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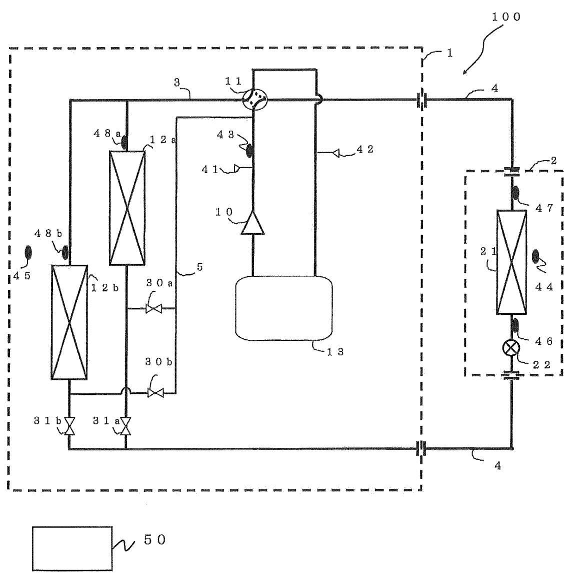
(54) **AIR CONDITIONING DEVICE**

(57) A heat source side heat exchanger 12 includes a plurality of fins 61 and 62 spaced apart from one another such that air passes between the fins 61 and 62 and a plurality of heat exchanger tubes 64 and 65 disposed in the fins 61 and 62 and allowing a refrigerant to flow in the heat exchanger tubes 64 and 65. Heat source side heat exchangers 12a and 12b are disposed adjacent to each other such that the fins 61 and 62 are oriented in an identical direction. A heat leakage reducing mechanism is disposed between the adjacent fins 61 and 62 and reduces the amount of heat leakage between the adjacent heat source side heat exchangers 12a and 12b.

FIG. 1



EP 2 930 450 A1

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 buildings, a refrigerant circulates in a refrigerant circuit formed by connecting, by pipes, an outdoor unit as a heat source unit disposed outside a structure, for example, and an indoor unit disposed in the structure. An air-conditioned space is heated or cooled by heating or cooling air by utilizing heat radiation or heat absorption of the refrigerant.

[0003] In a heating operation of such a multi-air-conditioning apparatus for buildings, a heat exchanger of the outdoor unit serves as an evaporator and exchanges heat between a low-temperature refrigerant and air so that moisture in the air is condensed on fins and heat exchanger tubes of the heat exchanger, and frost is accumulated on the heat exchanger.

[0004] This frost accumulated on the heat exchanger blocks air passages of the heat exchanger and reduces the heat transfer area of the heat exchanger that performs heat exchange with air, resulting in a problem of a shortage of heating capacity. To prevent this problem, a heating operation is stopped and a refrigerant flow switch valve is switched so that the heat exchanger of the outdoor unit serves as a condenser, and thereby, a defrosting operation is performed. Such a defrosting operation can prevent a decrease in heating capacity. However, during the defrosting operation, a heating operation of the room is also stopped, and thus, the temperature in the room decreases and comfort in the indoor environments is impaired.

[0005] To solve such problems, a typical technique performs a defrosting operation and a heating operation at the same time by using a plurality of outdoor heat exchangers and bypass pipes so as to allow a gas discharged from a compressor to be bypassed to the heat exchangers individually through shut-off valves and by operating some of the heat exchangers as evaporators and the other as condensers (see, for example, Patent Literature 1 and Patent Literature 2).

Citation List

Patent Literature

[0006]

Patent Literature 1: WO2010/082325 (e.g., Fig. 7 and Fig. 8, for example)
Patent Literature 2: US2010/0170270 (e.g., Fig. 2, for example)

Summary of Invention

Technical Problem

[0007] The air-conditioning apparatus described in each of Patent Literature 1 and Patent Literature 2 uses outdoor heat exchangers, some of which performs a heating operation as evaporators and the other of which perform a defrosting operation as condensers, and the heating operation and the defrosting operation are performed at the same time. However, none of these literatures clearly describes the positional relationship among the heat exchangers. For example, in a case where an evaporator and a condenser are disposed adjacent to each other (e.g., disposed one above the other) and heat exchangers constituting the evaporator and the condenser are connected to each other by fins, heat leaks from the condenser to the evaporator through the fins at the interface between the evaporator and the condenser.

[0008] Occurrence of the heat leakage reduces the defrosting capacity of the condenser near the interface between the evaporator and the condenser, resulting in insufficient defrosting near the interface. Thus, the time necessary for the defrosting increases, the capacity of heating the room during a defrosting operation decreases, and comfort in the indoor environments is impaired. In addition, water drops generated after the defrosting are frozen so that root ice is generated, the heat transfer area of the heat exchanger decreases, the heating capacity decreases, and the comfort in the indoor environments is impaired.

[0009] Although the time for a defrosting operation is increased in order to avoid remaining frost and root ice, the amount of frost accumulated on the heat exchanger operating as an evaporator in the defrosting operation increases. Thus, the heat transfer area of the heat exchanger serving as an evaporator decreases, and the heating capacity decreases, resulting in impairment of comfort in the indoor environments.

[0010] The present invention has been made in order to solve the above-described problems, and it is therefore an object of the invention to provide an air-conditioning apparatus that can reduce heat leakage through fins between adjacent heat exchangers.

Solution to Problem

[0011] An air-conditioning apparatus according to the present invention includes: a main circuit in which a compressor, a load side heat exchanger, a load side expansion device, and a plurality of heat source side heat exchangers connected in parallel are sequentially connected by pipes and in which a refrigerant circulates; a bypass pipe configured to cause part of a refrigerant discharged from the compressor to branch and flow into at least one of the plurality of heat source side heat exchangers to be defrosted; and a connection switching device configured to switch the one of the plurality of the heat source side heat exchangers to be defrosted by switching a channel of the bypass pipe between an open state and a closed state and switching a channel of the pipes of the main circuit connected to the plurality of heat source side heat exchangers between an open state and a closed state, wherein the heat source side heat exchanger includes a plurality of fins spaced apart from one another such that air passes between the plurality of fins, and a plurality of heat exchanger tubes disposed in the plurality of fins and allowing the refrigerant to flow in the heat exchanger tubes, the plurality of heat source side heat exchangers are disposed adjacent to one another such that the plurality of fins are oriented in an identical direction, and includes a heat leakage reducing mechanism that is sandwiched between adjacent ones of the plurality of fins and that reduces an amount of heat leakage between adjacent ones of the plurality of heat source side heat exchangers.

Advantageous Effects of Invention

[0012] According to the present invention, heat leakage through fins can be reduced between adjacent heat source side heat exchangers. Thus, even in a case where some of heat source side heat exchangers perform a defrosting operation and others perform a heating operation, generation of remaining frost and root ice can be reduced in the interface between adjacent ones of the heat source side heat exchangers. As a result, an air-conditioning apparatus that can achieve comfort in the indoor environments by reducing a defrosting time and a decrease in heating capacity can be obtained.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a circuit diagram schematically illustrating an example circuit configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[Fig. 2] Fig. 2 schematically illustrates an example configuration of heat source side heat exchangers placed in an outdoor unit in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 3] Fig. 3 is a refrigerant circuit diagram showing a refrigerant flow in a cooling-only operation mode of the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 4] Fig. 4 is a refrigerant circuit diagram showing a refrigerant flow in a heating-only operation mode of the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 5] Fig. 5 is a refrigerant circuit diagram showing a refrigerant flow in a case where a heat source side heat exchanger 12b is defrosted in a defrosting operation mode of the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 6] Fig. 6 is a refrigerant circuit diagram showing a refrigerant flow in a case where a heat source side heat exchanger 12a is defrosted in the defrosting operation mode of the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 7] Fig. 7 schematically illustrates an example configuration in which fins of heat source side heat exchangers are not shared but are separated in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 8] Fig. 8 schematically illustrates an example configuration in which the fins of the heat source side heat exchangers are not shared but are separated and a notch is provided in the air-conditioning apparatus 100 of Embodiment 1.
[FIG. 9] FIG. 9 schematically illustrates an example configuration in which part of the fins of the heat source side heat exchangers are shared and a notch is provided in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 10] Fig. 10 schematically illustrates an example configuration in which part of the fins of the heat source side heat exchangers is shared and a slit is provided in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 11] Fig. 11 schematically illustrates an example configuration in which the fins of the heat source side heat exchangers are not shared but are separated and an ellipsoidal notch is provided in the air-conditioning apparatus 100 of Embodiment 1.

[Fig. 12] Fig. 12 schematically illustrates an example configuration in which part of the fins is shared and two notches are provided in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 13] Fig. 13 schematically illustrates an example configuration in which heat source side heat exchangers are placed in an outdoor unit and are disposed one above the other with a clearance interposed therebetween in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 14] Fig. 14 is a graph for comparing a heat transfer area ratio and a COP, which is an index indicating the degree of performance of an air-conditioning apparatus, in the air-conditioning apparatus 100 of Embodiment 1.
[Fig. 15] Fig. 15 is a circuit diagram schematically illustrating an example circuit configuration of an air-conditioning apparatus 200 according to Embodiment 2 of the present invention.
[Fig. 16] Fig. 16 is a circuit diagram schematically illustrating an example circuit configuration in which one of third opening/closing devices 32 is changed to a expansion device having a variable opening degree in the air-conditioning apparatus 200 of Embodiment 2.
[Fig. 17] Fig. 17 is a circuit diagram schematically illustrating an example circuit configuration in which only one third opening/closing device 32 having a variable opening degree is provided in the air-conditioning apparatus 200 of Embodiment 2.
[Fig. 18] Fig. 18 is a circuit diagram schematically illustrating an example circuit configuration in which the internal pressure of a heat source side heat exchanger 12 serving as a condenser can be adjusted in the air-conditioning apparatus 200 of Embodiment 2.

Description of Embodiments

[0014] Embodiments of the present invention will be described hereinafter with reference to the drawings.

Embodiment 1

[0015] Fig. 1 is a circuit diagram schematically illustrating an example circuit configuration of an air-conditioning apparatus 100 according to Embodiment 1 of the present invention.
[0016] Referring to Fig. 1, the configuration of the air-conditioning apparatus 100 will be specifically described.
[0017] As illustrated in Fig. 1, the air-conditioning apparatus 100 includes an outdoor unit 1 and an indoor unit 2, and the outdoor unit 1 and the indoor unit 2 are connected to each other by refrigerant main pipe 4.
[0018] The air-conditioning apparatus 100 circulates a refrigerant therein so that air-conditioning is performed by using a refrigeration cycle. The air-conditioning apparatus 100 is configured to select a mode from a cooling-only operation mode in which all the operating indoor units 2 perform cooling, a heating-only operation mode in which all the operating indoor units 2 perform heating, and a defrosting operation mode in which the indoor units 2 defrost heat exchange units in the outdoor unit 1 while continuing a heating operation.

[Outdoor Unit 1]

[0019] The outdoor unit 1 includes a compressor 10, a refrigerant channel switching device 11 such as a four-way valve, a heat source side heat exchanger 12a, a heat source side heat exchanger 12b, an accumulator 13, refrigerant pipes 3, and a hot gas bypass pipe 5.
[0020] The compressor 10, the refrigerant channel switching device 11 such as a four-way valve, the heat source side heat exchanger 12a, the heat source side heat exchanger 12b, and the accumulator 13 are connected together by the refrigerant pipes 3.
[0021] The heat source side heat exchanger 12a and the heat source side heat exchanger 12b are connected in parallel to each other by the refrigerant pipes 3. Second opening/closing devices 31 a and 31 b are provided to portions of the refrigerant pipes 3 connected to the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, the portions of the refrigerant pipes 3 connecting to a load side expansion device 22.
[0022] The hot gas bypass pipe 5 branches part of a high-temperature refrigerant discharged from the compressor 10, and allows the refrigerant to flow into a defrosting-target heat source side heat exchanger 12 of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b.
[0023] Specifically, as illustrated in Fig. 1, an end of the hot gas bypass pipe 5 is connected to the refrigerant pipe 3 between a discharge part of the compressor 10 and the refrigerant channel switching device 11.
[0024] The other end of the hot gas bypass pipe 5 is divided into two parts, one of which is connected to the refrigerant pipe 3 between the heat source side heat exchanger 12a and the second opening/closing device 31 a and the other is connected to the refrigerant pipe 3 between the heat source side heat exchanger 12b and the second opening/closing device 31 b.
[0025] The hot gas bypass pipe 5 connected to the heat source side heat exchanger 12a is provided with a first

opening/closing device 30a. The hot gas bypass pipe 5 connected to the heat source side heat exchanger 12b is provided with a first opening/closing device 30b.

[0026] The first opening/closing device 30a, the first opening/closing device 30b, the second opening/closing device 31 a, and the second opening/closing device 31 b of Embodiment 1 constitute "connection switching devices" of the invention.

[0027] The compressor 10 sucks a refrigerant therein, and compresses the refrigerant into a high-temperature high-pressure state. The compressor 10 is, for example, an inverter compressor whose capacity can be controlled.

[0028] The refrigerant channel switching device 11 switches a refrigerant flow between a flow in the heating-only operation mode and a flow in the cooling-only operation mode.

[0029] The heat source side heat exchanger 12a and the heat source side heat exchanger 12b serve as evaporators in the heating-only operation mode, and serve as condensers in the cooling-only operation mode. In a defrosting operation, one of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b serves as an evaporator, and the other serves as a condenser.

[0030] Fig. 2 schematically illustrates an example configuration of heat source side heat exchangers placed in an outdoor unit in the air-conditioning apparatus 100 of Embodiment 1.

[0031] As illustrated in Fig. 2, the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed in a casing 51 of the outdoor unit 1. The heat source side heat exchanger 12a and the heat source side heat exchanger 12b include a plurality of fins spaced from each other to allow air to pass threrethrough and a plurality of heat exchanger tubes disposed among the fins and allowing a refrigerant to flow therethrough. The heat source side heat exchanger 12a and the heat source side heat exchanger 12b exchange heat between air from air-sending devices such as the a fan 52 and a refrigerant.

[0032] The heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed adjacent to each other such that the fins are oriented in the same direction. For example, as illustrated in Fig. 2, the heat source side heat exchanger 12a is located above the heat source side heat exchanger 12b. The heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed side by side along the direction of stages, that is, the stage direction, of the heat exchanger tubes. Specifically, the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed one above the other such that the fins of the exchangers 12a and 12b are oriented in an identical direction.

[0033] A heat leakage reducing mechanism for reducing the amount of heat leakage between the adjacent heat source side heat exchangers 12a and 12b is provided between adjacent fins. Detailed description will be given later.

[0034] Referring to Fig. 1 again, the configuration will be described.

[0035] The accumulator 13 is provided at a suction side of the compressor 10, and stores a surplus refrigerant generated by the difference in operating state between the heating-only operation mode and the cooling-only operation mode and a surplus refrigerant generated by a transient change in operation.

[0036] The first opening/closing device 30a is a shut-off valve for causing a high-temperature refrigerant from the hot 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. The first opening/closing device 30b is a shut-off valve for causing a high-temperature refrigerant from the hot 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. The first opening/closing devices 30a and 30b are, for example, two way valves, solenoid valves, and electronic expansion valves, which can open and close refrigerant channels.

[0037] The second opening/closing device 31 a is a shut-off valve for shutting off a refrigerant channel in order to prevent a low-temperature two-phase refrigerant flowing out of the indoor unit 2 into the outdoor unit 1 through a refrigerant main pipe 4 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. The second opening/closing device 31 b is a shut-off valve for shutting off a refrigerant channel in order to prevent a low-temperature two-phase refrigerant flowing out of the indoor unit 2 into the outdoor unit 1 through the refrigerant main pipe 4 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. The second opening/closing devices 31 a and 31 b are, for example, two way valves, solenoid valves, and electronic expansion valves, which can open and close refrigerant channels.

[0038] The outdoor unit 1 includes a first pressure sensor 41 and a second pressure sensor 42, as pressure detection means.

[0039] The first pressure sensor 41 is provided to the pipe between the compressor 10 and the refrigerant channel switching device 11. The first pressure sensor 41 detects the pressure of a high-temperature high-pressure refrigerant discharged from the compressor 10.

[0040] The second pressure sensor 42 is provided to the pipe between the refrigerant channel switching device 11 and the accumulator 13. The second pressure sensor 42 detects the pressure of a low-pressure refrigerant to be sucked into the compressor 10.

[0041] The outdoor unit 1 includes, as temperature detection means, a first temperature sensor 43, a second temperature sensor 45, a third temperature sensor 48a, and a third temperature sensor 48b. The first temperature sensor 43, the second temperature sensor 45, the third temperature sensor 48a, and the third temperature sensor 48b are, for example, thermistors.
[0042] The first temperature sensor 43 is provided to the pipe between the compressor 10 and the refrigerant channel switching device 11. The first temperature sensor 43 measures the temperature of a refrigerant discharged from the compressor 10.
[0043] The second temperature sensor 45 is provided to an air inlet of one of the heat source side heat exchanger 12a or the heat source side heat exchanger 12b. The second temperature sensor 45 measures the temperature of the air around the outdoor unit 1.
[0044] The third temperature sensor 48a is provided to the pipe between the heat source side heat exchanger 12a and the refrigerant channel switching device 11.
[0045] The third temperature sensor 48a measures the temperature of a refrigerant that has flowed from the heat source side heat exchanger 12a operating as an evaporator.
[0046] The third temperature sensor 48b is provided to the pipe between the heat source side heat exchanger 12b and the refrigerant channel switching device 11. The third temperature sensor 48b measures the temperature of a refrigerant that has flowed from the heat source side heat exchanger 12b operating as an evaporator.

[Indoor Unit 2]

[0047] The indoor unit 2 includes a load side heat exchanger 21 and a load side expansion device 22.
[0048] The load side heat exchanger 21 is connected to the outdoor unit 1 through the refrigerant main pipe 4 so that a refrigerant flows in or out of the load side heat exchanger 21. The load side heat exchanger 21 exchanges heat between air from an air-sending device such as a fan and a refrigerant. The load side heat exchanger 21 generates air for heating or air for cooling to be supplied to an interior space.
[0049] The load side expansion device 22 has functions of a pressure reducing valve and an expansion valve, and reduces the pressure of a refrigerant and expands the refrigerant. The load side expansion device 22 is located upstream of the load side heat exchanger 21 in a refrigerant flow in the cooling-only operation mode. The load side expansion device 22 is a valve whose opening degree is variable by control. The load side expansion device 22 is, for example, an electronic expansion valve.
[0050] The indoor unit 2 includes, as temperature detection means, a fourth temperature sensor 46, a fifth temperature sensor 47, and a sixth temperature sensor 44. The fourth temperature sensor 46, the fifth temperature sensor 47, and the sixth temperature sensor 44 are, for example, thermistors.
[0051] The fourth temperature sensor 46 is provided to the pipe between the load side expansion device 22 and the load side heat exchanger 21. The fourth temperature sensor 46 detects the temperature of a refrigerant flowing in the load side heat exchanger 21 or a refrigerant that has flowed from the load side heat exchanger.
[0052] The fifth temperature sensor 47 is provided to the pipe between the load side heat exchanger 21 and the refrigerant channel switching device 11 of the outdoor unit 1. The fifth temperature sensor 47 detects the temperature of a refrigerant flowing in the load side heat exchanger 21 or a refrigerant that has flowed from the load side heat exchanger 21.
[0053] The sixth temperature sensor 44 is provided at the air inlet of the load side heat exchanger 21. The sixth temperature sensor 44 detects an ambient air temperature in the room.
[0054] In the foregoing configuration of the air-conditioning apparatus 100, the compressor 10, the refrigerant channel 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 sequentially connected to one another by pipes, and constitute a main circuit in which a refrigerant circulates. A bypass through which part of a refrigerant discharged from the compressor 10 branches off and flows into a defrosting-target heat source side heat exchanger 12 of the heat source side heat exchangers 12a and 12b.
[0055] As illustrated in Fig. 1, in the example configuration of Embodiment 1, one indoor unit 2 is connected to the outdoor unit 1 through the refrigerant main pipe 4, but the invention is not limited to this configuration. Alternatively, a plurality of indoor units 2 may be connected in parallel to the outdoor unit 1.
[0056] The control device 50 is a microcomputer, and the air-conditioning apparatus 100 includes the control device 50 that is the microcomputer. Based on detection information obtained by the detection means and an instruction from a remote controller, the control device 50 controls the driving frequency of the compressor 10, the rotation speed (including ON/OFF) of the air-sending device, switching of the refrigerant channel switching device 11, opening/closing of the first opening/closing devices 30a and 30b, opening/closing of the second opening/closing device 31, and the opening degree of the load side expansion device 22, for example, and performs operation modes described later. The control device 50 may be provided to each unit, or may be provided to the outdoor unit 1 or the indoor unit 2.

[0057] Operation modes of the air-conditioning apparatus 100 will now be described.
[0058] The operation modes will be described below together with a refrigerant flow.

[Cooling-Only Operation Mode]

[0059] Fig. 3 is a refrigerant circuit diagram showing a refrigerant flow in a cooling-only operation mode of the air-conditioning apparatus 100 of Embodiment 1.
[0060] Fig. 3 shows a cooling-only operation mode using a case where a cooling energy load is generated in the load side heat exchanger 21 as an example. In Fig. 3, the flow direction of a refrigerant is indicated by solid arrow lines.
[0061] In the cooling-only operation mode, the refrigerant channel switching device 11 is switched to a state indicated by the solid lines in Fig. 3. The first opening/closing device 30a and the first opening/closing device 30b are switched to closed states, and shut off the refrigerant. The second opening/closing device 31 a and the second opening/closing device 31 b are switched to open states, and allow the refrigerant to pass therethrough.
[0062] When the compressor 10 is driven, a low-temperature low-pressure refrigerant is compressed and becomes a high-temperature high-pressure gas refrigerant, and the resulting refrigerant is discharged. The high-temperature high-pressure gas refrigerant discharged from the compressor 10 flows into the heat source side heat exchanger 12a and the heat source side heat exchanger 12b through the refrigerant channel switching device 11.
[0063] The high-temperature high-pressure gas refrigerant that has flowed into the heat source side heat exchanger 12a and the heat source side heat exchanger 12b dissipates heat to the outdoor air in the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, and becomes a high-pressure liquid refrigerant. The high-pressure liquid refrigerant that has flowed from the heat source side heat exchanger 12a and the heat source side heat exchanger 12b merge through the second opening/closing device 31 a and the second opening/closing device 31 b, and the resulting refrigerant flows out of the outdoor unit 1.
[0064] The high-pressure liquid refrigerant from the outdoor unit 1 flows into the indoor unit 2 through the refrigerant main pipe 4, expands in the load side expansion device 22, and becomes a low-temperature low-pressure two-phase refrigerant. This two-phase refrigerant flows into the load side heat exchanger 21 operating as an evaporator, receives heat from the indoor air so as to cool the indoor air, and becomes a low-temperature low-pressure gas refrigerant.
[0065] The gas refrigerant that has flowed from the load side heat exchanger 21 flows into the outdoor unit 1 again through the refrigerant main pipe 4. The refrigerant that has flowed into the outdoor unit 1 is sucked into the compressor 10 again through the refrigerant channel switching device 11 and the accumulator 13.
[0066] The control device 50 controls the opening degree of the load side expansion device 22 such that the degree of superheat obtained as the difference between the temperature detected by the fourth temperature sensor 46 and the temperature detected by the fifth temperature sensor 47 is constant.

[Heating-Only Operation Mode]

[0067] Fig. 4 is a refrigerant circuit diagram showing a refrigerant flow in a heating-only operation mode of the air-conditioning apparatus 100 of Embodiment 1.
[0068] Fig. 4 shows a heating-only operation mode using a case where a heating energy load is generated in the load side heat exchanger 21 as an example. In Fig. 4, the flow direction of a refrigerant is indicated by solid arrow lines.
[0069] In the heating-only operation mode, the refrigerant channel switching device 11 is switched to a state indicated by the solid lines in Fig. 4. The first opening/closing device 30a and the first opening/closing device 30b are switched to closed states, and shut off the refrigerant. The second opening/closing device 31 a and the second opening/closing device 31 b are switched to an open state, and allow the refrigerant to pass therethrough.
[0070] When the compressor 10 is driven, the low-temperature low-pressure refrigerant is compressed and becomes a high-temperature high-pressure gas refrigerant, and the resulting refrigerant is discharged. The high-temperature high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant channel switching device 11.
[0071] The high-temperature high-pressure gas refrigerant that has flowed from the outdoor unit 1 flows into the indoor unit 2 through the refrigerant main pipe 4, transfers heat to the indoor air in the load side heat exchanger 21, and thereby, becomes a liquid refrigerant while heating the indoor air.
[0072] The liquid refrigerant that has flowed out of the load side heat exchanger 21 expands in the load side expansion device 22, becomes a low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant, and the resulting refrigerant flows into the outdoor unit 1 again through the refrigerant main pipe 4.
[0073] The low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 flows into the heat source side heat exchanger 12a and the heat source side heat exchanger 12b through the second opening/closing device 31 a and the second opening/closing device 31 b, respectively. The refrigerant that has flowed into each of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b absorbs

heat from the outdoor air and becomes a low-temperature low-pressure gas refrigerant, and the resulting refrigerant is sucked into the compressor 10 again through the refrigerant channel switching device 11 and the accumulator 13.

[0074] The control device 50 controls the opening degree of the load side expansion device 22 such that the degree of subcooling obtained as the difference between a value of a saturation temperature converted from the pressure detected by the first pressure sensor 41 and the temperature detected by the fourth temperature sensor 46.

[Defrosting Operation Mode]

[0075] A defrosting operation mode is performed when detection results of the third temperature sensors 48a and 48b at the outlets of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are less than or equal to a predetermined value. Specifically, when the heating-only operation is performed so that the detection results of the third temperature sensors 48a and 48b decrease to a predetermined value or less (e.g., about -10 degrees C or less), the control device 50 determines that a predetermined amount of frost is accumulated on the fins of the heat source side heat exchangers 12a and 12b, and the defrosting operation is performed.

[0076] In the defrosting operation mode of the air-conditioning apparatus 100 of Embodiment 1, the heat source side heat exchanger 12b located in a lower space of the casing 51 is defrosted, and then the heat source side heat exchanger 12a located in an upper space of the casing 51 is defrosted. One of the heat source side heat exchanger 12a or the heat source side heat exchanger 12b that is not a defrosting target operates as an evaporator, and the load side heat exchanger 21 of the indoor unit 2 operates as a condenser. In this manner, the heating operation continues.

(Defrosting of Heat Source Side Heat Exchanger 12b)

[0077] Fig. 5 is a refrigerant circuit diagram showing a refrigerant flow in a case where the heat source side heat exchanger 12b is defrosted in the defrosting operation mode of the air-conditioning apparatus 100 of Embodiment 1. In Fig. 5, the flow direction of a refrigerant is indicated by solid arrow lines.

[0078] In the defrosting operation mode, the refrigerant channel switching device 11 is maintained in a state indicated by solid lines in Fig. 5.

[0079] In the defrosting operation mode, in a case where the heat source side heat exchanger 12b is a defrosting target, the first opening/closing device 30b is switched to an open state and allows a refrigerant to pass therethrough.

[0080] The second opening/closing device 31 b is switched to a closed state and shuts off the refrigerant.

[0081] The first opening/closing device 30a is maintained in a closed state and shuts off the refrigerant.

[0082] The second opening/closing device 31 a is maintained in an open state and allows the refrigerant to pass therethrough.

[0083] When the compressor 10 is driven, the low-temperature low-pressure refrigerant is compressed and becomes a high-temperature high-pressure gas refrigerant, and the resulting refrigerant is discharged.

[0084] Part of the high-temperature high-pressure gas refrigerant discharged from the compressor 10 passes through the hot gas bypass pipe 5, and flows into the heat source side heat exchanger 12b through the first opening/closing device 30b. The high-temperature high-pressure gas refrigerant that has flowed into the heat source side heat exchanger 12b becomes a low-temperature gas refrigerant while melting frost on the heat source side heat exchanger 12b, and merges with a refrigerant that has flowed from the heat source side heat exchanger 12a.

[0085] The other part of the high-temperature high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant channel switching device 11.

[0086] The high-temperature high-pressure gas refrigerant that has flowed from the outdoor unit 1 flows into the indoor unit 2 through the refrigerant main pipe 4, transfers heat to the indoor air in the load side heat exchanger 21, and becomes a liquid refrigerant while heating the indoor air.

[0087] The liquid refrigerant that has flowed from the load side heat exchanger 21 expands in the load side expansion device 22, becomes a low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant, and flows into the outdoor unit 1 again through the refrigerant main pipe 4.

[0088] The low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 flows into the heat source side heat exchanger 12a through the second opening/closing device 31 a. The refrigerant that has flowed into the heat source side heat exchanger 12a absorbs heat from the outdoor air, and becomes a low-temperature low-pressure gas refrigerant. The gas refrigerant that has flowed from the heat source side heat exchanger 12a merges with the gas refrigerant that has flowed from the heat source side heat exchanger 12b, and is sucked into the compressor 10 again through the refrigerant channel switching device 11 and the accumulator 13.

[0089] After a lapse of a predetermined time or when the temperature of the gas refrigerant detected by the third temperature sensor 48b at the outlet of the heat source side heat exchanger 12b reaches a predetermined value or more (e.g., 10 degrees C or more), the control device 50 finishes defrosting of the heat source side heat exchanger 12b.

[0090] Thereafter, the heat source side heat exchanger 12a is defrosted.

[0091] The predetermined time can be a time until all the frost melts in a case where frost is accumulated over the entire heat source side heat exchanger 12b without a clearance and part of the high-temperature high-pressure refrigerant flows into the heat source side heat exchanger 12b.

(Defrosting of Heat Source Side Heat Exchanger 12a)

[0092] Fig. 6 is a refrigerant circuit diagram showing a refrigerant flow in a case where the heat source side heat exchanger 12a is defrosted in the defrosting operation mode of the air-conditioning apparatus 100 of Embodiment 1. In Fig. 6, the flow direction of a refrigerant is indicated by solid arrow lines.

[0093] In the defrosting operation mode, the refrigerant channel switching device 11 is maintained in a state indicated by the solid lines in Fig. 6.

[0094] In the defrosting operation mode, in a case where the heat source side heat exchanger 12a is a defrosting target, the first opening/closing device 30a is switched to an open state and allows a refrigerant to pass therethrough.

[0095] The second opening/closing device 31 a is switched to a closed state and shuts off the refrigerant.

[0096] The first opening/closing device 30b is switched to a closed state and shuts off the refrigerant.

[0097] The second opening/closing device 31 b is switched to an open state and allows the refrigerant to pass therethrough.

[0098] When the compressor 10 is driven, the low-temperature low-pressure refrigerant is compressed and becomes a high-temperature high-pressure gas refrigerant, and the resulting refrigerant is discharged.

[0099] Part of the high-temperature high-pressure gas refrigerant discharged from the compressor 10 passes through the hot gas bypass pipe 5, and flows into the heat source side heat exchanger 12a through the first opening/closing device 30a. The high-temperature high-pressure gas refrigerant that has flowed into the heat source side heat exchanger 12a becomes a low-temperature gas refrigerant while melting frost attached to the heat source side heat exchanger 12a, and merges with a refrigerant that has flowed from the heat source side heat exchanger 12b.

[0100] The other part of the high-temperature high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant channel switching device 11.

[0101] The high-temperature high-pressure gas refrigerant that has flowed out of the outdoor unit 1 flows into the indoor unit 2 through the refrigerant main pipe 4, transfers heat to the indoor air in the load side heat exchanger 21, and becomes a liquid refrigerant while heating indoor air.

[0102] The liquid refrigerant that has flowed out of the load side heat exchanger 21 expands in the load side expansion device 22 and becomes a low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant, and the resulting refrigerant flows into the outdoor unit 1 again through the refrigerant main pipe 4.

[0103] The low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 flows into the heat source side heat exchanger 12b through the second opening/closing device 31 b. The refrigerant that has flowed into the heat source side heat exchanger 12b absorbs heat from the outdoor air and becomes a low-temperature low-pressure gas refrigerant. The gas refrigerant that has flowed out of the heat source side heat exchanger 12b merges with a gas refrigerant that has flowed from the heat source side heat exchanger 12a, and is sucked into the compressor 10 again through the refrigerant channel switching device 11 and the accumulator 13.

[0104] After a lapse of a predetermined time or when the temperature of the gas refrigerant detected by the third temperature sensor 48a at the outlet of the heat source side heat exchanger 12a reaches a predetermined value or more (e.g., 10 degrees C or more), the control device 50 finishes defrosting of the heat source side heat exchanger 12a.

[0105] The predetermined time can be a time until all the frost melts in a case where frost is accumulated over the entire heat source side heat exchanger 12a without a clearance and part of the high-temperature high-pressure refrigerant flows into the heat source side heat exchanger 12a.

[0106] Performing the defrosting operation mode in this manner can defrost the heat source side heat exchangers 12a and 12b while continuing the heating operation.

[0107] The heat source side heat exchanger 12b located in the lower space of the casing 51 is defrosted, and then the heat source side heat exchanger 12a located in the lower space of the casing 51 is defrosted. Thus, it is possible to prevent water obtained by defrosting the heat source side heat exchanger 12a from being frozen again in the heat source side heat exchanger 12b in the lower space yet to be defrosted, and thus, defrosting can be efficiently performed.

[0108] In the above description, the heat source side heat exchanger 12b is defrosted, and then the heat source side heat exchanger 12a is defrosted. However, the invention is not limited to this example. For example, in a case where the temperature detected by the third temperature sensor 48a reaches a predetermined temperature or less (e.g., -10 degrees C or less) earlier than that detected by the third temperature sensor 48b, the heat source side heat exchanger 12a may be first defrosted.

[Heat Leakage Reducing Mechanism]

(Fin Structure (1))

[0109] Fig. 7 schematically illustrates an example configuration in which the fins of the heat source side heat exchangers are not shared but are separated in the air-conditioning apparatus 100 of Embodiment 1.

[0110] In Fig. 7, reference numeral 61 denotes a fin of the heat source side heat exchanger 12a. Reference numeral 64 denotes a heat transmission pipe of the heat source side heat exchanger 12a. Reference numeral 62 denotes a fin of the heat source side heat exchanger 12b. Reference numeral 65 denotes a heat transmission pipe of the heat source side heat exchanger 12b.

[0111] The heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed one above the other (in the stage direction). The lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a is separated from the uppermost end face of the fin 62 of the lower heat source side heat exchanger 12b.

[0112] The lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a is in contact with the lowermost end face of the fin 62 of the lower heat source side heat exchanger 12b at an interface 63.

[0113] At the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, the end face of each of the fin 61 and the fin 62 is subjected to a roughening process and forms a heat leakage reducing mechanism.

[0114] The roughening process only needs to be performed on the end face of at least one of the fin 61 or the fin 62 in the interface 63.

[0115] The heat leakage reducing mechanism causes the fin 61 and the fin 62 to be partially in contact with each other in the interface 63. Thus, the amount of heat leakage from the condenser to the evaporator by thermal conduction between the fin 61 and the fin 62 can be reduced as compared to a case where the fin 61 and the fin 62 are integrated (shared).

[0116] The heat leakage amount Q1 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b is expressed as Equation (1) of the amount of heat exchange due to typical thermal conduction.

[0117] In the equation, T1 [degrees C] is a refrigerant gas temperature of the heat source side heat exchanger 12 serving as a condenser in the heat source side heat exchangers 12a and 12b;
T2 [degrees C] is a two-phase refrigerant temperature at the inlet of the heat source side heat exchanger 12 serving as an evaporator of the heat source side heat exchangers 12a and 12b;
λ [W/mK] a thermal conductivity of a fin;
δ [m] is an inter-fin distance indicating the distance between an end of a heat transmission pipe of the heat source side heat exchanger 12a near the interface 63 and an end of a heat transmission pipe of the heat source side heat exchanger 12b near the interface 63; and
A [m^2] is an area calculated by multiplying the fin width [m], a fin thickness [m], and the number of fins.
[Equation 1]

$$Q1 = \frac{\lambda}{\delta} \times (T1 - T2) \times A \qquad (1)$$

[0118] The heat leakage amount Q1 in a case where the fin 61 and the fin 62 are integrated (shared) will be discussed.

[0119] For example, suppose the mean temperature T1 of a gas refrigerant flowing in the condenser performing defrosting is 20 degrees C and the temperature T2 of a refrigerant flowing in the evaporator used in heating operation is -15 degrees C. The inter-fin distance δ between the heat transmission pipe end of the evaporator and the heat transmission pipe end of the condenser in the interface 63 is 12.5 mm, and in a state where the heat exchangers are not separated, the fin width is 17 mm, the fin thickness is 0.1 mm, and the number of fins is 3700.

[0120] In this case, the heat leakage amount Q1 from the condenser to the evaporator in a case where the fins are not separated and are shared is about 3.60 kW from Equation (1).

[0121] On the other hand, in a case where the fins in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are separated from each other as shown in Fig. 7, the heat leakage amount Q1 is discussed.

[0122] For example, suppose the product of a heat transfer area (a contact area) at which the fin 61 of the upper heat source side heat exchanger 12a and the fin 62 of the lower heat source side heat exchanger 12b are in contact with each other and the overall heat transfer coefficient is a half of the product of a heat transfer area (a contact area) and the overall heat transfer coefficient in a case where the fins are shared.

[0123] In this case, the heat leakage amount Q1 from the condenser to the evaporator due to thermal conduction of the fins is reduced, as compared to the case where all the fins are shared, by about 25% or more, and the heat leakage amount Q1 is about 2.7 kW.

[0124] The reason why the heat leakage amount Q1 is not reduced to a half of that of a case where all the fins are shared is the influence of temperature distribution in the fins.

[0125] Then, the time required for completion of defrosting will be discussed.

[0126] For example, suppose the quantity of heat Q2 (calculated by multiplying latent heat of melting frost and the weight of frost) necessary for melting frost accumulated on the evaporator is about 1.5 MJ, and the heat exchange amount Q3 between frost and a refrigerant used in defrosting in a case where no heat leakage amount is present from the condenser to the evaporator by thermal conduction of the fins is about 5.5 kW.

[0127] The time required for completion of defrosting is obtained by subtracting the difference between the heat exchange amount Q3 and the heat leakage amount Q1 from the solution heat amount Q2 of frost.

[0128] In the case where the fin 61 and the fin 62 are integrated (shared), suppose the heat leakage amount Q1 is about 3.60 kW and the heat exchange amounts Q2 and Q3 are under the above conditions, then the time required for completion of defrosting is about 13 minutes.

[0129] On the other hand, in the case where the fins are separated as illustrated in Fig. 7, the heat leakage amount Q1 is reduced by about 25% to be about 2.7 kW, and suppose the heat exchange amounts Q2 and Q3 are under the above conditions, the time required for completion of defrosting is about 9 minutes.

[0130] Thus, the time required for completion of defrosting can be reduced by about 4 minutes.

[0131] In this manner, the reduction of the time required for completion of defrosting enables part of a refrigerant discharged from the compressor 10 for defrosting to be quickly used for heating, as compared to a case where heat leakage occurs from the condenser to the evaporator by thermal conduction of the fins. Thus, a decrease in heating capacity can be reduced. In addition, a temperature decrease in the room can be reduced, thereby comfort of the indoor environments can be obtained.

[0132] Further, a temperature decrease is reduced in the fin at the condenser side of the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, and thus, adfreezing of water drops generated by defrosting of the upper heat exchanger serving as the condenser can be reduced, thereby reducing generation of root ice.

(Fin Structure (2))

[0133] Another configuration of the heat leakage reducing mechanism will now be described.

[0134] Fig. 8 schematically illustrates an example configuration in which the fins of the heat source side heat exchangers are not shared but are separated and a notch is provided in the air-conditioning apparatus 100 of Embodiment 1.

[0135] As illustrated in Fig. 8, a notch 66 is formed in part of the lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a or part of the uppermost end face of the fin 62 of the lower heat source side heat exchanger 12b. The notch 66 constitutes a heat leakage reducing mechanism.

[0136] In the example illustrated in Fig. 8, the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed one above the other (in the stage direction). The lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a is separated from the uppermost end face of the fin 62 of the lower heat source side heat exchanger 12b.

[0137] The lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a is in contact with the uppermost end face of the fin 62 of the lower heat source side heat exchanger 12b in the interface 63.

[0138] In this manner, the notch 66 formed in part of the fins in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b can reduce the contact area of the fins in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, as compared to the case illustrated in Fig. 7. Thus, the heat leakage amount from the condenser to the evaporator by thermal conduction of the fins can be further reduced.

[0139] The thermal conductivity of the air is much lower than that of a material (e.g., aluminum) for the fins. The thermal conductivity of the air is about 0.026 [W/(m·K)], whereas the thermal conductivity of aluminum is about 200 [W/(m·K)].

[0140] Thus, even when the height of the notch 66 of the fin in the stage direction is about 0.1 mm, the amount of heat leakage caused by thermal conduction of the air is less than 1 % of the amount of heat leakage caused by thermal conduction of aluminum as a material for the fin, and the advantage of heat leakage reduction can be sufficiently obtained. In view of this, the height of the notch 66 of the fin is greater than or equal to about 0.1 mm, for example.

[0141] As the width (i.e., the horizontal direction) of the notch 66 of the fin increases, the heat leakage amount decreases. Thus, the width may be determined such that the notch 66 is not crushed by the weight of the upper heat source side heat exchanger 12a of the heat source side heat exchangers 12 in the stage direction. For example, the width of the notch 66 can be a half or more of the width of the fin. In this case, defrosting can be performed without remaining frost.

(Fin Structure (3))

[0142] Still another configuration of the heat leakage reducing mechanism will be described.
[0143] FIG. 9 schematically illustrates an example configuration in which part of the fins of the heat source side heat exchangers is shared and a notch is provided in the air-conditioning apparatus 100 of Embodiment 1.
[0144] As illustrated in FIG. 9, the fin 61 of the upper heat source side heat exchanger 12a and the fin 62 of the lower heat source side heat exchanger 12b are integrated (shared). That is, the fin 61 and the fin 62 are not separated but are shared.
[0145] Then, a notch 66 is formed in part of the interface 63 between the fins at the lowermost heat transmission pipe 64 of the upper heat source side heat exchanger 12a and the uppermost heat transmission pipe 65 of the lower heat source side heat exchanger 12b. The notch 66 constitutes a heat leakage reducing mechanism.
[0146] Such a configuration as described above can obtain similar advantages as those obtained by the configurations illustrated in Figs. 7 and 8.
[0147] The configuration in which part of the fins is shared and the notch 66 is provided in the interface 63 between the fins enables the heat source side heat exchanger 12a and the heat source side heat exchanger 12b to be fabricated at the same time. Thus, as compared to a case where the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are separately fabricated, the number of fabrication processes can be reduced, and the cost for fabricating the heat source side heat exchangers 12 can be reduced.

(Fin Structure (4))

[0148] Yet another configuration of the heat leakage reducing mechanism will be described.
[0149] Fig. 10 schematically illustrates an example configuration in which part of the fins of the heat source side heat exchangers is shared and a slit is provided in the air-conditioning apparatus 100 of Embodiment 1.
[0150] As illustrated in Fig. 10, the fin 61 of the heat source side heat exchanger 12a and the fin 62 of the heat source side heat exchanger 12b are integrated (shared), and the fins are subjected to a process (a lancing process) such that parts of the fins at the ends of the notch are not cut off and remain in the interface 63 between the fins, thereby forming a slit 67. The slit 67 constitutes a heat leakage reducing mechanism.
[0151] Such a configuration as described above allows a space to be formed in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, and thus, can obtain advantages similar to those of the configurations illustrated in Figs. 7, 8, and 9.

(Fin Structure (5))

[0152] Another example configuration of the heat leakage reducing mechanism will be described.
[0153] Fig. 11 schematically illustrates an example configuration in which the fins of the heat source side heat exchangers are not shared but are separated and an ellipsoidal notch is provided in the air-conditioning apparatus 100 of Embodiment 1.
[0154] The shape of the notch 66 or the slit 67 of the fins in the interface between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b is not limited the rectangles illustrated in Figs. 7, 8, and 10 as long as a space is present in a portion of the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b where the fins are in contact with each other.
[0155] For example, the shape may be various shapes such as a semi-ellipsoidal shape illustrated in Fig. 11. In such a case, advantages similar to those of the configurations illustrated in Figs. 7 and 8 can be obtained.
[0156] In the configurations illustrated in Figs. 7, 8, and 10, the notch 66 or the slit 67 is provided in the heat source side heat exchanger 12a. However, the present invention is not limited to these configurations. The notch 66 or the slit 67 may be provided in the heat source side heat exchanger 12b. In such a case, advantages similar to those in the configurations illustrated in Figs. 7, 8, and 10 can be obtained.

(Fin Structure (6))

[0157] Another configuration of the heat leakage reducing mechanism will be described.
[0158] Fig. 12 schematically illustrates an example configuration in which part of the fins is shared and two notches are provided in the air-conditioning apparatus 100 of Embodiment 1.
[0159] The number of notches 66 or slits 67 of the fins in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b is not one notch 66 or slit 67 as illustrated in Figs. 7, 8, and 10.
[0160] For example, two notches 66 may be formed as illustrated in Fig. 12, or three or more notches 66 may be formed. In such configurations, advantages similar to those illustrated in Figs. 7, 8, and 10 can be obtained. That is, if

the product of the heat transfer area and the overall heat transfer coefficient between the fins sandwiching the notches 66 is the same, the heat leakage amount can be reduced to the same degree as the configurations illustrated in Figs. 7, 8, and 10.

[0161] In Figs. 7, 8, and 10, the notch 66 or slit 67 is provided in the lower end of the heat source side heat exchanger 12a. However, the present invention is not limited to these examples, and the notch 66 or slit 67 may be provided in the upper end of the heat source side heat exchanger 12b. In this case, advantages similar to those illustrated in Figs. 7, 8, and 10 can be obtained.

(Fin Structure (7))

[0162] Another configuration of the heat leakage reducing mechanism will be described.

[0163] Fig. 13 schematically illustrates an example configuration in which heat source side heat exchangers are placed in an outdoor unit and are disposed one above the other with a clearance interposed therebetween in the air-conditioning apparatus 100 of Embodiment 1.

[0164] As illustrated in Fig. 13, the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are disposed one above the other (in the stage direction). The lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a is separated from the uppermost end face of the fin 62 of the heat source side heat exchanger 12b.

[0165] A clearance 54 is provided between the lowermost end face of the fin 61 of the upper heat source side heat exchanger 12a and the uppermost end face of the fin 62 of the lower heat source side heat exchanger 12b. The clearance 54 constitutes a heat leakage reducing mechanism.

[0166] In this manner, the configuration including the clearance 54 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b can obtain advantages similar to those obtained in the configurations illustrated in Figs. 7 to 12.

[0167] The heat source side heat exchanger 12a and the heat source side heat exchanger 12b may be disposed in any manner as long as a space is present between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b.

[0168] For example, as illustrated in Fig. 13, a support plate 53 of, for example, a SUS plate or a coated steel plate may be provided at the bottom of the heat source side heat exchanger 12a so as to support the heat source side heat exchanger 12a.

[0169] In this layout, wind detours from the clearance 54 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b so that the amount of wind passing through the heat source side heat exchanger 12a decreases in some cases. In view of this, the air passage in the clearance 54 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b is preferably covered with, for example, a SUS plate or a coated steel plate so as to reduce the detour of wind.

[0170] The dimensions of the clearance 54 will be discussed.

[0171] As compared to a case where no clearance 54 is provided, the presence of the clearance 54 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b can reduce the heights of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b that can be placed in the casing of the outdoor unit 1. Thus, the number of stages of heat exchanger tubes decreases, and thus, the entire heat transfer area of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b decreases.

[0172] Fig. 14 is a graph for comparing the heat transfer area ratio and a COP, which is an index indicating the degree of performance of an air-conditioning apparatus, in the air-conditioning apparatus 100 of Embodiment 1.

[0173] The relationship between the heat transfer area ratio and the COP of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b is shown in, for example, Fig. 14.

[0174] In Fig. 14, the capacity of the outdoor unit 1 is 10 horse power (28 kW) with a constant airflow rate.

[0175] The coefficient of performance (COP) is a value (efficiency) obtained by diving the heating capacity by the total input power of the outdoor unit 1 and the indoor unit 2.

[0176] As shown in Fig. 14, suppose the decreasing rate of the COP is reduced about 1% or less in order to maintain the performance of the air-conditioning apparatus 100, the heat transfer area ratio of the heat source side heat exchanger 12 is about 96.7% or more.

[0177] Suppose the total number of stages of the heat source side heat exchanger 12a and the heat source side heat exchanger 12b is 60, the product of the number of stages and the heat transfer area ratio is about 58. That is, in order to reduce the decreasing rate of the COP within 1 % or less, about 58 or more stages of the heat exchangers are needed.

[0178] The length of the clearance 54 in the stage direction can be obtained by multiplying the difference between the number of stages without the clearance 54 and the number of stages with the clearance 54 by the distance between the centers of the heat exchanger tubes in the stage direction. For example, suppose the distance between the centers of the heat exchanger tubes in the stage direction is about 20 mm, the length of the clearance 54 in the stage direction needs to be about 40 mm or less, which is obtained by a difference of 2 stages between the 60 stages without the clearance 54 and the 58 stages with the clearance 54 by about 20 mm.

[0179] Thus, the length Ls of the clearance 54 in the stage direction can be expressed as Equation (2), where Ac[-] is a heat transfer area ratio, Dd [stages] is the number of stages without the clearance 54, and Ld [mm] is the distance between the centers of the heat exchanger tubes in the stage direction.

[0180] In the case of reducing the decreasing rate of the COP to about 1 % or less, 96.7% is substituted into Ac in Equation (2), and Equation (3) is obtained as follows:

[Equation 2]

$$Ls \leq (Dd - Ac \times Dd) \times Ld \qquad (2)$$

[Equation 3]

$$Ls \leq 0.033 \times Dd \times Ld \qquad (3)$$

[0181] In this manner, the use of the length Ls of the clearance 54 can reduce the decreasing rate of the COP to about 1% or less and reduce the amount of heat leakage between the heat source side heat exchanger 12a and the heat source side heat exchanger 12a.

[0182] As described above, in Embodiment 1, heat leakage between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b can be reduced in the defrosting operation mode. Thus, even in a case where part of the plurality of heat source side heat exchangers 12 is defrosted and the other is heated, generation of remaining frost and root ice can be reduced in the interface 63 between the adjacent heat source side heat exchangers 12. As a result, the defrosting time is reduced and a decrease in heating capacity is reduced, thereby obtaining comfort in the indoor environments.

Embodiment 2

[0183] Fig. 15 is a circuit diagram schematically illustrating an example circuit configuration of an air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

[0184] Referring to Fig. 15, a configuration of the air-conditioning apparatus 200 of Embodiment 2 will be described based on the difference from the air-conditioning apparatus 100 of Embodiment 1.

[0185] As illustrated in Fig. 15, a second opening/closing device 31 a that shuts off a refrigerant of a heat source side heat exchanger 12a is disposed between the heat source side heat exchanger 12a and a refrigerant channel switching device 11. A second opening/closing device 31 b that shuts off a refrigerant of a heat source side heat exchanger 12b is disposed between the heat source side heat exchanger 12b and the refrigerant channel switching device 11.

[0186] An end of a hot gas bypass pipe 5 is connected to a refrigerant pipe 3 between a discharge part of a compressor 10 and the refrigerant channel switching device 11. The other end of the hot gas bypass pipe 5 branches into two, one of which is connected to a refrigerant pipe 3 between the heat source side heat exchanger 12a and the second opening/closing device 31 a and the other is connected to a refrigerant pipe 3 between the heat source side heat exchanger 12b and the second opening/closing device 31 b.

[0187] The hot gas bypass pipe 5 connected to the heat source side heat exchanger 12a is provided with a first opening/closing device 30a. The hot gas bypass pipe 5 connected to the heat source side heat exchanger 12b is provided with a first opening/closing device 30b.

[0188] In addition, a third opening/closing device 32a whose opening degree is variable is provided in the pipe of the load side expansion device 22 of the heat source side heat exchanger 12a. A third opening/closing device 32b whose opening degree is variable is provided in the pipe of a load side expansion device 22 of the heat source side heat exchanger 12b.

[0189] The third opening/closing devices 32a and 32b are expansion devices whose opening degrees (the areas of the opening ports) can be changed in order to adjust the internal pressure of the heat source side heat exchanger 12 serving as a condenser.

[0190] The other part of the configuration is similar to that of the air-conditioning apparatus 100 of Embodiment 1, and thus, description thereof is not repeated.

[0191] Flows of a refrigerant in the cooling-only operation mode and the heating-only operation mode in the air-conditioning apparatus 200 are similar to those in air-conditioning apparatus 100 of Embodiment 1, and thus, description thereof is not repeated.

[0192] In Embodiment 2, the first opening/closing device 30a, the first opening/closing device 30b, the second opening/closing device 31 a, the second opening/closing device 31 b, the third opening/closing device 32a, and the third opening/closing device 32b constitute "connection switching devices" of the invention.

(Defrosting Operation Mode)

[0193] In the defrosting operation mode of the air-conditioning apparatus 200 of Embodiment 2, the lower heat source side heat exchanger 12b in the casing 51 is defrosted, and then the upper heat source side heat exchanger 12a in the casing 51 is defrosted.
[0194] Conditions for starting the defrosting operation mode are similar to those in the air-conditioning apparatus 100 of Embodiment 1.

(Defrosting of Heat Source Side Heat Exchanger 12b)

[0195] In Fig. 15, the flow direction of a refrigerant in defrosting of the heat source side heat exchanger 12b is indicated by solid arrow lines.
[0196] In the defrosting operation mode, the refrigerant channel switching device 11 is maintained in a state indicated by the solid lines in Fig. 15.
[0197] In the defrosting operation mode, in a case where the heat source side heat exchanger 12b is a defrosting target, the first opening/closing device 30b is switched to an open state, and allows the refrigerant to pass therethrough.
[0198] The second opening/closing device 31 b is switched to a closed state, and shuts off the refrigerant.
[0199] The first opening/closing device 30a is kept in a closed state, and shuts off the refrigerant.
[0200] The second opening/closing device 31 a is kept in an open state, and allows the refrigerant to pass therethrough.
[0201] The third opening/closing device 32b is set in a fully open state, and allows the refrigerant to pass therethrough.
[0202] The opening degree of the third opening/closing device 32a is controlled by the control device 50 such that the saturation pressure of a two-phase refrigerant calculated from the detection result of the sixth temperature sensor 48b is a predetermined value (e.g., about 0.8 MPa in the case of an R410A refrigerant) or more.
[0203] When the compressor 10 is driven, the low-temperature low-pressure refrigerant is compressed and becomes a high-temperature high-pressure gas refrigerant, and the resulting refrigerant is discharged.
[0204] Part of the high-temperature high-pressure gas refrigerant discharged from the compressor 10 is subjected to a pressure reduction in the hot gas bypass pipe 5 and the first opening/closing device 30b such that the temperature of the gas refrigerant is 0 degrees C or more in terms of the saturation temperature. The resulting refrigerant becomes an intermediate-pressure high-temperature gas refrigerant, and 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 becomes an intermediate-pressure low-quality two-phase refrigerant or an intermediate-pressure refrigerant while melting frost on the heat source side heat exchanger 12b, and passes through the third opening/closing device 32b. The refrigerant passed through the third opening/closing device 32b merges with the intermediate-pressure low-temperature low-quality two-phase refrigerant or the liquid refrigerant that has flowed into the outdoor unit 1 from the indoor unit 2 upstream of the third opening/closing device 32a.
[0205] The other part of the high-temperature high-pressure gas refrigerant discharged from the compressor 10 flows out of the outdoor unit 1 through the refrigerant channel switching device 11. The high-temperature high-pressure gas refrigerant that has flowed from the outdoor unit 1 flows into the indoor unit 2 through the refrigerant main pipe 4, transfers heat to the indoor air in the load side heat exchanger 21, and becomes a liquid refrigerant while heating the indoor air. The liquid refrigerant that has flowed from the load side heat exchanger 21 expands in the load side expansion device 22, becomes a low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant, and flows into the outdoor unit 1 again through the refrigerant main pipe 4.
[0206] The low-temperature intermediate-pressure two-phase refrigerant or liquid refrigerant that has flowed into the outdoor unit 1 merges with the refrigerant from the third opening/closing device 32b upstream of the third opening/closing device 32a, and the merged refrigerant flows into the heat source side heat exchanger 12a. The refrigerant that has flowed into the heat source side heat exchanger 12a absorbs heat from the outdoor air, and becomes a low-temperature low-pressure gas refrigerant. The gas refrigerant that has flowed from the heat source side heat exchanger 12a is sucked into the compressor 10 again through the refrigerant channel switching device 11 and an accumulator 13.
[0207] The control device 50 controls the opening degree of the third opening/closing device 32a such that the saturation pressure of the two-phase refrigerant calculated from the detection result of the sixth temperature sensor 48b is a predetermined value (e.g., about 0.8 MPa in the case of an R410A refrigerant) or more. That is, the control device 50 controls the opening degree of the third opening/closing device 32a such that the saturation pressure of the two-phase refrigerant calculated from the detection result of the sixth temperature sensor 48b is 0 degrees C or more in terms of the saturation temperature.

[0208] In determining completion of defrosting of the heat source side heat exchanger 12b, frost is determined to be melt when the temperature of the third temperature sensor 48b reaches a predetermined temperature (e.g., 5 degrees C) or more, for example.

[0209] Other operation in the defrosting operation mode is similar to that in the air-conditioning apparatus 100 of Embodiment 1.

[0210] To defrost the heat source side heat exchanger 12a after completion of defrosting of the heat source side heat exchanger 12b, an operation in which components denoted by "a" are replaced by components denoted by "b" in the description of defrosting the heat source side heat exchanger 12b is performed. That is, the open/closed states of the first opening/closing devices 30a and 30b and the second opening/closing devices 31 a and 31 b are reversed, and the flow of the refrigerant in the heat source side heat exchanger 12a is replaced by the flow of the refrigerant in the heat source side heat exchanger 12b. The third opening/closing device 32a is in a fully open state, and the opening degree of the third opening/closing device 32b is controlled.

[0211] In this manner, in the defrosting operation mode of the heat source side heat exchanger 12, the saturation temperature of the refrigerant in the heat source side heat exchanger 12 serving as a condenser is set at an intermediate pressure (e.g., about 0.8 MPa or more in the case of an R410A refrigerant), which is higher than the frost temperature, that is, higher than 0 degrees C. Thus, the two-phase range (latent heat) of the refrigerant can be used, and substantially the same degrees of defrosting capacity can be obtained with an amount of refrigerant circulation smaller than that in the configuration of the air-conditioning apparatus 100 of Embodiment 1.

[0212] The heat leakage amount Q1 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b will now be discussed.

[0213] In the following case of the air-conditioning apparatus 200 of Embodiment 2, the heat leakage reducing mechanism is configured such that fins are not shared but are separated in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b as illustrated in Fig. 7.

[0214] For example, suppose the saturation temperature T1 of a two-phase refrigerant flowing in a condenser that performs defrosting is 5 degrees C, and the temperature T2 of a refrigerant flowing in an evaporator that performs heating operation is -25 degrees C. In addition, the inter-fin distance δ between an end of the heat transmission pipe of the evaporator and an end of the heat transmission pipe of the condenser in the interface 63 is 12.5 mm, and in a state where the heat exchangers are not separated, the fin width is 17 mm, the fin thickness is 0.1 mm, and the number of fins is 3700.

[0215] In this case, the heat leakage amount Q1 from the condenser to the evaporator in a case where the fins are separated and are shared is about 3.22 kW from Equation (1).

[0216] On the other hand, in a case where fins in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b are separated from each other as shown in Fig. 7, the heat leakage amount Q1 is discussed.

[0217] For example, suppose the product of a heat transfer area (a contact area) at which the fin 61 of the upper heat source side heat exchanger 12a and the fin 62 of the lower heat source side heat exchanger 12b are in contact with each other and the overall heat transfer coefficient is a half of the product of a heat transfer area (a contact area) and the overall heat transfer coefficient in a case where the fins are shared.

[0218] In this case, the heat leakage amount Q1 from the condenser to the evaporator by thermal conduction of the fins is reduced as compared to the case where all the fins are shared by about 25% or more, and the heat leakage amount Q1 is about 2.42 kW.

[0219] Then, the time required for completion of defrosting will be discussed.

[0220] For example, suppose the quantity of heat Q2 (calculated by multiplying latent heat of melting frost and the weight of frost) necessary for melting frost accumulated on the evaporator is about 1.5 MJ, and the heat exchange amount Q3 between frost and a refrigerant used in defrosting in a case where no heat leakage amount is present from the condenser to the evaporator by thermal conduction of the fins is about 5.5 kW.

[0221] The time required for completion of defrosting is obtained by subtracting the difference between the heat exchange amount Q3 and the heat leakage amount Q1 from the solution heat amount Q2 of frost.

[0222] In the case where the fin 61 and the fin 62 are integrated (shared), suppose the heat leakage amount Q1 is about 3.22 kW and the heat exchange amounts Q2 and Q3 are under the above conditions, then the time required for completion of defrosting is about 11 minutes.

[0223] On the other hand, in the case where the fins are separated in the air-conditioning apparatus 200 of Embodiment 2, the heat leakage amount Q1 is reduced by about 25% to be about 2.42 kW, and suppose the heat exchange amounts Q2 and Q3 are under the above conditions, the time required for completion of defrosting is about 8 minutes.

[0224] Thus, the time required for completion of defrosting can be reduced by about 3 minutes.

[0225] In this manner, the reduction of the time required for completion of defrosting enables part of a refrigerant discharged from the compressor 10 for defrosting to be quickly used for heating, as compared to a case where heat leakage occurs from the condenser to the evaporator by thermal conduction of the fins. Thus, a decrease in heating capacity can be reduced. In addition, a temperature decrease in the room can be reduced, thereby obtaining comfort in the indoor environments.

[0226] Further, a temperature decrease is reduced in the fin at the condenser side in the interface 63 between the heat source side heat exchanger 12a and the heat source side heat exchanger 12b, and thus, adfreezing of water drops generated by defrosting of the upper heat exchanger serving as the condenser can be reduced, thereby reducing generation of root ice.

[0227] In the foregoing description, the air-conditioning apparatus 200 of Embodiment 2 employs the configuration illustrated in Fig. 7 as a configuration of the heat leakage reducing mechanism, but the present invention is not limited to this configuration. The configuration of the heat leakage reducing mechanism may be any one of the configurations illustrated in Figs. 8 to 13 described in Embodiment 1. In such cases, similar advantages as those obtained in the configuration illustrated in Fig. 7 can be obtained.

[0228] In the air-conditioning apparatus 200 illustrated in Fig. 15, the two devices, that is, the third opening/closing device 32a and the third opening/closing device 32b, are expansion devices whose opening degrees (areas of opening ports) are variable, but the present invention is not limited to this example.

(Variation 1)

[0229] For example, as illustrated in Fig. 16, in the air-conditioning apparatus 200 of Embodiment 2, the third opening/closing device 32b (or the third opening/closing device 32a) may be changed to a expansion device whose opening degree (the area of the opening port) is variable. In this case, in the defrosting operation, the unchanged third opening/closing device 32a (or the third opening/closing device 32b) is always open, and the third opening/closing device 32b (or the third opening/closing device 32a) changed to the expansion device whose opening degree (the area of the opening port) is variable is used. Then, the internal pressure of the heat source side heat exchanger 12 serving as a condenser is adjusted. In this state, an operation similar to that of the air-conditioning apparatus 200 illustrated in Fig. 15 can be performed, and similar advantages can be obtained.

[0230] Specifically, in this alternative circuit configuration, the saturation temperature of a refrigerant in the heat source side heat exchanger 12 serving as a condenser can be set at a temperature corresponding to an intermediate pressure (e.g., about 0.8 MPa or more in the case of an R410A refrigerant) higher than the frost temperature, that is, higher than 0 degrees C, in the defrosting operation. For example, the number of second opening/closing devices 31 that are expansion devices whose opening degrees (the areas of the opening ports) can be changed may be one.

[0231] Such a configuration can reduce the number of expansion devices whose opening degrees (the areas of the opening ports), such as electronic expansion valves including stepping motors, generally having structures more complicated and expensive than solenoid valves, and thus, the outdoor unit 1 can be fabricated at low cost.

(Variation 2)

[0232] Alternatively, as illustrated in Fig. 17, for example, in the air-conditioning apparatus 200 of Embodiment 2, the third opening/closing device 32b (or the third opening/closing device 32a) may be changed to a expansion device whose opening degree (the area of the opening port) is variable. In this case, only one third opening/closing device 32 is provided, and the internal pressure of the heat source side heat exchanger 12 serving as a condenser is adjusted in the defrosting operation. In such a configuration, an operation similar to that of the air-conditioning apparatus 200 illustrated in Fig. 15 can be performed, and similar advantages can be obtained. The configuration illustrated in Fig. 17 can simplify the circuit configuration, and thus, the outdoor unit 1 can be fabricated at low cost.

(Variation 3)

[0233] Alternatively, as illustrated in Fig. 18, in the air-conditioning apparatus 200 of Embodiment 2, the third opening/closing device 32b (or the third opening/closing device 32a) may be changed to a expansion device whose opening degree (the area of the opening port) is variable, and this third opening/closing device 32 is provided. In addition, a fourth opening/closing device 33a and a fourth opening/closing device 33b for shutting off the refrigerant in the heat source side heat exchanger 12a or the heat source side heat exchanger 12b are disposed in refrigerant pipes 3 connecting the heat source side heat exchanger 12a and the heat source side heat exchanger 12b to the third opening/closing device 32b (or the third opening/closing device 32a).

[0234] Further, a refrigerant bypass pipe 6 is provided. An end of the refrigerant bypass pipe 6 is connected to the refrigerant pipes 3 connecting the heat source side heat exchangers 12a and 12b to the fourth opening/closing devices 33, and the other end of the refrigerant bypass pipe 6 is connected to the channel between the third opening/closing device 32 and the load side expansion device 22. The refrigerant bypass pipe 6 allows the refrigerant in the heat source side heat exchanger 12 serving as a condenser in the defrosting operation mode to flow in the refrigerant pipes 3.

[0235] A fifth opening/closing device 34a and a fifth opening/closing device 34b for switching a refrigerant channel of the refrigerant bypass pipe 6 is provided in the refrigerant bypass pipe 6 between the heat source side heat exchanger 12 and the fourth opening/closing device 33 whose one ends correspond to each other.

[0236] In a case where the heat source side heat exchanger 12b is defrosted in the air-conditioning apparatus 200 illustrated in Fig. 18, the fourth opening/closing device 33a is an open state. The fourth opening/closing device 33b is a closed state. The fifth opening/closing device 34a is in a closed state. The fifth opening/closing device 34b is in an open state.

[0237] In the defrosting operation mode, the internal pressure of the heat source side heat exchanger 12b serving as a condenser is adjusted by the third opening/closing device 32b (of the third opening/closing device 32a). Part of condensed refrigerant merges with another refrigerant flowing out of the load side expansion device 22 into the outdoor unit 1 in the refrigerant pipes 3 between the third opening/closing device 32b (or the third opening/closing device 32a) and the load side expansion device 22 through the fifth opening/closing device 34b. In addition, all the refrigerant absorbs heat from the air in the heat source side heat exchanger 12a serving as an evaporator through the third opening/closing device 32b (or the third opening/closing device 32a) and the fourth opening/closing device 33a, becomes a low-pressure two-phase or gas refrigerant, and then is sucked into the compressor 10 through the second opening/closing device 31 a, the refrigerant channel switching device 11, and the accumulator 13.

[0238] The other part of the operation is the same as that illustrated in Fig. 15.

[0239] To defrost the heat source side heat exchanger 12a after completion of defrosting of the heat source side heat exchanger 12b, an operation in which components denoted by "a" are replaced by components denoted by "b" in the description of defrosting of the heat source side heat exchanger 12b is performed.

[0240] That is, the open/closed states of the first opening/closing devices 30a and 30b, the fourth opening/closing devices 33a and 33b, and the fifth opening/closing devices 34a and 34b are reversed, and the flow of the refrigerant in the heat source side heat exchanger 12a is replaced by the flow of the refrigerant in the heat source side heat exchanger 12b.

[Refrigerant]

[0241] The heat source side refrigerant of each of Embodiment 1 and Embodiment 2 may be a nonflammable refrigerant such as R410A, R407C, and R22, HFO1234yf, HFO1234ze(E), R32, HC, a mixed refrigerant including R32 and HFO1234yf, a slightly flammable refrigerant such as a refrigerant using a mixed refrigerant including at least one of the previously listed refrigerants, a highly flammable refrigerant such as propane (R290), and a refrigerant such as CO2(R744) operating in a supercritical state under high pressures.

[First Opening/closing Device]

[0242] In the Embodiment 1 and the Embodiment 2, the first opening/closing devices 30a and 30b are solenoid valves. Alternatively, valves whose opening degrees are variable, such as electronic expansion valves, may be used as shut-off valves, as well as the solenoid valves.

[Second Opening/closing Device]

[0243] In Embodiment 1 and Embodiment 2, the second opening/closing devices 31 a and 31 b are solenoid valves. Alternatively, valves whose opening degrees are variable, such as electronic expansion valves, may be used as shut-off valves, as well as the solenoid valves.

[Third Opening/closing Device]

[0244] In Embodiment 2, the third opening/closing devices 32a and 32b are expansion devices whose opening degrees (the areas of the opening ports) are variable, but any devices may be used as long as the area of the opening port of the channel can be changed.

[0245] For example, the expansion devices may be electronic expansion valves driven by stepping motors, or a plurality of small solenoid valves may be arranged in parallel so that the area of the opening port can be changed by switching the solenoid valves.

[Fourth Opening/closing Device]

[0246] The fourth opening/closing device 33 of Embodiment 2 is a solenoid valve as an example. Alternatively, valves whose opening degrees are variable, such as electronic expansion valves, may be used as shut-off valves, as well as the solenoid valves.

[Fifth Opening/closing Device]

[0247] The fifth opening/closing device 34 of Embodiment 2 is a solenoid valve as an example. Alternatively, valves whose opening degrees are variable, such as electronic expansion valves, may be used as shut-off valves, as well as the solenoid valves.

[Heat Source Side Heat Exchanger]

[0248] The heat source side heat exchangers 12a and 12b of Embodiment 1 and Embodiment 2 are bent in U shapes, and are stacked in two stages in a stage direction (i.e., vertically such that the fins thereof are oriented in the same direction). However, the present invention is not limited to this configuration.
[0249] The heat source side heat exchangers 12 may be straight and stacked in three stages in the stage direction (i.e., vertically such that the fins thereof are oriented in the same direction).
[0250] The heat source side heat exchangers 12 do not need to be disposed one above the other vertically, and may be disposed side by side or laterally or longitudinally.
[0251] Each of the air-conditioning apparatus 100 of Embodiment 1 and the air-conditioning apparatus 200 of Embodiment 2 is an air-conditioning apparatus that switches between a cooling operation and a heating operation, as an example. However, the present invention is not limited to this type, and is applicable to an air-conditioning apparatus having a circuit configuration that can perform a cooling operation and a heating operation at the same time. The refrigerant channel switching device 11 may be omitted so that only the heating-only operation mode and the defrosting operation mode are performed. Reference Signs List
[0252] 1 outdoor unit, 2 indoor unit, 3 refrigerant pipe, 4 refrigerant main pipe, 5 hot gas bypass pipe, 6 refrigerant bypass pipe, 10 compressor, 11 refrigerant channel switching device, 12a and 12b heat source side heat exchanger, 13 accumulator, 21 load side heat exchanger, 22 load side expansion device, 30a and 30b first opening/closing device, 31a and 31b second opening/closing device, 32a and 32b third opening/closing device, 33a and 33b fourth opening/closing device, 34a and 34b fifth opening/closing device, 41 first pressure sensor, 42 second pressure sensor, 43 first temperature sensor, 44 second temperature sensor, 45 third temperature sensor, 46 fourth temperature sensor, 47 fifth temperature sensor, 48a and 48b sixth temperature sensor, 50 control device, 51 casing, 52 fan, 53 support plate, 54 clearance, 61 fin, 62 fin, 63 interface, 63 and 64 heat transmission pipe, 65 heat transmission pipe, 66 notch, 67 slit, 100 air-conditioning apparatus, 200 air-conditioning apparatus.

Claims

1. An air-conditioning apparatus comprising:

a main circuit in which a compressor, a load side heat exchanger, a load side expansion device, and a plurality of heat source side heat exchangers connected in parallel are sequentially connected by pipes and in which a refrigerant circulates;
a bypass pipe configured to cause part of a refrigerant discharged from the compressor to branch and flow into at least one of the plurality of heat source side heat exchangers to be defrosted; and
a connection switching device configured to switch the one of the plurality of the heat source side heat exchangers to be defrosted by switching a channel of the bypass pipe between an open state and a closed state and switching a channel of the pipes of the main circuit connected to the plurality of heat source side heat exchangers between an open state and a closed state, wherein
the heat source side heat exchangers each include
a plurality of fins spaced apart from one another such that air passes between the plurality of fins, and
a plurality of heat exchanger tubes disposed in the plurality of fins and allowing the refrigerant to flow in the heat exchanger tubes,
the plurality of heat source side heat exchangers
are disposed adjacent to one another such that the plurality of fins are oriented in an identical direction, and
includes a heat leakage reducing mechanism that is sandwiched between adjacent ones of the plurality of fins and that reduces an amount of heat leakage between adjacent ones of the plurality of heat source side heat exchangers.

2. The air-conditioning apparatus of claim 1, wherein

at least one of the plurality of heat source side heat exchangers except the at least one of the plurality of heat source side heat exchangers to be defrosted serves as an evaporator and performs a heating operation in a defrosting operation in which part of the refrigerant discharged from the compressor flows into the at least one of the plurality of heat source side heat exchangers to be defrosted, and
at least one of the plurality of heat source side heat exchangers to be defrosted is sequentially replaced by another one of the plurality of heat source side heat exchangers.

3. The air-conditioning apparatus of claim 1 or 2, wherein
the connection switching device includes
a plurality of first opening/closing devices that each open or close a channel from the bypass pipe to the plurality of heat source side heat exchangers, and
a plurality of second opening/closing devices that each open or close a channel of at least one of the pipes connected to the plurality of heat source side heat exchangers and connecting to the load side expansion device, and
at least one of the first opening/closing devices corresponding to the at least one of the plurality of heat source side heat exchangers to be defrosted is opened, and one of the second opening/closing devices corresponding to the at least one of the plurality of heat source side heat exchangers to be defrosted is closed.

4. The air-conditioning apparatus of claim 1 or 2, wherein
the connection switching device includes
a plurality of first opening/closing devices that each open or close a channel from the bypass pipe to the plurality of heat source side heat exchangers,
a plurality of second opening/closing devices that each open or close a channel of at least one of the pipes connected to the plurality of heat source side heat exchangers and connecting to a suction side of the compressor, and
at least one third opening/closing device provided to at least one of the pipes connected to the plurality of heat source side heat exchangers and connecting to the load side expansion device and having a variable opening degree,
at least one of the plurality of first opening/closing devices corresponding to the at least one of the plurality of heat source side heat exchangers to be defrosted is opened, and at least one of the plurality of second opening/closing devices corresponding to the at least one of the plurality of heat source side heat exchangers to be defrosted is closed, and
the opening degree of the at least one third opening/closing device is adjusted such that a pressure of the refrigerant flowing out of the at least one of the plurality of heat source side heat exchangers to be defrosted is higher than 0 degrees C in terms of a saturation temperature.

5. The air-conditioning apparatus of any one of claims 1 to 4, wherein
the plurality of heat source side heat exchangers are adjacent to each other and arranged one above another, and
a lowermost end face of each of the fins of an upper one of the plurality of heat source side heat exchangers is separated from an uppermost end face of each of the fins of a lower one of the plurality of heat source side heat exchangers.

6. The air-conditioning apparatus of claim 5, wherein
the heat leakage reducing mechanism is constituted by a clearance between the lowermost end face of each of the fins of the upper one of the plurality of heat source side heat exchangers and the uppermost end face of each of the fins of the lower one of the plurality of heat source side heat exchangers,
and a length (Ls) of the clearance is less than or equal to a value calculated by multiplying the number of stages (Dd) of the plurality of heat exchanger tubes in a state where the plurality of heat source side heat exchangers are not separated, a distance (Ld) between center portions of adjacent ones of the plurality of heat exchanger tubes in the stage direction in a state where the plurality of heat source side heat exchangers are not separated, and 0.033.

7. The air-conditioning apparatus of claim 5, wherein
the lowermost end face of each of the fins of the upper one of the plurality of heat source side heat exchangers is in contact with the uppermost end face of each of the fins of the lower one of the plurality of heat source side heat exchangers, and
the heat leakage reducing mechanism is constituted by a rough surface located in at least one of the lowermost end face of each of the fins of the upper one of the plurality of heat source side heat exchangers or the uppermost end face of each of the fins of the lower one of the plurality of heat source side heat exchangers.

8. The air-conditioning apparatus of claim 5, wherein
the lowermost end face of each of the fins of the upper one of the plurality of heat source side heat exchangers is

in contact with the uppermost end face of each of the fins of the lower one of the plurality of heat source side heat exchangers, and
the heat leakage reducing mechanism is constituted by a notch located in part of at least one of the lowermost end face of each of the fins of the upper one of the plurality of heat source side heat exchangers or the uppermost end face of each of the fins of the lower one of the plurality of heat source side heat exchangers.

9. The air-conditioning apparatus of any one of claims 1 to 4, wherein
the plurality of heat source side heat exchangers are adjacent to each other and arranged one above another,
the fin of the upper one of the plurality of heat source side heat exchangers is integrated with the lower one of the plurality of heat source side heat exchangers,
the heat leakage reducing mechanism is constituted by a notch located in the fin between the upper one of the plurality of heat source side heat exchangers and the lower one of the plurality of heat source side heat exchangers.

10. The air-conditioning apparatus of claim 8 or 9, wherein
a width of the notch is greater than or equal to a half of a width of the fin.

11. The air-conditioning apparatus of any one of claims 1 to 10, wherein
the plurality of heat source side heat exchangers are adjacent to each other and arranged one above another,
a defrosting operation is performed on the lower one of the plurality of heat source side heat exchangers while the upper one of the plurality of heat source side heat exchangers serves as an evaporator in a heating operation, and then a defrosting operation is performed on the upper one of the plurality of heat source side heat exchangers while the lower one of the plurality of heat source side heat exchangers serves as an evaporator.

FIG. 1

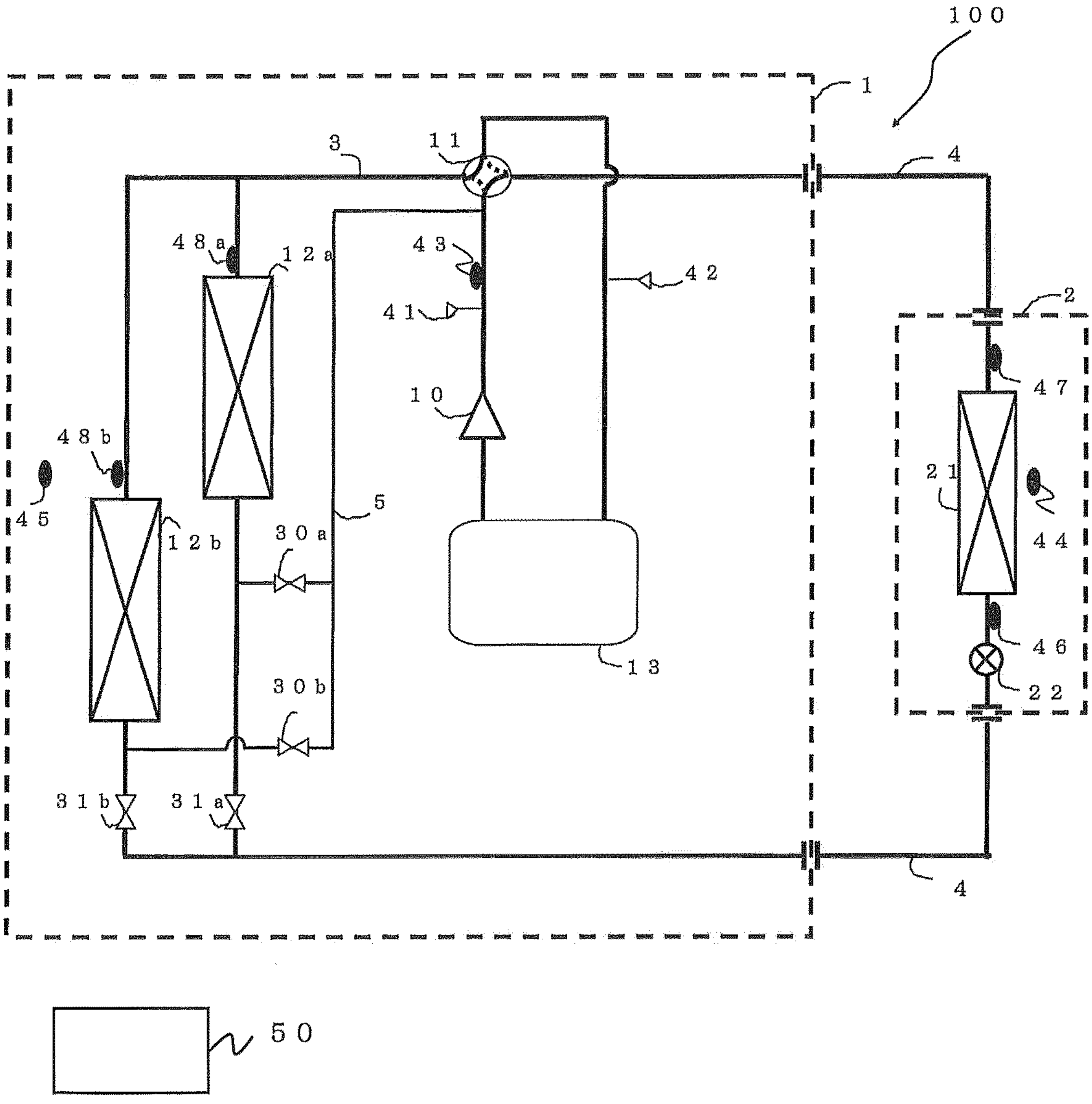

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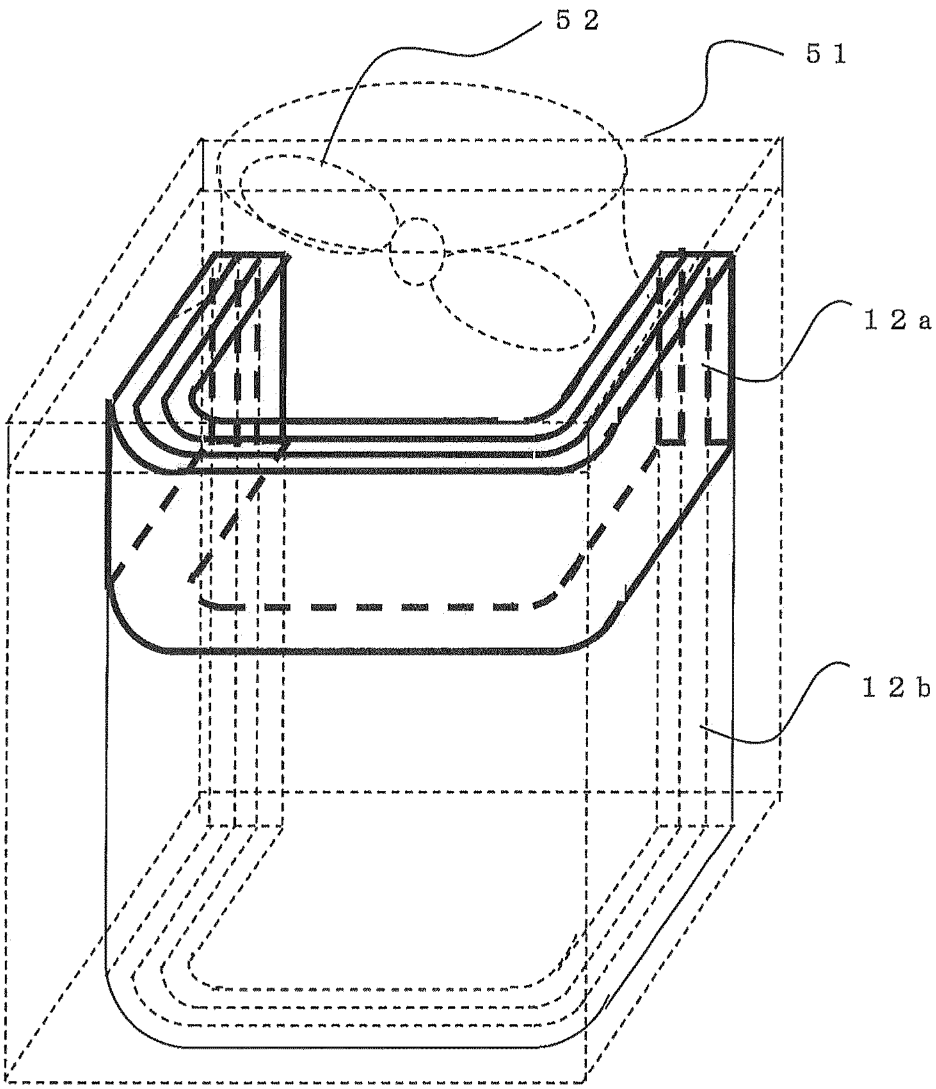
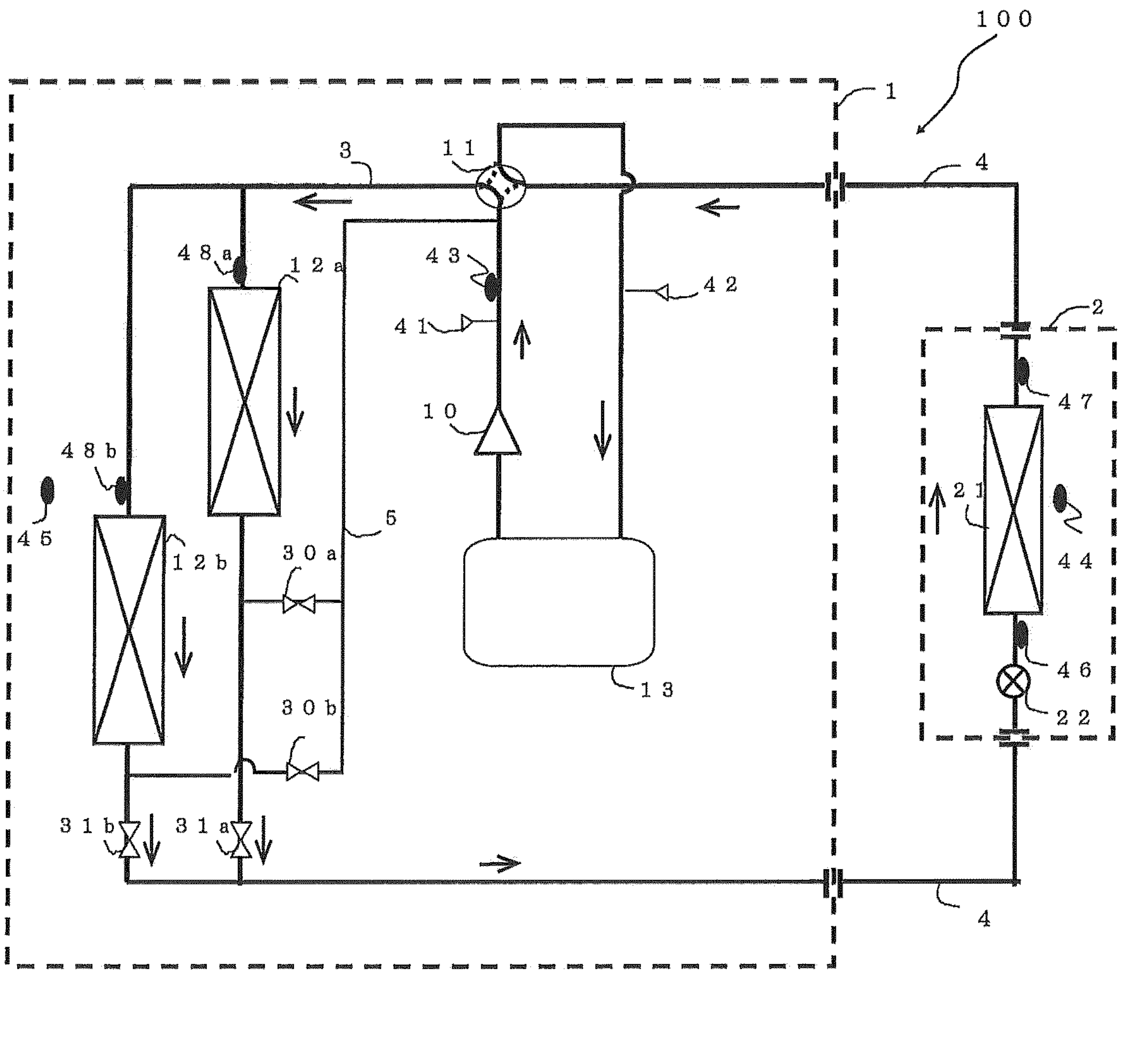
FIG. 2



F I G. 3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F I G. 4

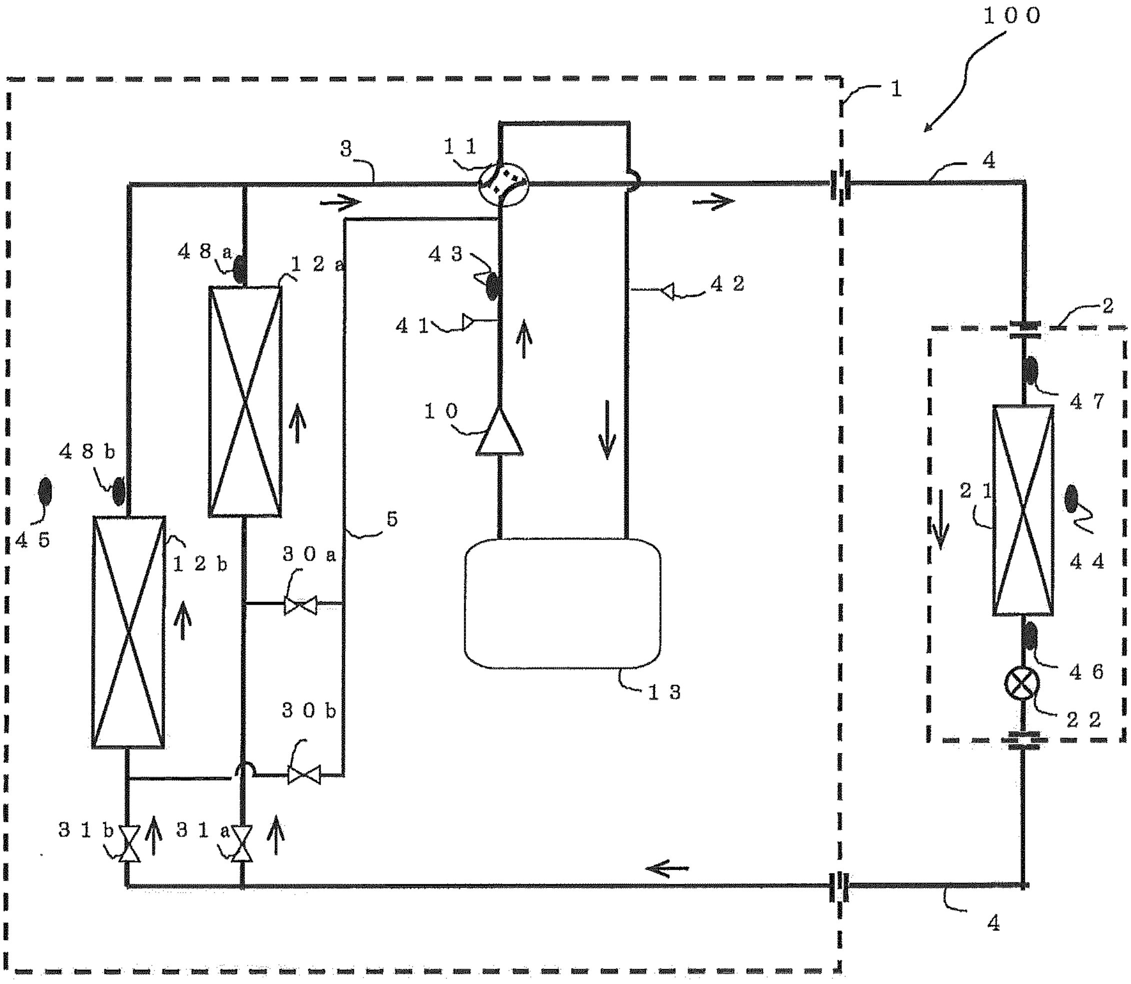
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FIG. 5

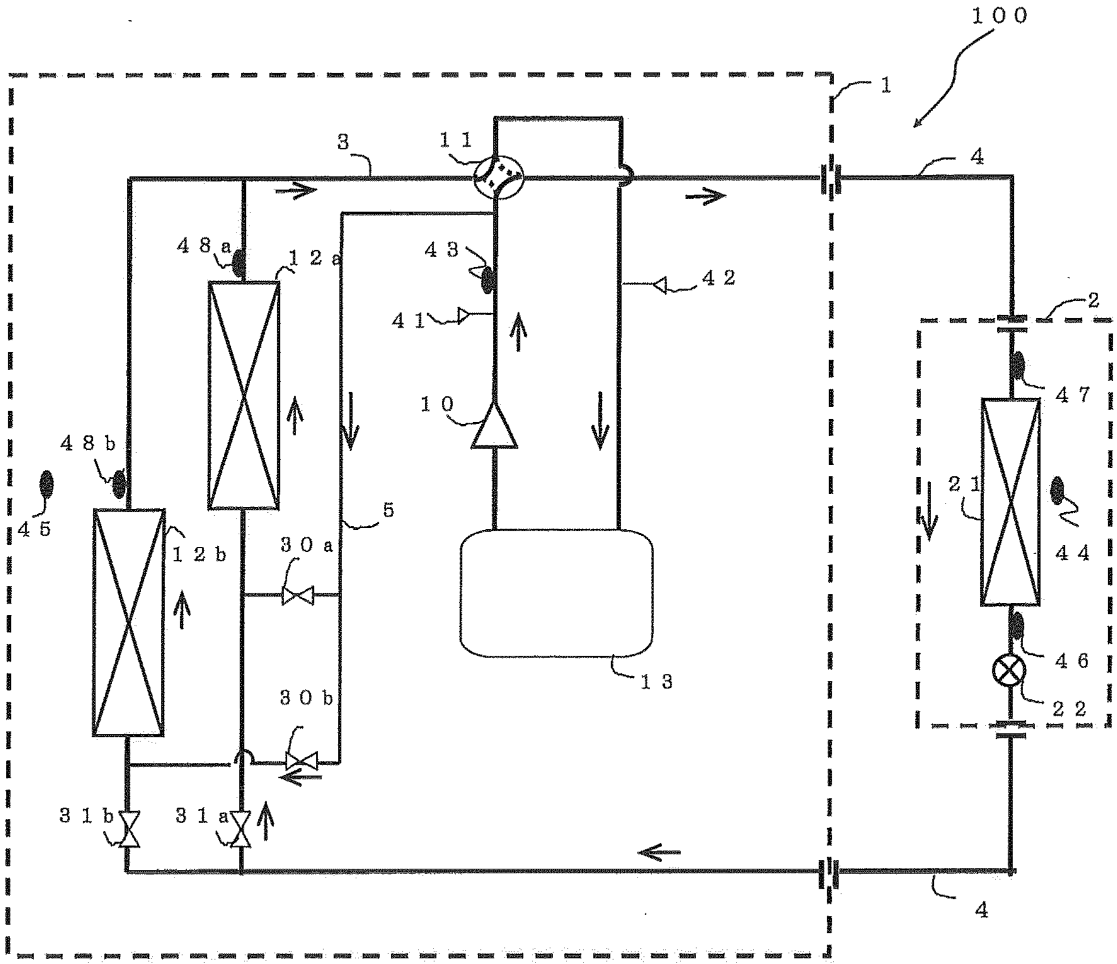
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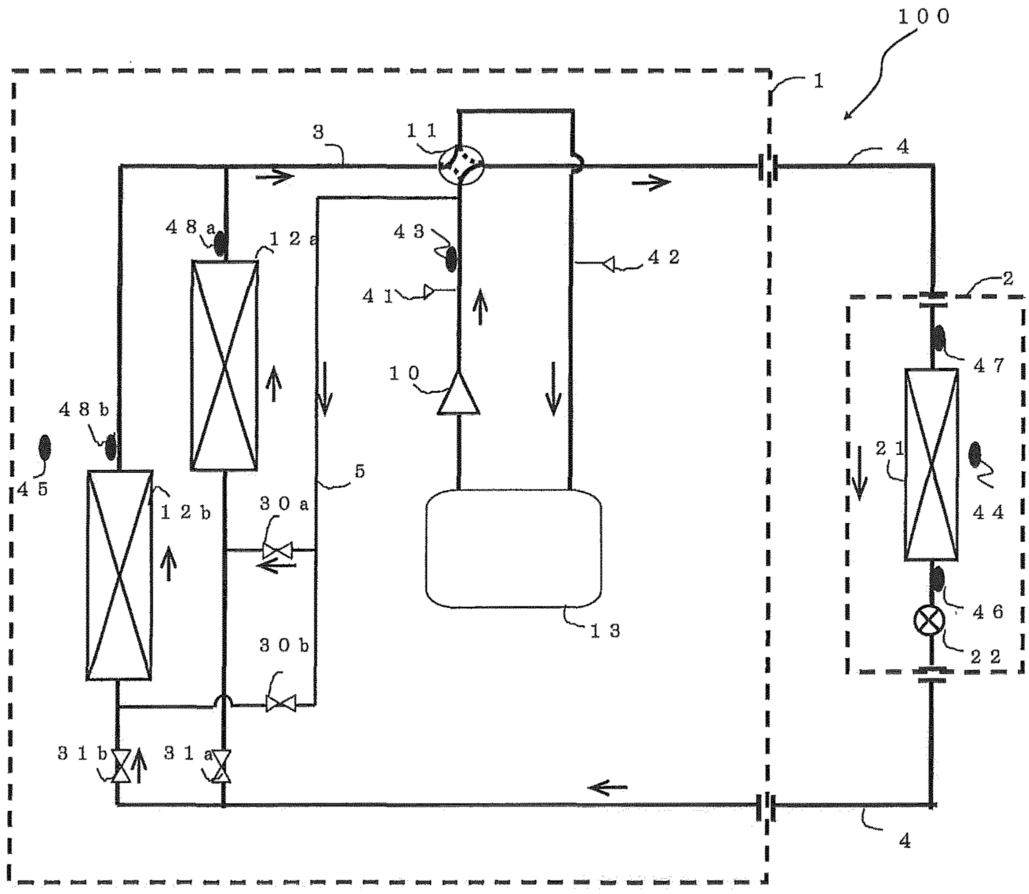
FIG. 6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31a
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FIG. 7

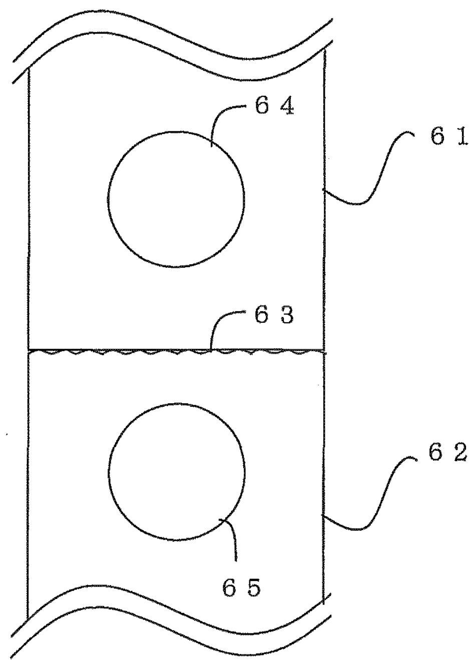
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FIG. 8

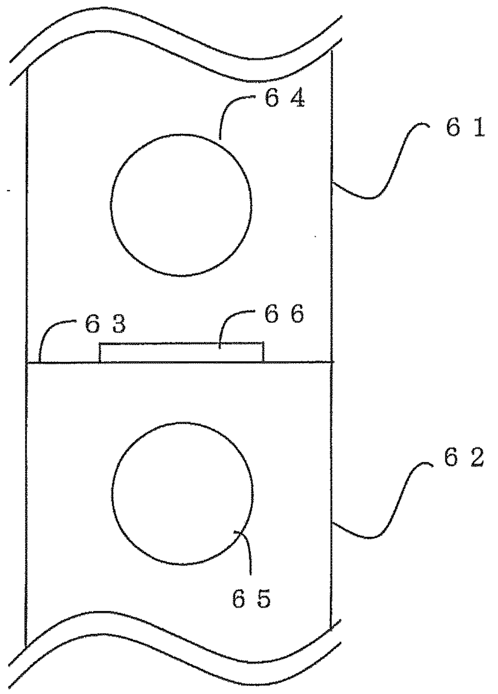
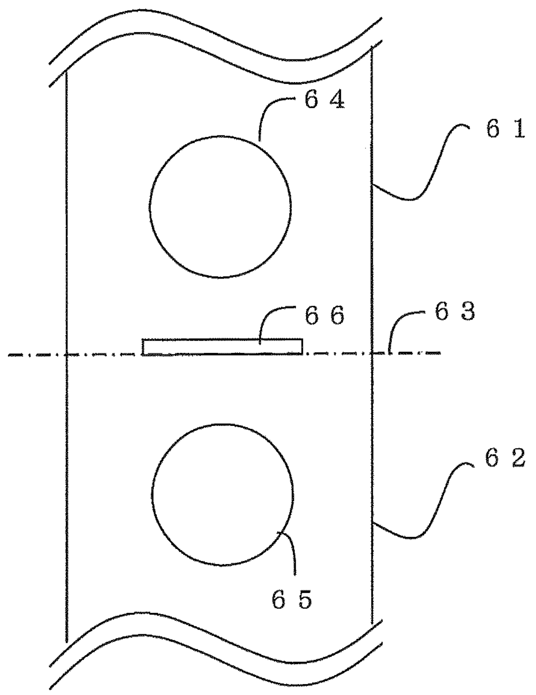


FIG. 9



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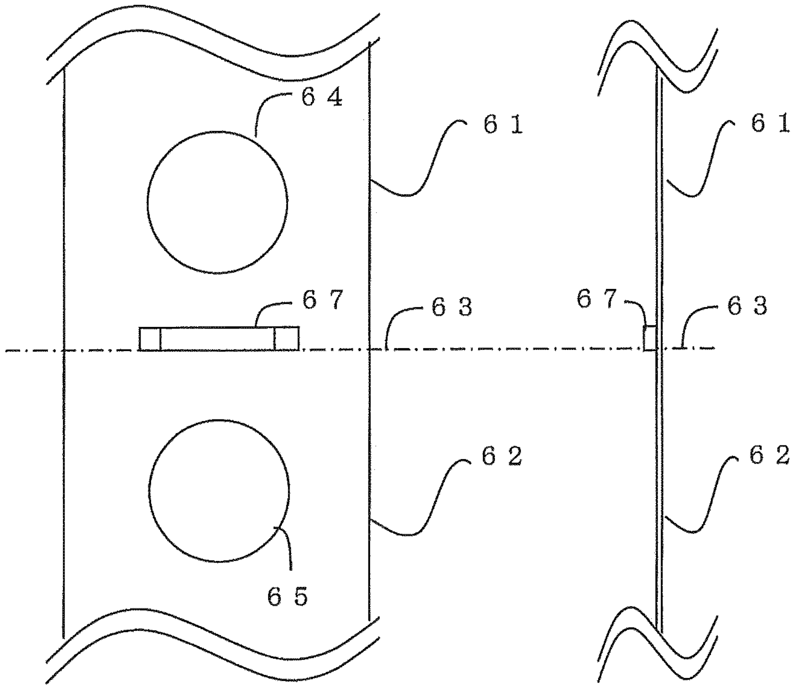
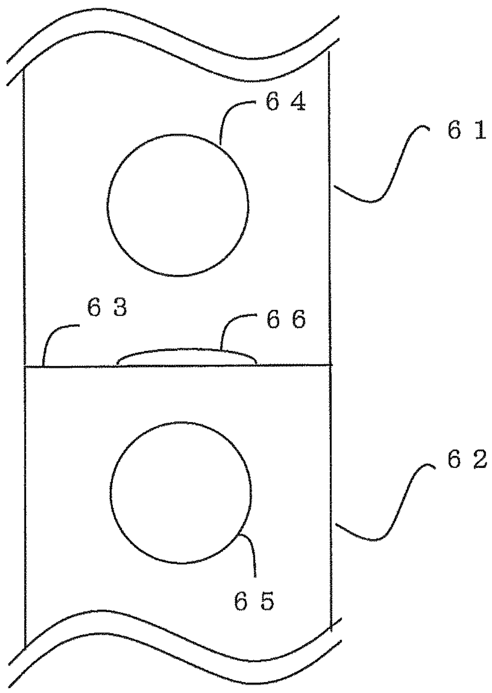


ＦＩＧ．１１



ＦＩＧ．１２

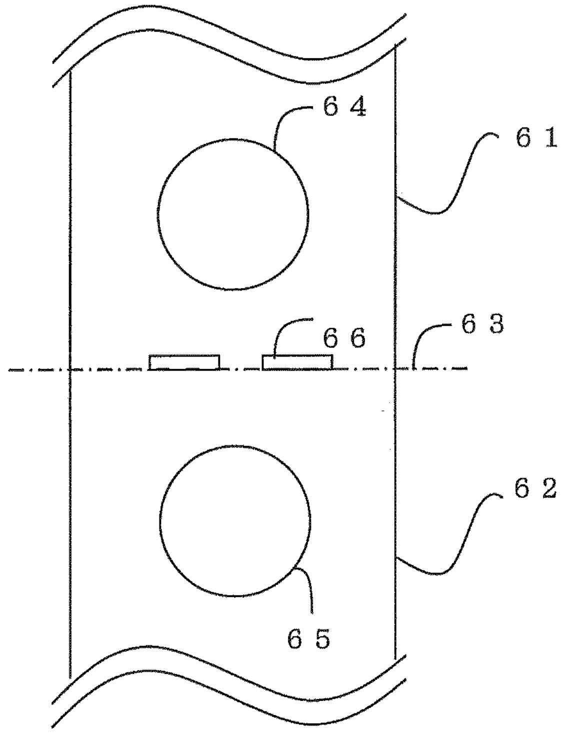
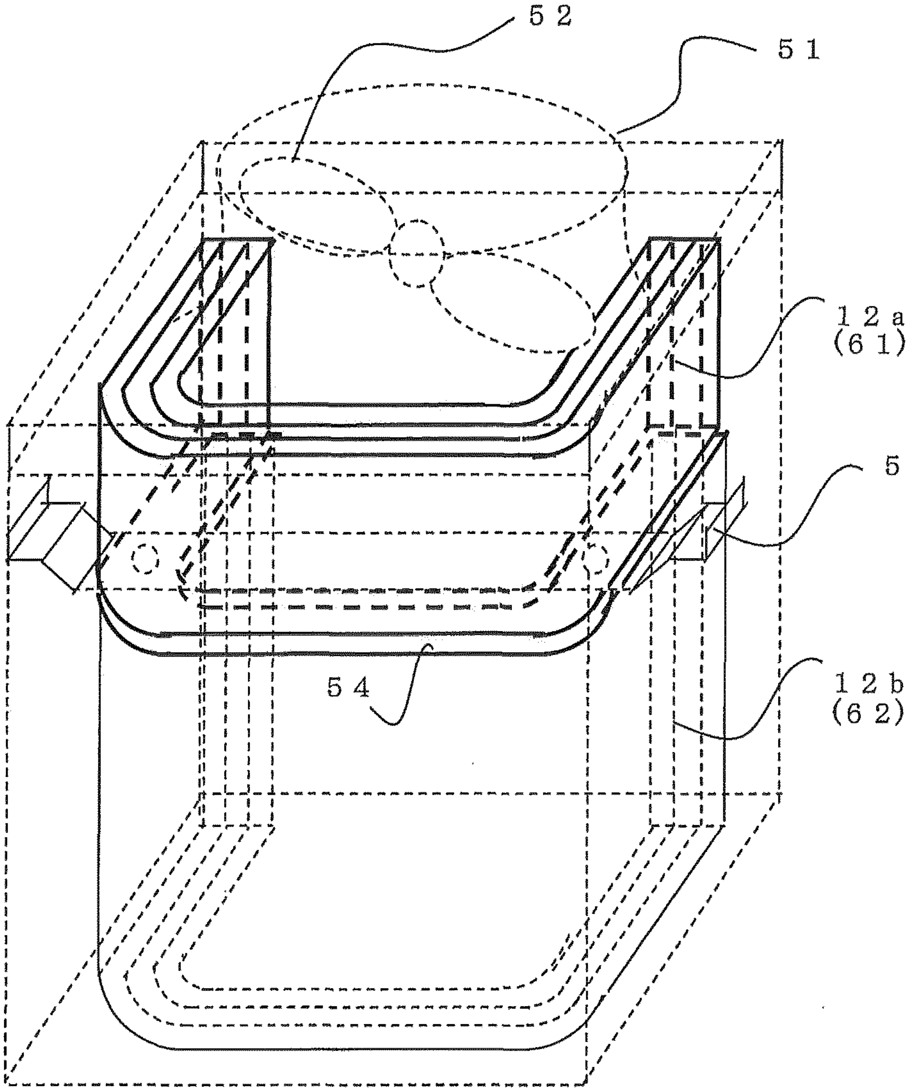
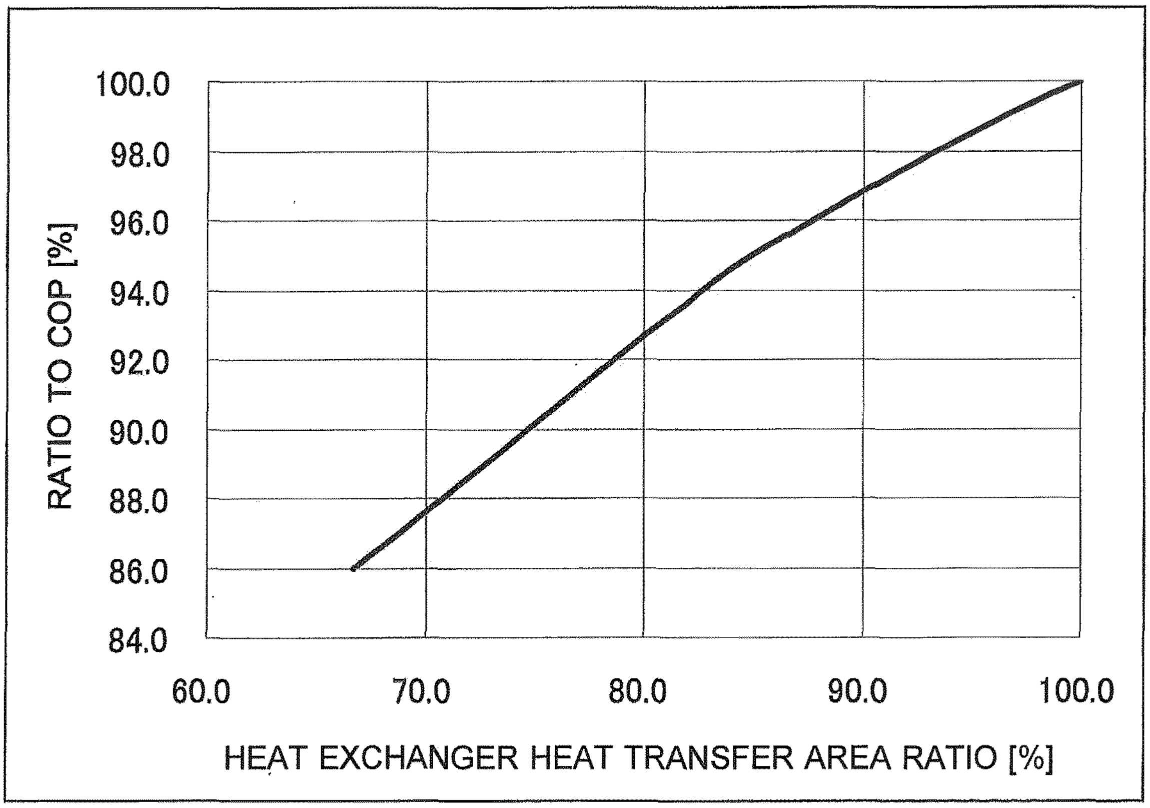


FIG. 13



F I G. 1 4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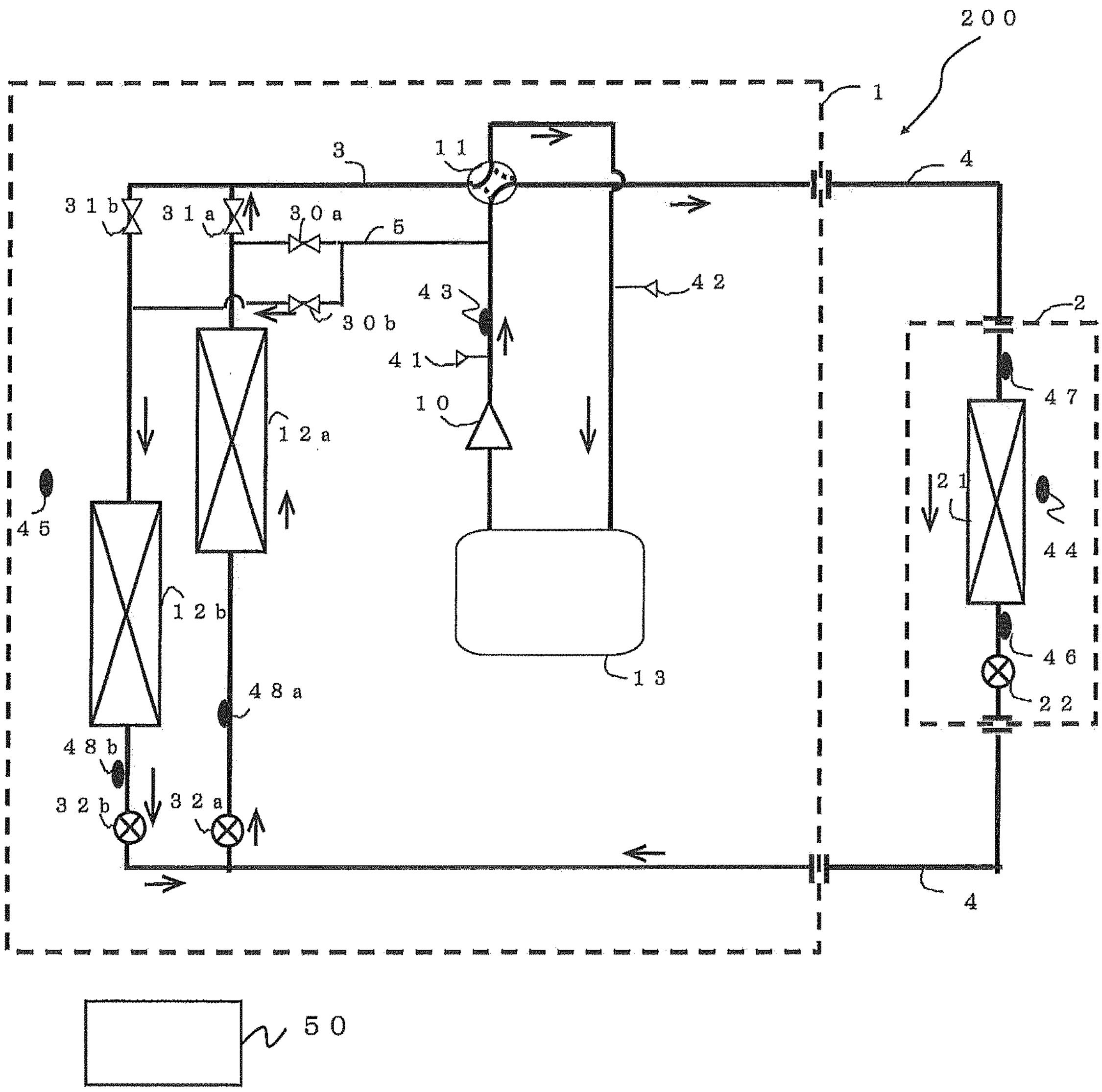
100.0
HEAT EXCHANGER HEAT TRANSFER AREA RATIO [%]

FIG. 15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31a
30a
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2
30b
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44
12b
13
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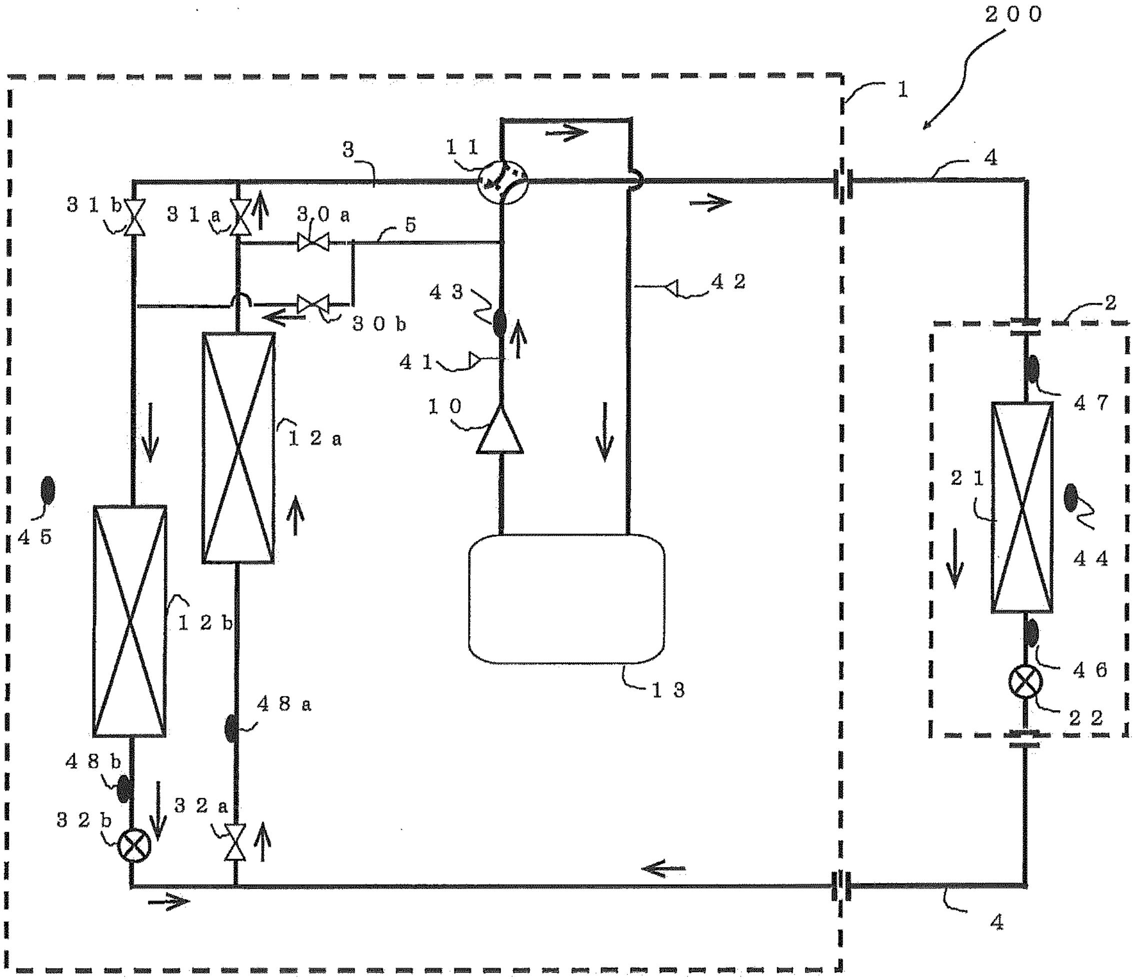
48a
22
48b
32b
32a
4
50

FIG. 16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30b
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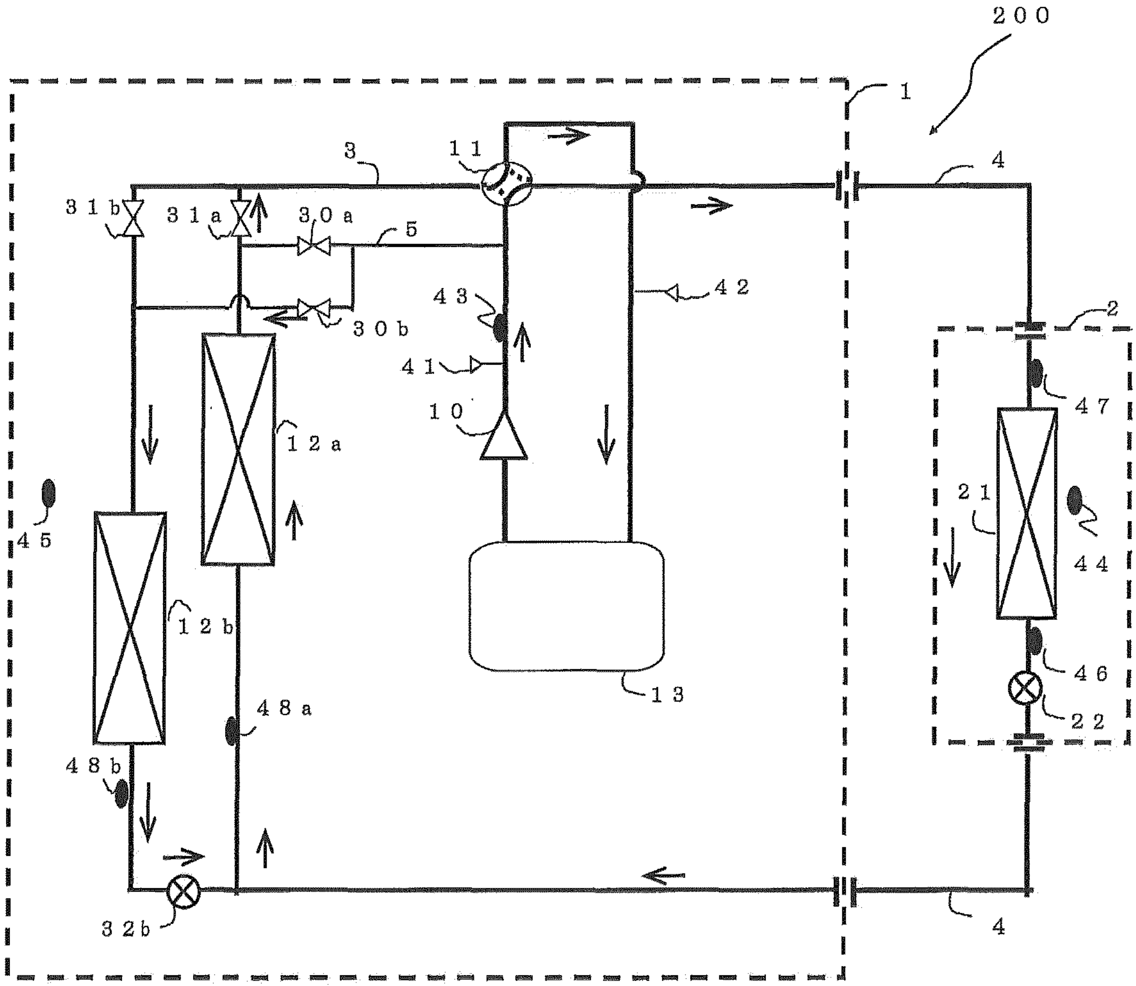
22
48b
32a
32b
4

FIG. 17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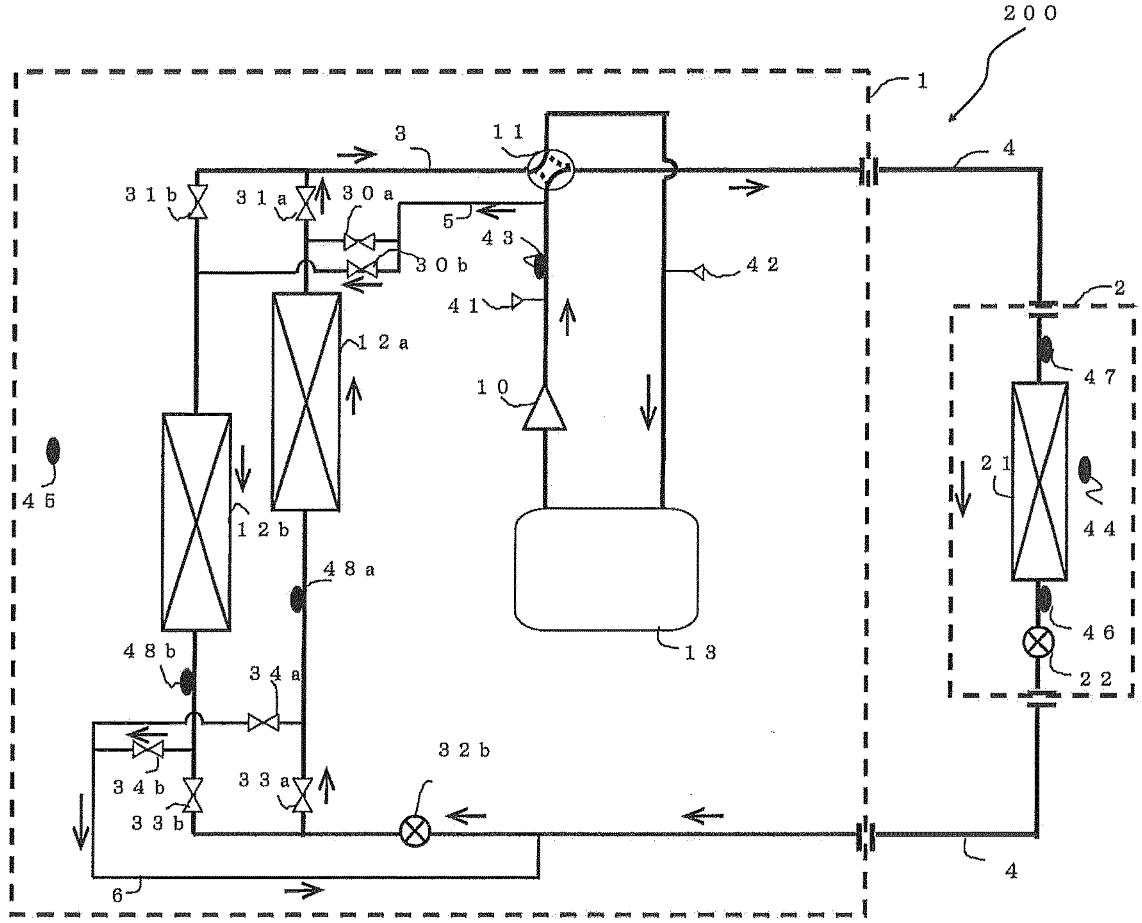
F I G. 1 8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46
22
48b
34a
32b
34b
33a
33b
4
6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/080912

A. CLASSIFICATION OF SUBJECT MATTER
F25B47/02(2006.01)i, *F28F1/32*(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)
F25B47/02, F28F1/32

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.
X Y	JP 2009-85484 A (Daikin Industries, Ltd.), 23 April 2009 (23.04.2009), paragraphs [0031] to [0058]; fig. 1 to 5 (Family: none)	1-3,5 1-11
Y	JP 2008-249236 A (Mitsubishi Electric Corp.), 16 October 2008 (16.10.2008), paragraphs [0042] to [0062]; fig. 1 to 2 (Family: none)	1-11
Y	JP 2010-249335 A (Mitsubishi Electric Corp.), 04 November 2010 (04.11.2010), paragraphs [0023] to [0033]; fig. 4 to 5 (Family: none)	1-11

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

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 February, 2013 (13.02.13)	26 February, 2013 (26.02.13)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2012/080912

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2012-159256 A (Daikin Industries, Ltd.), 23 August 2012 (23.08.2012), paragraphs [0038] to [0040], [0058]; fig. 2 (Family: none)	1-11
Y	JP 2009-36404 A (Denso Corp.), 19 February 2009 (19.02.2009), paragraphs [0016] to [0018]; fig. 2 (Family: none)	1-11
Y	JP 62-175530 A (Matsushita Electric Industrial Co., Ltd.), 01 August 1987 (01.08.1987), page 2, lower right column, lines 12 to 15; fig. 1 (Family: none)	7

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2010082325 A **[0006]**
- US 20100170270 A **[0006]**