discharged from the compressor to flow into the accumulator in accordance with an amount of refrigerant circulated through the main circuit.

3. The air-conditioning apparatus of claim 1 or 2, further

comprising:

a defrosting mode refrigerant decrease detecting unit configured to detect an amount of refrigerant circulated through the main circuit, wherein opening and closing of the second opening and closing device is controlled in accordance with a detection result of the defrosting mode refrigerant decrease detecting unit.

4. The air-conditioning apparatus of any one of claims 1 to 3, further comprising:

a refrigerant flow switching device disposed on the discharge side of the compressor; a plurality of third opening and closing devices arranged in one-to-one correspondence to the heat source side heat exchangers, each of the third opening and closing devices being disposed between the corresponding heat source side heat exchanger and the refrigerant flow switching device, the third opening and closing device permitting or stopping the flow of the refrigerant from the corresponding heat source side heat exchanger to the accumulator; and at least one flow control device disposed between the heat source side heat exchangers and the load side expansion device, the flow control device having a variable opening degree, wherein the third opening and closing device corresponding to the defrosting-target heat source side heat exchanger is closed, and wherein the flow control device controls a pressure of the refrigerant flowing from the defrosting-target heat source side heat exchanger such that a saturation temperature converted from the pressure is greater than 0 degrees C.

5. The air-conditioning apparatus of any one of claims 1 to 3, further comprising:

a refrigerant flow switching device disposed on the discharge side of the compressor; a plurality of third opening and closing devices arranged in one-to-one correspondence to the heat source side heat exchangers, each of the third opening and closing devices being disposed between the corresponding heat source side heat exchanger and the refrigerant flow switching device, the third opening and closing device permitting or stopping the flow of the refrigerant from the corresponding heat source side heat exchanger to the accumulator; a plurality of fourth opening and closing devices arranged in one-to-one correspondence to the heat source side heat exchangers, each of the fourth opening and closing devices being disposed between the corresponding heat source

side heat exchanger and the load side expansion device, the fourth opening and closing device permitting or stopping the flow of the refrigerant from the corresponding heat source side heat exchanger to the load side expansion device;

a refrigerant bypass pipe connecting a passage between each of the third opening and closing devices and the corresponding one of the heat source side heat exchangers to a passage between the fourth opening and closing devices and the load side expansion device and allowing the refrigerant flowing from the defrosting-target heat source side heat exchanger to flow into the passage between the fourth opening and closing devices and the load side expansion device; a plurality of fifth opening and closing devices arranged in the refrigerant bypass pipe in one-to-one correspondence to the heat source side heat exchangers, each of the fifth opening and closing devices permitting or stopping the flow of the refrigerant; and

at least one flow control device disposed in the refrigerant bypass pipe, the flow control device having a variable opening degree,

wherein the third opening and closing device and the fourth opening and closing device corresponding to the defrosting-target heat source side heat exchanger are closed and the first opening and closing device and the fifth opening and closing device corresponding to the defrosting-target heat source side heat exchanger are opened, and

wherein the flow control device controls a pressure of the refrigerant flowing from the defrosting-target heat source side heat exchanger such that a saturation temperature converted from the pressure is greater than 0 degrees C.

6. The air-conditioning apparatus of claim 3 or claim 4 or 5 as dependent on claim 3, wherein the defrosting mode refrigerant decrease detecting unit is a pressure sensor configured to detect a refrigerant pressure on a suction side of the compressor, and wherein the second opening and closing device is opened when a detection result of the pressure sensor is less than or equal to a first predetermined value set in advance.
7. The air-conditioning apparatus of claim 3 or claim 4 or 5 as dependent on claim 3, wherein the defrosting mode refrigerant decrease detecting unit is a temperature sensor configured to detect an outdoor air temperature, and wherein the second opening and closing device is opened when a detection result of the temperature sensor is less than or equal to a second predetermined

value set in advance.

8. The air-conditioning apparatus of claim 3 or claim 4 or 5 as dependent on claim 3, wherein the defrosting mode refrigerant decrease detecting unit includes a pressure sensor configured to detect a refrigerant pressure on a suction side of the compressor and a temperature sensor configured to detect an outdoor air temperature, and wherein the second opening and closing device is opened when a detection result of the pressure sensor is less than or equal to a first predetermined value set in advance and a detection result of the temperature sensor is less than or equal to a second predetermined value set in advance.
9. The air-conditioning apparatus of claim 6, wherein the first predetermined value is set based on a saturation pressure at which a saturation temperature of the refrigerant used is -27 degrees C or less, wherein the second opening and closing device is opened when the detection result of the pressure sensor is less than or equal to the first predetermined value, and wherein the second opening and closing device is closed after the defrosting operation is completed.
10. The air-conditioning apparatus of claim 7, wherein the second predetermined value is set at or below 0 degrees C, wherein the second opening and closing device is opened when the detection result of the temperature sensor is less than or equal to the second predetermined value, and wherein the second opening and closing device is closed after the defrosting operation is completed.
11. The air-conditioning apparatus of claim 8, wherein the first predetermined value is set based on a saturation pressure at which a saturation temperature of the refrigerant used is -27 degrees C or less, wherein the second predetermined value is set at or below 0 degrees C, wherein the second opening and closing device is opened when the detection result of the pressure sensor is less than or equal to the first predetermined value and the detection result of the temperature sensor is less than or equal to the second predetermined value, and wherein the second opening and closing device is closed when the detection result of the pressure sensor is greater than the first predetermined value and the detection result of the temperature sensor is greater than the second predetermined value.
12. The air-conditioning apparatus of any one of claims 1 to 11, wherein the second opening and closing device is a selected device that allows a value ob-

tained by dividing a flow rate of the refrigerant flowing through the second gas bypass pipe by a flow rate of the refrigerant discharged from the compressor to be less than 0.65.

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13. The air-conditioning apparatus of any one of claims 1 to 12,

wherein the heat source side heat exchangers are adjacently arranged in a top-bottom direction of the apparatus, and

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wherein while the heating operation and the defrosting operation are simultaneously performed, the heat source side heat exchanger at a lower level is subjected to the defrosting operation and the heat source side heat exchanger at an upper level is then subjected to the defrosting operation.

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FIG. 2

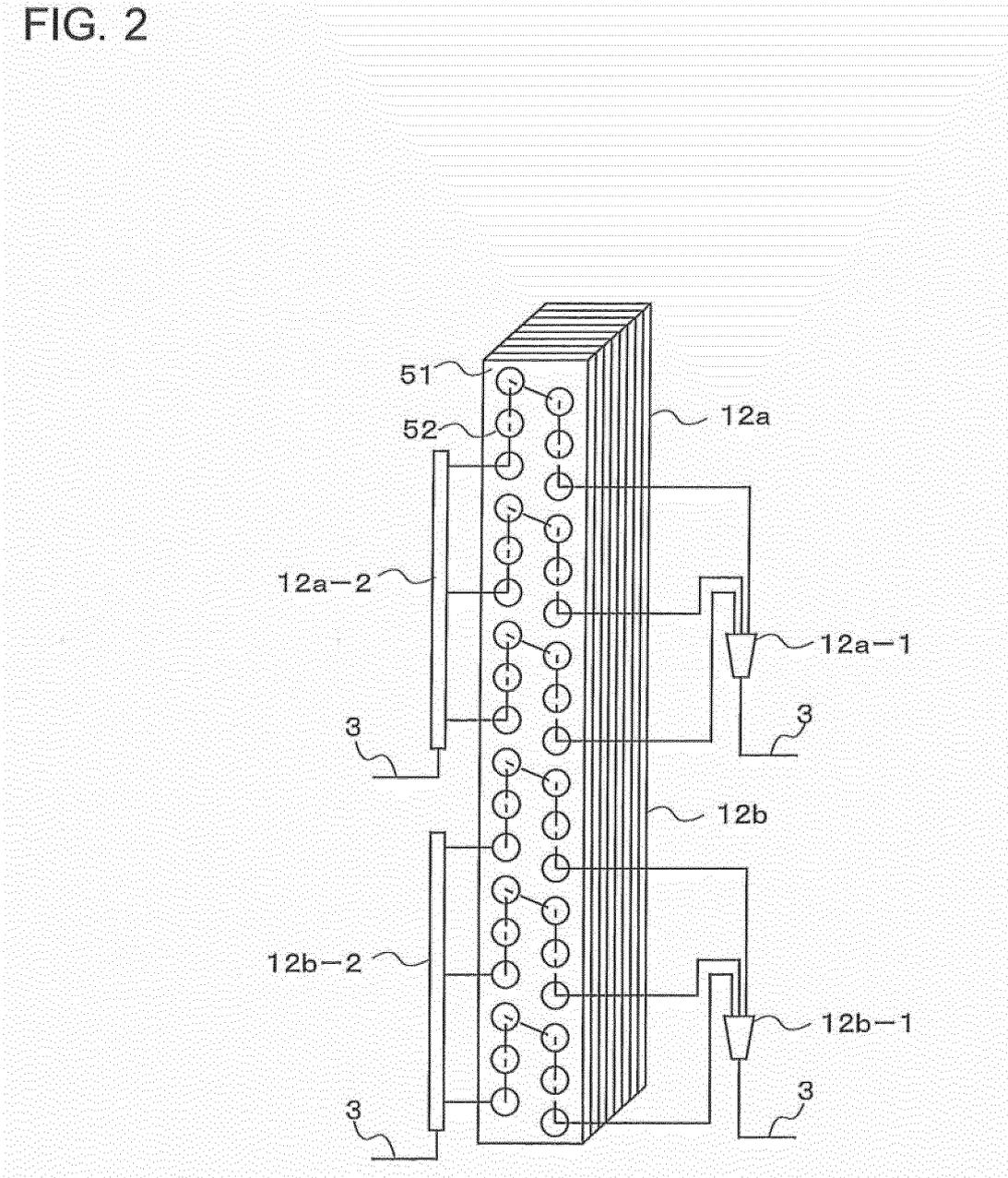




FIG. 4

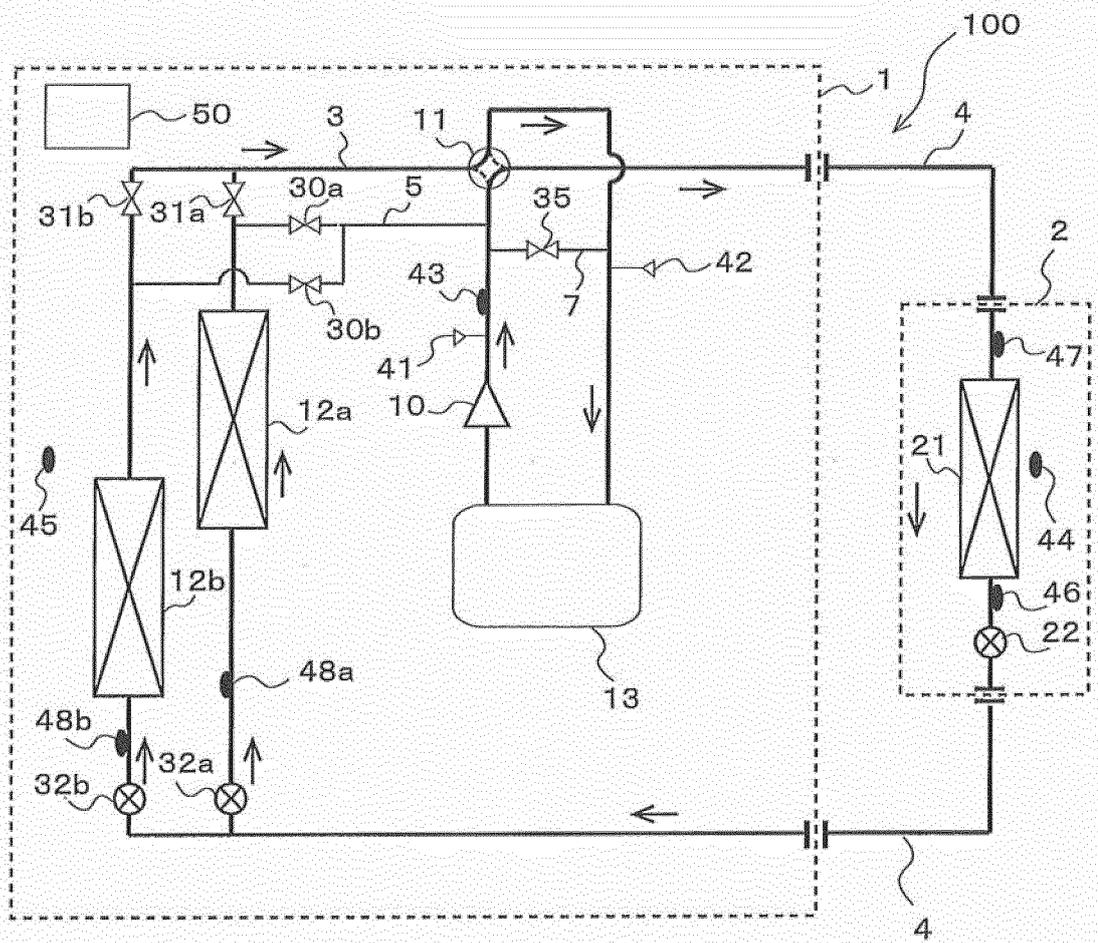




FIG. 6

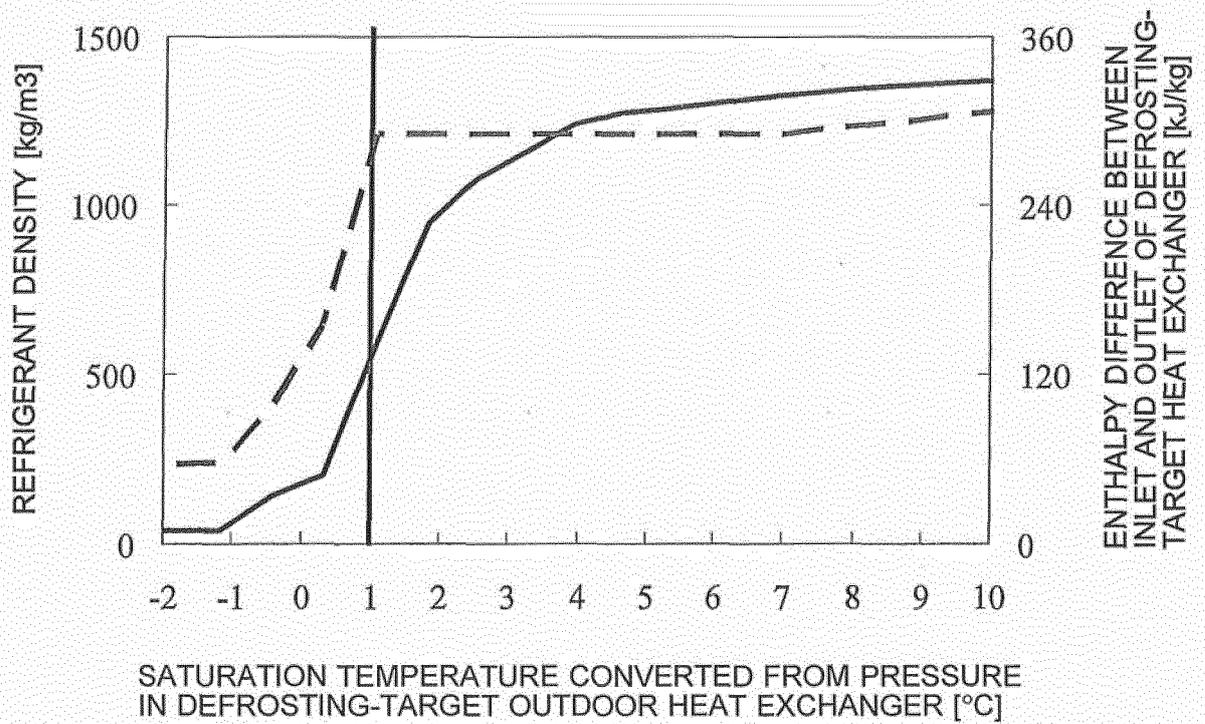


FIG. 7

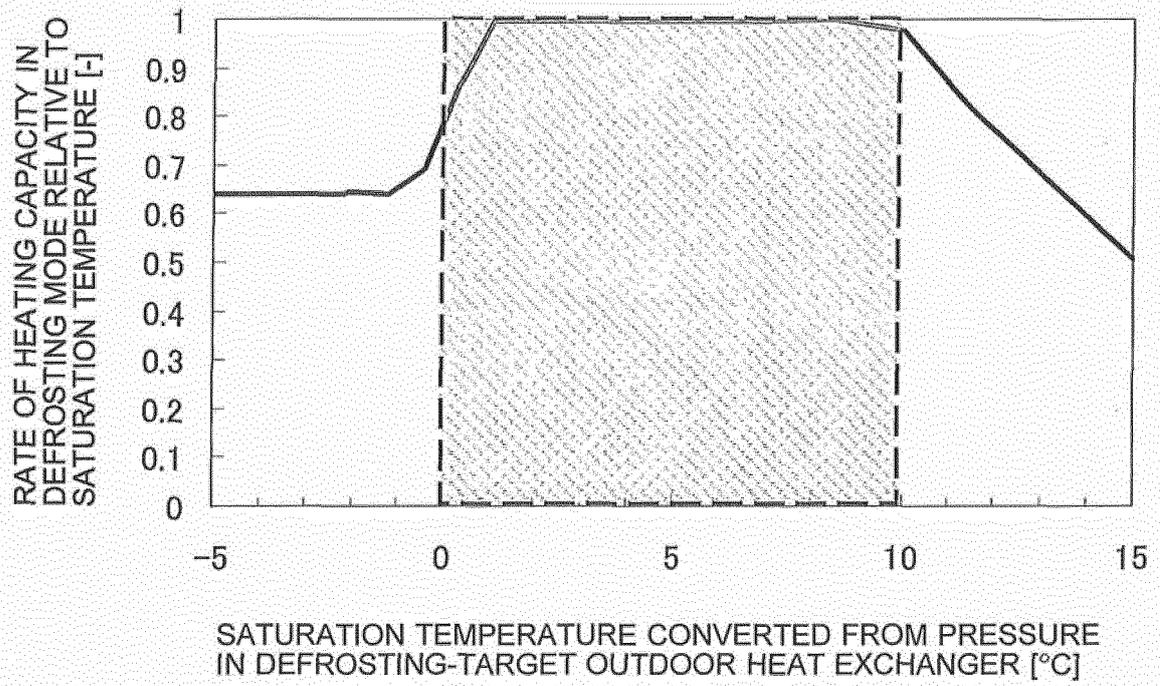


FIG. 8

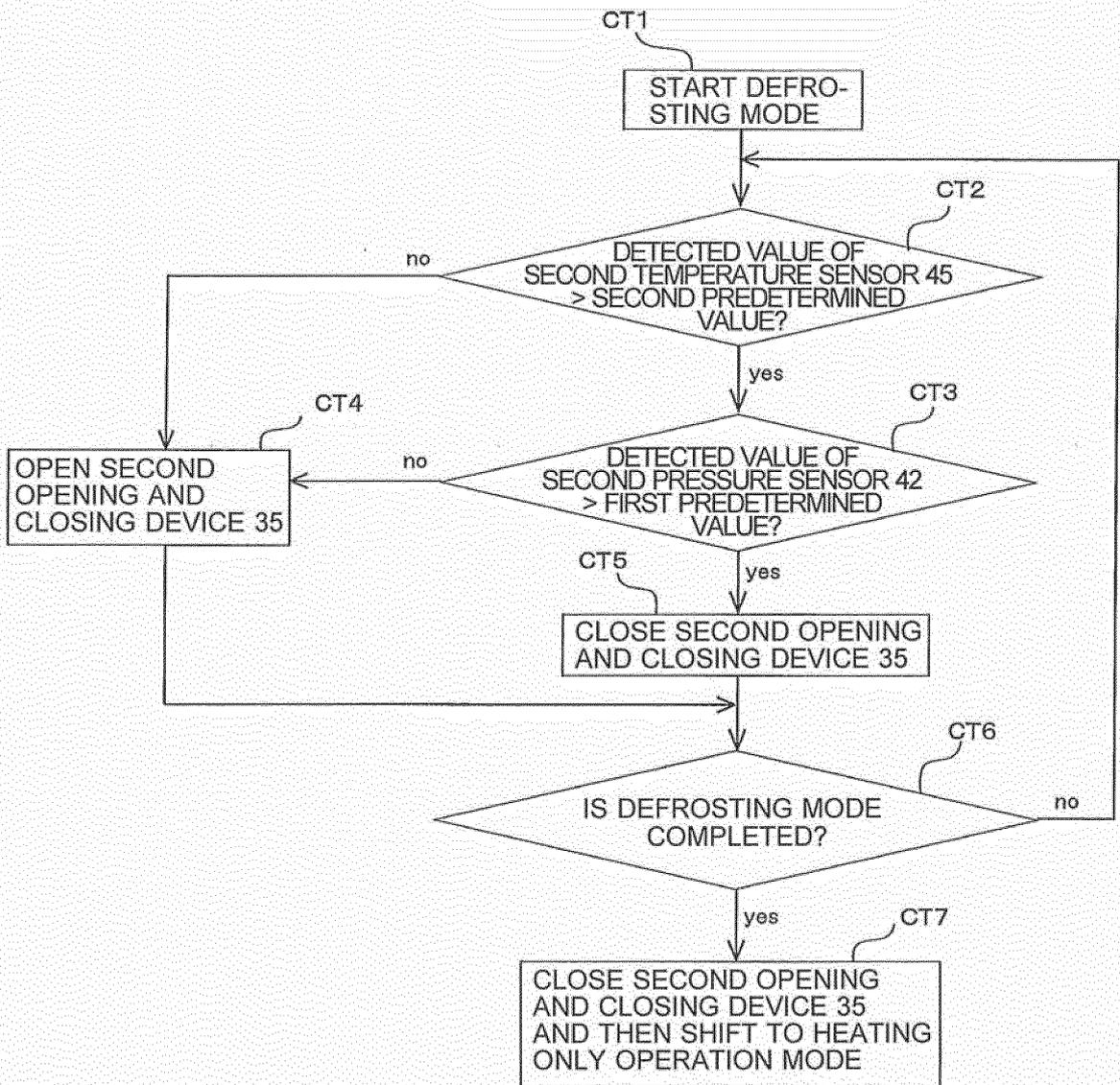


FIG. 9

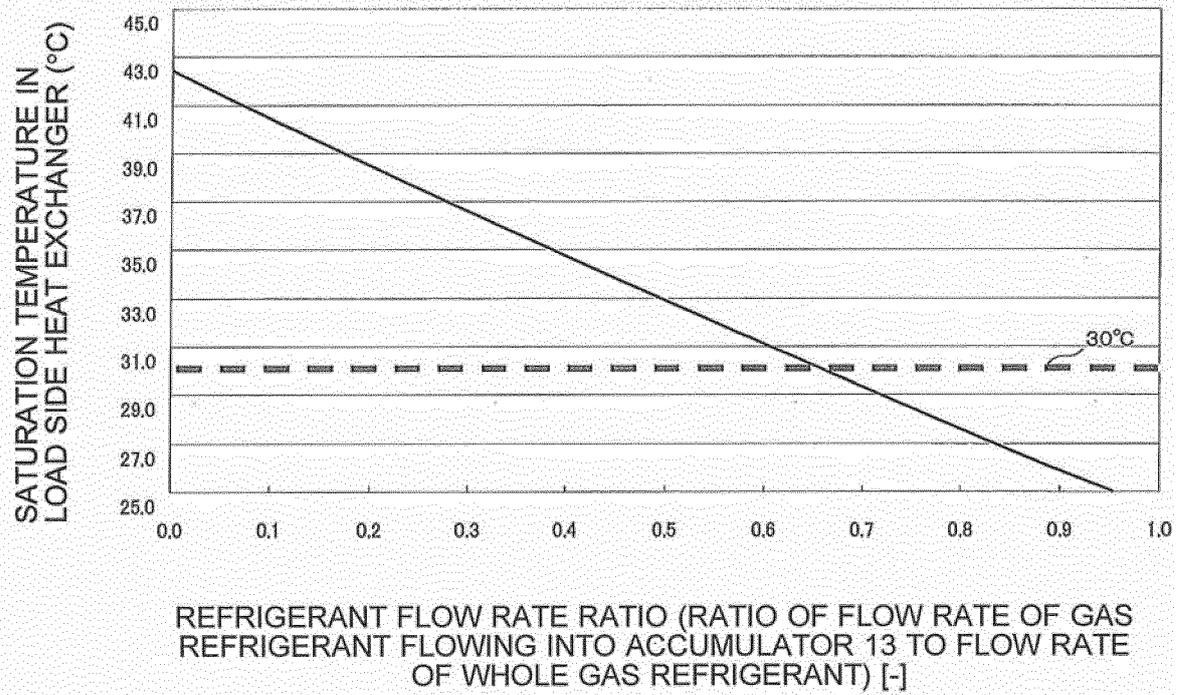


FIG. 10

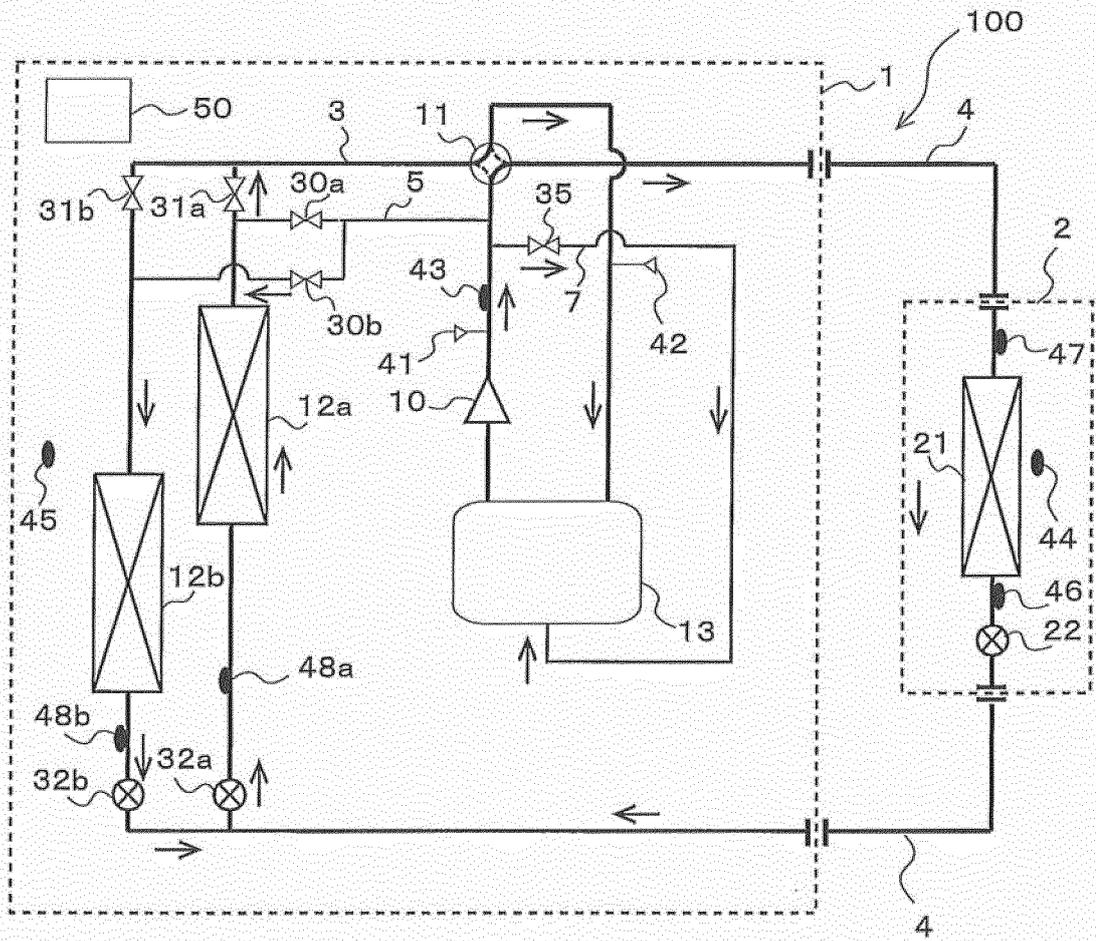
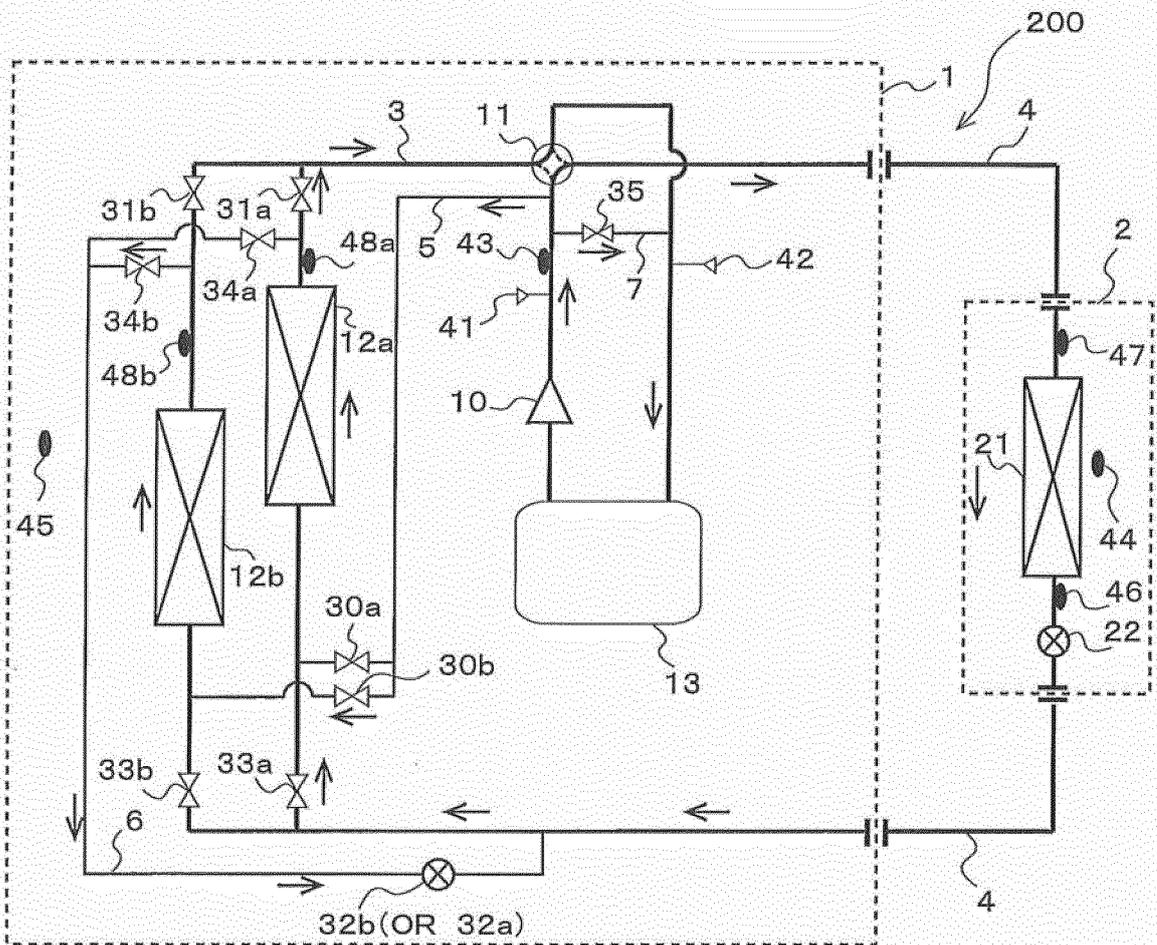


FIG. 11



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/078779

## A. CLASSIFICATION OF SUBJECT MATTER

F24F11/02(2006.01)i, F25B47/02(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)

F24F11/02, F25B47/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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 2010/082325 A1 (Mitsubishi Electric Corp.), 22 July 2010 (22.07.2010), paragraphs [0007], [0019] to [0022], [0059] to [0071] & US 2011/0232308 A1 & EP 2378215 A1 & CN 102272534 A	1-3 4-13
Y	JP 2011-163708 A (Toshiba Carrier Corp.), 25 August 2011 (25.08.2011), paragraphs [0003] to [0005], [0025], [0040] to [0058] (Family: none)	1-3

 Further documents are listed in the continuation of Box C.
  See patent family annex.

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Date of the actual completion of the international search  
11 December, 2013 (11.12.13)Date of mailing of the international search report  
24 December, 2013 (24.12.13)Name and mailing address of the ISA/  
Japanese Patent Office

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/078779

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 6-337178 A (Mitsubishi Heavy Industries, Ltd.), 06 December 1994 (06.12.1994), entire text; all drawings (Family: none)	1
A	WO 2013/111177 A1 (Mitsubishi Electric Corp.), 01 August 2013 (01.08.2013), entire text; all drawings (Family: none)	1
A	JP 3-20571 A (Mitsubishi Electric Corp.), 29 January 1991 (29.01.1991), page 5, upper left column, line 10 to upper right column, line 15; fig. 1 (Family: none)	1
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A	JP 2010-139097 A (Mitsubishi Electric Corp.), 24 June 2010 (24.06.2010), paragraphs [0007], [0008], [0026] to [0043] (Family: none)	13

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**REFERENCES CITED IN THE DESCRIPTION**

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