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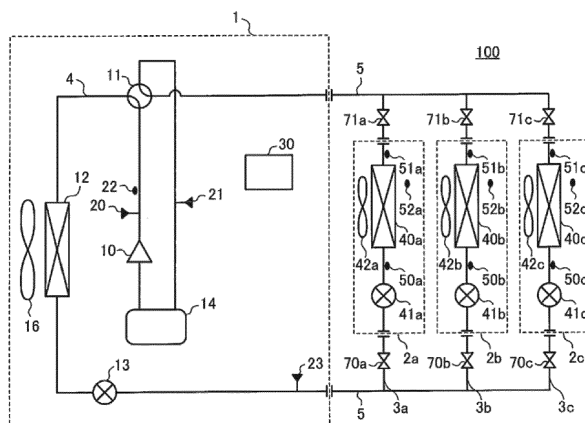
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(54) **AIR CONDITIONER**

(57) An air-conditioning apparatus includes an outdoor unit and an indoor unit, the outdoor unit having at least a compressor, a refrigerant flow path switching device, a heat source side heat exchanger, and a first expansion device, the indoor unit having at least a load side heat exchanger and a second expansion device, the compressor, the refrigerant flow path switching device, the heat source side heat exchanger, the first expansion device, the load side heat exchanger and the second expansion device being connected by refrigerant pipes to form a refrigerant circuit a first valve device provided at a refrigerant pipe of the refrigerant pipes, the refrigerant-

ant pipe connecting between the first expansion device and the second expansion device; a second valve device provided at a refrigerant pipe of the refrigerant pipes, the refrigerant pipe connecting between the refrigerant flow path switching device and the load side heat exchanger; and a controller configured to control the first expansion device during a cooling operation mode to expand, into a two-phase gas-liquid state, refrigerant flowing through the first expansion device to the refrigerant pipe between the first expansion device and the second expansion device. The first valve device and the second valve device are closed when leakage of the refrigerant is detected.

FIG. 1



Description

Solution to Problem

Technical Field

[0001] The present invention relates to an air-conditioning apparatus that air-conditions an indoor space.

Background Art

[0002] In an existing air-conditioning apparatus such as a multi-air-conditioning apparatus for building, the total length of a refrigerant pipe that connects an outdoor unit and a plurality of indoor units is several hundred meters in some cases, and thus the amount of refrigerant used is very large. In such an air-conditioning apparatus, there is a possibility that a large amount of the refrigerant will leak to one room when refrigerant leakage occurs.

[0003] In addition, in recent years, from the viewpoint of global warming, replacement with refrigerants having a low global warming potential has been required, but many of those refrigerants that have a low global warming potential have combustibility. In the future, when replacement with refrigerants having a low global warming potential progresses, further consideration for safety would be required. To overcome such a problem, a technique has been proposed in which a shutoff valve for blocking flow of refrigerant is provided in a refrigerant circuit, thereby reducing a leakage amount of the refrigerant when the refrigerant leaks (see, for example, Patent Literature 1).

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2000-97527

Summary of Invention

Technical Problem

[0005] However, in the technique disclosed in Patent Literature 1, while it is possible to reduce the leakage amount of the refrigerant when the refrigerant leaks, there is a risk that a large amount of the refrigerant will leak depending on: the position of the shutoff valve for blocking flow of the refrigerant; a location where refrigerant leakage occurs; and the amount of the refrigerant used in the air-conditioning apparatus.

[0006] The present invention has been made to overcome the above-described disadvantage, and an object of the present invention is to provide an air-conditioning apparatus that is able to further reduce a leakage amount of refrigerant when refrigerant leakage occurs.

[0007] An air-conditioning apparatus according to an embodiment of the present invention is an air-conditioning apparatus an outdoor unit and an indoor unit, the outdoor unit having at least a compressor, a refrigerant flow path switching device, a heat source side heat exchanger, and a first expansion device, the indoor unit having at least a load side heat exchanger and a second expansion device, the compressor, the refrigerant flow path switching device, the heat source side heat exchanger, the first expansion device, the load side heat exchanger and the second expansion device being connected by refrigerant pipes to form a refrigerant circuit a first valve device provided at a refrigerant pipe of the refrigerant pipes, the refrigerant pipe connecting between the first expansion device and the second expansion device; a second valve device provided at a refrigerant pipe of the refrigerant pipes, the refrigerant pipe connecting between the refrigerant flow path switching device and the load side heat exchanger; and a controller configured to control the first expansion device during a cooling operation mode to expand, into a two-phase gas-liquid state, refrigerant flowing through the first expansion device to the refrigerant pipe between the first expansion device and the second expansion device, wherein the first valve device and the second valve device are closed when leakage of the refrigerant is detected.

Advantageous Effects of Invention

[0008] According to the present invention, since the refrigerant flowing in a part of the refrigerant pipe between the first expansion device and the second expansion device is made into a two-phase gas-liquid state, it is possible to reduce the weight of the refrigerant present between the first expansion device and the second expansion device, so that it is possible to reduce a leakage amount of the refrigerant when refrigerant leakage occurs.

[0009] In addition, since the first valve device and the second valve device are closed when leakage of the refrigerant is detected, it is possible to further reduce a leakage amount of the refrigerant to the indoor space.

Brief Description of Drawings

[0010]

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

Fig. 2 is a refrigerant circuit diagram showing flow of refrigerant during a cooling operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention.

Fig. 3 is a refrigerant circuit diagram showing flow of

the refrigerant during a heating operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention.

Fig. 4 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 2 of the present invention.

Fig. 5 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 3 of the present invention.

Fig. 6 is a flowchart showing operation of an actuator in a pump-down function of the air-conditioning apparatus according to Embodiment 3 of the present invention.

Fig. 7 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 4 of the present invention.

Fig. 8 is a flowchart showing operation of an actuator in a pump-down function of the air-conditioning apparatus according to Embodiment 4 of the present invention.

Fig. 9 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 5 of the present invention.

Fig. 10 is a refrigerant circuit diagram showing flow of refrigerant and a heat medium during a cooling operation mode of the air-conditioning apparatus according to Embodiment 5 of the present invention.

Fig. 11 is a refrigerant circuit diagram showing flow of the refrigerant and the heat medium during a heating operation mode of the air-conditioning apparatus according to Embodiment 5 of the present invention.

Description of Embodiments

[0011] Hereinafter, Embodiments of the air-conditioning apparatus according to the present invention will be described with reference to the drawings. It should be noted that Embodiments of the drawings are examples and are not intended to limit the present invention. In addition, in each drawing, components designated by the same reference signs are the same or equivalent components, and this applies throughout the specification. Furthermore, the relationship of the sizes of components in the drawings described below may be different from actual ones.

Embodiment 1

[0012] Fig. 1 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 1 of the present invention.

[0013] The air-conditioning apparatus 100 according to Embodiment 1 circulates refrigerant in a circuit and

performs air-conditioning using a refrigeration cycle, and is an air-conditioning system that is able to select a cooling operation mode in which all operating indoor units 2a, 2b, and 2c perform cooling or a heating operation mode in which all the indoor units 2a, 2b, and 2c perform heating, for example, as in a multi-air-conditioning apparatus for building or other apparatuses.

[0014] As shown in Fig. 1, an outdoor unit 1 and the indoor units 2a, 2b, and 2c are connected to each other by a refrigerant main pipe 5 and refrigerant branch pipes 3a, 3b, and 3c. Fig. 1 shows the case where the three indoor units 2a, 2b, and 2c are connected to the outdoor unit 1, but the number of indoor units is not limited.

15 [Configuration of outdoor unit 1]

[0015] The outdoor unit 1 includes a compressor 10, a refrigerant flow path switching device 11 such as a four-way valve, a heat source side heat exchanger 12, a first expansion device 13, and an accumulator 14, and these components are connected to each other by a refrigerant pipe 4. In addition, an outdoor fan 16 for sending air to the heat source side heat exchanger 12 is provided to the outdoor unit 1.

[0016] The compressor 10 sucks low-temperature, low-pressure refrigerant, and compresses the refrigerant into high-temperature, high-pressure gas refrigerant. The compressor 10 is, for example, a capacity-controllable inverter compressor or another compressor. The refrigerant flow path switching device 11 switches between flow of the refrigerant during the cooling operation mode and flow of the refrigerant during the heating operation mode.

[0017] The heat source side heat exchanger 12 serves as a condenser during the cooling operation mode, serves as an evaporator during the heating operation mode, and, for example, exchanges heat between the refrigerant and air supplied from the outdoor fan 16. The first expansion device 13 reduces the pressure of the refrigerant that circulates in the refrigerant pipe 4, the refrigerant main pipe 5, and the refrigerant branch pipes 3a, 3b, and 3c, and is, for example, an electronic expansion valve whose opening degree is variably controllable, or another device. The accumulator 14 is provided at the suction side of the compressor 10 and stores excess refrigerant generated due to the difference between the operating states of the cooling operation mode and the heating operation mode, or excess refrigerant with respect to transient change in operation.

[0018] In the outdoor unit 1, a first pressure detection device 20, a second pressure detection device 21, and a third pressure detection device 23 are provided as a pressure detection device. The first pressure detection device 20 is provided at the refrigerant pipe 4 connecting the discharge side of the compressor 10 and the refrigerant flow path switching device 11 and detects the pressure of the high-temperature, high-pressure gas refrigerant compressed and discharged by the compressor

10. In addition, the second pressure detection device 21 is provided at the refrigerant pipe 4 connecting the refrigerant flow path switching device 11 and the suction side of the compressor 10 and detects the pressure of the low-temperature and low-pressure liquid refrigerant sucked into the compressor 10. The third pressure detection device 23 is provided at the refrigerant pipe 4 between the first expansion device 13 and the refrigerant main pipe 5 and detects the pressure of two-phase gas-liquid refrigerant.

[0019] In the outdoor unit 1, a first temperature detection device 22 is provided as a temperature detection device and is, for example, a thermistor or another device. The first temperature detection device 22 is provided at the refrigerant pipe 4 connecting the discharge side of the compressor 10 and the refrigerant flow path switching device 11 and detects the temperature of the high-temperature, high-pressure gas refrigerant compressed and discharged by the compressor 10.

[Configurations of indoor units 2a, 2b, and 2c]

[0020] The indoor units 2a, 2b, and 2c include load side heat exchangers 40a, 40b, and 40c, second expansion devices 41a, 41b, and 41c, and indoor fans 42a, 42b, and 42c. The indoor units 2a, 2b, and 2c are connected to the outdoor unit 1 by the refrigerant branch pipes 3a, 3b, and 3c and the refrigerant main pipe 5, and the refrigerant flows thereinto and flows out therefrom. The load side heat exchangers 40a, 40b, and 40c exchange heat between the refrigerant and indoor air supplied by the indoor fans 42a, 42b, and 42c and generate heating air or cooling air to be supplied to an indoor space. In addition, the second expansion devices 41a, 41b, and 41c have a function as a pressure reducing valve or an expansion valve and reduce the pressure of the refrigerant to expand the refrigerant, and are each, for example, an electronic expansion valve whose opening degree is variably controllable, or another device.

[0021] In the indoor units 2a, 2b, and 2c, second temperature detection devices 50a, 50b, and 50c, third temperature detection devices 51a, 51b, and 51c, and fourth temperature detection devices 52a, 52b, and 52c are provided. The second temperature detection devices 50a, 50b, and 50c are provided at pipes connecting the second expansion devices 41a, 41b, and 41c and the load side heat exchangers 40a, 40b, and 40c. The third temperature detection devices 51a, 51b, and 51c are provided at pipes at the side opposite to the second expansion devices 41a, 41b, and 41c relative to the load side heat exchangers 40a, 40b, and 40c. Furthermore, the fourth temperature detection devices 52a, 52b, and 52c are provided at air-inlet portions of the load side heat exchangers 40a, 40b, and 40c.

[0022] During the cooling operation mode, the second temperature detection devices 50a, 50b, and 50c detect the temperatures of the refrigerant flowing into the load side heat exchangers 40a, 40b, and 40c, and the third

temperature detection devices 51a, 51b, and 51c detect the temperatures of the refrigerant flowing out of the load side heat exchangers 40a, 40b, and 40c. Furthermore, the fourth temperature detection devices 52a, 52b, and 52c detect the temperature of the indoor air. Each temperature detection device is, for example, a thermistor or another device.

[0023] The air-conditioning apparatus 100 includes a controller 30 being a microcomputer or another device. The controller 30 is configured to execute each of later-described operation modes by controlling the frequency of the compressor 10, the rotation speed (including ON/OFF) of the outdoor fan 16 for the heat source side heat exchanger 12, switching of the refrigerant flow path switching device 11, the opening degrees of the second expansion devices 41a, 41b, and 41c, etc. on the basis of detection values of various detection devices and commands from a remote controller. Fig. 1 shows an example in which the controller 30 is provided in the outdoor unit 1, but the controller 30 may be provided for each of the indoor units 2a, 2b, and 2c in addition to the outdoor unit 1.

[0024] The air-conditioning apparatus 100 also includes: first valve devices 70a, 70b, and 70c respectively provided at the refrigerant branch pipes 3a, 3b, and 3c that become the inlet sides of the indoor units 2a, 2b, and 2c, respectively, during the cooling operation mode; and second valve devices 71a, 71b, and 71c respectively provided at the refrigerant branch pipes 3a, 3b, and 3c that become the outlet sides of the indoor units 2a, 2b, and 2c, respectively, during the cooling operation mode. The first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c are closed when a refrigerant leakage detection signal sent from a refrigerant leakage detection device provided in the indoor space or in each of the indoor units 2a, 2b, and 2c is inputted thereinto, thereby preventing leakage of the refrigerant to the indoor space.

[0025] Hereinafter, regarding the air-conditioning apparatus 100 according to Embodiment 1, operation during the cooling operation mode will be initially described with reference to Fig. 2, and operation during the heating operation mode will be described next with reference to Fig. 3.

[Cooling operation mode]

[0026] Fig. 2 is a refrigerant circuit diagram showing flow of the refrigerant during the cooling operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention. Fig. 2 illustrates the cooling operation mode in the case where cooling energy loads have been generated in the load side heat exchangers 40a, 40b, and 40c, and solid arrows in the drawing indicate the direction of flow of the refrigerant during the cooling operation mode.

[0027] During the cooling operation mode, the low-temperature and low-pressure refrigerant is compressed into high-temperature, high-pressure gas refrigerant by

the compressor 10 and discharged therefrom. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows into the heat source side heat exchanger 12 owing to the refrigerant flow path switching device 11. The high-temperature, high-pressure gas refrigerant flowing into the heat source side heat exchanger 12 condenses into high-pressure liquid refrigerant while rejecting heat to outdoor air. Then, the high-pressure liquid refrigerant having flowed out from the heat source side heat exchanger 12 is reduced in pressure by the first expansion device 13 into intermediate-pressure two-phase gas-liquid refrigerant, flows out from the outdoor unit 1, flows through the refrigerant main pipe 5 into the refrigerant branch pipes 3a, 3b, and 3c, and flows to the indoor units 2a, 2b, and 2c.

[0028] Meanwhile, the controller 30 controls the opening degree of the first expansion device 13 such that the detection value of the third pressure detection device 23 becomes a predetermined value. The average pressure of the pressure detected by the first pressure detection device 20 and the pressure detected by the second pressure detection device 21 may be set as the predetermined value. Alternatively, a temperature detection device may be provided instead of the third pressure detection device 23, and the first expansion device 13 may be controlled such that the detection value of the temperature detection device becomes a target temperature, or another means may be provided as long as it is possible to produce intermediate-pressure two-phase gas-liquid refrigerant.

[0029] Because of action of the first expansion device 13, the phase state of the refrigerant flowing in the refrigerant main pipe 5 and the refrigerant branch pipes 3a, 3b, and 3c changes from a supercooled liquid state to a two-phase gas-liquid state. Accordingly, it is possible to reduce the weight of the refrigerant present in the refrigerant main pipe 5 and the refrigerant branch pipes 3a, 3b, and 3c.

[0030] The intermediate-pressure two-phase gas-liquid refrigerant flowing into the indoor units 2a, 2b, and 2c is reduced in pressure by the second expansion devices 41a, 41b, and 41c into low-temperature and low-pressure two-phase gas-liquid refrigerant, then flows into the load side heat exchangers 40a, 40b, and 40c that act as an evaporator, and removes heat from indoor air to cool the indoor air, thereby becoming low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant having flowed out from the load side heat exchangers 40a, 40b, and 40c flows to the refrigerant branch pipes 3a, 3b, and 3c and flows through the refrigerant main pipe 5 into the outdoor unit 1. The refrigerant flowing into the outdoor unit 1 flows to the accumulator 14 owing to the refrigerant flow path switching device 11 and is sucked into the compressor 10.

[0031] Meanwhile, the controller 30 controls the opening degrees of the second expansion devices 41a, 41b, and 41c such that superheat (degree of superheat) ob-

tained on the basis of the differences between the temperatures detected by the second temperature detection devices 50a, 50b, and 50c and the temperatures detected by the third temperature detection devices 51a, 51b, and 51c is constant. In addition, the controller 30 controls the opening degrees of the first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c such that flow of the refrigerant during the cooling operation mode is not blocked. In this state, when the refrigerant leakage detection device inputs a refrigerant leakage detection signal to the first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c, the first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c are closed, thereby preventing leakage of the refrigerant to the indoor space.

[0032] In the case where the first expansion device 13 is not provided, high-pressure supercooled liquid refrigerant flows in sections between the heat source side heat exchanger 12 and the second expansion devices 41a, 41b, and 41c during the cooling operation mode. On the other hand, in Embodiment 1, by reducing the pressure of the refrigerant having flowed out from the heat source side heat exchanger 12 by the first expansion device 13, it is possible to make the refrigerant flowing between the first expansion device 13 and the second expansion devices 41a, 41b, and 41c into a two-phase gas-liquid state during the cooling operation mode.

[0033] With such a configuration, it is possible to reduce the weight of the refrigerant present between the first expansion device 13 and the second expansion devices 41a, 41b, and 41c, so that it is possible to reduce a leakage amount of the refrigerant when refrigerant leakage occurs.

[Heating operation mode]

[0034] Fig. 3 is a refrigerant circuit diagram showing flow of the refrigerant during the heating operation mode of the air-conditioning apparatus according to Embodiment 1 of the present invention. Fig. 3 illustrates the heating operation mode in the case where heating energy loads have been generated in the load side heat exchangers 40a, 40b, and 40c, and solid arrows in the drawing indicate the direction of flow of the refrigerant during the heating operation mode.

[0035] During the heating operation mode, the low-temperature and low-pressure refrigerant is compressed into high-temperature, high-pressure gas refrigerant by the compressor 10 and discharged therefrom. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows through the refrigerant main pipe 5 into the refrigerant branch pipes 3a, 3b, and 3c owing to the refrigerant flow path switching device 11, and flows into the indoor units 2a, 2b, and 2c. The high-temperature, high-pressure gas refrigerant flowing into the indoor units 2a, 2b, and 2c rejects heat to the indoor air at the load side heat exchangers 40a, 40b, and 40c to become high-pressure liquid refrigerant, and flows into

the second expansion devices 41a, 41b, and 41c. Then, the high-pressure liquid refrigerant is reduced in pressure by the second expansion devices 41a, 41b, and 41c into low-temperature and low-pressure two-phase gas-liquid refrigerant, flows out from the indoor units 2a, 2b, and 2c, and flows via the refrigerant branch pipes 3a, 3b, and 3c through the refrigerant main pipe 5 into the outdoor unit 1.

[0036] The low-temperature and low-pressure two-phase gas-liquid refrigerant flowing into the outdoor unit 1 passes through the first expansion device 13 that has been opened, removes heat from outdoor air at the heat source side heat exchanger 12 thereby to evaporate into low-temperature and low-pressure two-phase gas-liquid refrigerant having higher quality. The low-temperature and low-pressure two-phase gas-liquid refrigerant having flowed out from the heat source side heat exchanger 12 flows to the accumulator 14 owing to the refrigerant flow path switching device 11 and is separated into gas refrigerant and liquid refrigerant, and only the gas refrigerant is sucked into the compressor 10.

[0037] Meanwhile, in the case where the first expansion device 13 is a device whose opening degree is adjustable such as an electronic expansion valve, the controller 30 sets the opening degree of the first expansion device 13 during the heating operation mode to such an opening degree that the operating state (for example, heating capacity, etc.) of the refrigeration cycle is not adversely affected (for example, full opening). In addition, the controller 30 controls the opening degrees of the second expansion devices 41a, 41b, and 41c such that sub-cooling (degree of supercooling) obtained on the basis of the differences between the saturated liquid temperature of the refrigerant calculated from the pressure detected by the first pressure detection device 20 and the temperatures detected by the second temperature detection devices 50a, 50b, and 50c is constant. Moreover, the controller 30 controls the opening degrees of the first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c such that flow of the refrigerant during the heating operation mode is not blocked.

[0038] In this state, when refrigerant leakage is detected by the refrigerant leakage detection device, the first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c are closed, thereby preventing leakage of the refrigerant to the indoor space. In addition, in this case, the refrigerant flowing from the indoor units 2a, 2b, and 2c toward the first expansion device 13 is in a two-phase gas-liquid state, and thus it is possible to reduce a leakage amount of the refrigerant.

Embodiment 2

[0039] Fig. 4 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 2 of the present invention. In Embodiment 2, only the differences from Embodiment 1 will be described.

[0040] In Embodiment 2, a first valve device 70d is provided at a shared refrigerant path shared between the indoor units 2b and 2c. A second valve device 71d is provided at a shared refrigerant path shared between the indoor units 2b and 2c. As shown in Fig. 4, the first valve device 70d and the second valve device 71d are each provided at the refrigerant main pipe 5 between the indoor unit 2a and the indoor unit 2b.

[0041] In the air-conditioning apparatus 100 according to Embodiment 2, flow of the refrigerant during the cooling operation mode and during heating operation mode is the same as in Embodiment 1, and control of each component such as the compressor 10, the first expansion device 13, and the second expansion devices 41a, 41b, and 41c is also the same as in Embodiment 1.

[0042] In Embodiment 2, as described in Embodiment 1, the refrigerant flowing between the first expansion device 13 and the second expansion devices 41a, 41b, and 41c during the cooling operation mode is made into a two-phase gas-liquid state owing to the first expansion device 13. Accordingly, the amount of the leaking refrigerant is small as compared to the case where the first expansion device 13 is not provided. Thus, in an air-conditioning system or another system in which the refrigerant branch pipes 3a, 3b, and 3c are short, it becomes unnecessary to provide valve devices to refrigerant branch pipes 3b and 3c connected to the front and the rear of the indoor units 2b and 2c, respectively, and thus it is possible to reduce the number of used valve devices, so that it is possible to provide an inexpensive air-conditioning system.

[0043] For example, by providing the first valve device 70d and the second valve device 71d in Embodiment 2 at such positions that a maximum refrigerant concentration that may occur during refrigerant leakage becomes smaller than a predetermined value, it is possible to provide an air-conditioning apparatus 100 having higher safety. The maximum refrigerant concentration is calculated from the diameters of the refrigerant branch pipes 3b and 3c between the first valve device 70d and the second valve device 71d, the sum of the weights of the refrigerant included in the indoor units 2b and 2c, and the smaller volume of an indoor space among the volumes of indoor spaces that are air-conditioned by the indoor unit 2b and the indoor unit 2c.

[0044] Fig. 4 shows an example in which the first valve device 70d is provided at a shared refrigerant path shared between the indoor units 2b and 2c and the second valve device 71d is provided at a shared refrigerant path shared between the indoor units 2b and 2c, but the present invention is not limited thereto. For example, each of the first valve device 70d and the second valve device 71d may be provided at a shared refrigerant path shared among three indoor units including the indoor unit 2a as long as the maximum refrigerant concentration in each indoor space during refrigerant leakage is not high. Alternatively, also in an air-conditioning system in which four or more indoor units are provided, if the above-de-

scribed maximum refrigerant concentration is not high, the first valve device 70d may be provided at a shared refrigerant path that is shared among the four or more indoor units and the second valve device 71d may be provided at a shared refrigerant path that is shared among the four or more indoor units.

[0045] For example, for determining the weights of the refrigerant included in the refrigerant branch pipes 3a, 3b, and 3c and the indoor units 2a, 2b, and 2c, a method may be used in which refrigerant weights for the diameters of pipes and the capacities of indoor units as targets are referred to from data of refrigerant added/filled amount at a site, the data being provided from the manufacture.

[0046] The predetermined value for the maximum refrigerant concentration may be a value specified by law of each country or an international standard, or another value. For example, the predetermined value may be a value of RCL (Refrigerant Concentration Limit) defined by an international standard such as ISO5149, or a value calculated from RCL in accordance with the risk of the used refrigerant, such as RLC/2 and RCL/5, may be used.

[0047] In the case where the first valve device 70d and the second valve device 71d are provided in a space above a ceiling, it is possible to prevent the refrigerant concentration in a specific indoor space from becoming high. This is because even when refrigerant leakage occurs at a part of the refrigerant main pipe 5 or the refrigerant branch pipes 3a, 3b, and 3c, the part being other than a part which is located in the indoor units 2a, 2b and 2c and the section between the first valve device 70d and the second valve device 71d, the refrigerant is agitated in the space above the ceiling and thereafter leaks to the indoor spaces in which those indoor units 2a, 2b, and 2c, which are located in the section between the first valve device 70d and the second valve device 71d, are installed.

[0048] When refrigerant leakage is detected by the refrigerant leakage detection device, the controller 30 brings the first valve devices 70a and 70d and the second valve devices 71a and 71d into a closed state. Accordingly, it is possible to inhibit leakage of the refrigerant to the indoor space.

Embodiment 3

[0049] Fig. 5 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 3 of the present invention. In Embodiment 3, only the differences from Embodiment 1 will be described.

[0050] The air-conditioning apparatus 100 according to Embodiment 3 includes: a bypass pipe 6 that branches from the refrigerant pipe 4 connecting the first expansion device 13 of the outdoor unit 1 and the refrigerant main pipe 5 and is connected to the refrigerant pipe 4 between the refrigerant flow path switching device 11 and the ac-

cumulator 14; and a bypass valve device 15 provided at the bypass pipe 6. In addition, a pump-down function that reduces the amount of the refrigerant leaking to the indoor space when refrigerant leakage occurs is added to the controller 30.

[0051] Fig. 5 shows an example in which the branch point and the meeting point of the bypass pipe 6 and the refrigerant pipe 4 are located in the outdoor unit 1, but the present invention is not limited thereto. In addition, the bypass valve device 15 serves to block flow of the refrigerant in the bypass pipe 6, may be any device as long as the device is able to block flow of the refrigerant, and may be, for example, a solenoid valve or another device.

[0052] During the cooling operation mode and during the heating operation mode, the bypass valve device 15 is in a closed state, so that the refrigerant is prevented from flowing to the bypass pipe 6. Accordingly, flow of the refrigerant during the cooling operation mode and that during the heating operation mode are the same as in Embodiment 1, and control of each component such as the compressor 10, the first expansion device 13, and the second expansion devices 41a, 41b, and 41c is also the same as in Embodiment 1.

[0053] Next, the pump-down function added to the controller 30 will be described with reference to Fig. 6.

[0054] Fig. 6 is a flowchart showing operation of an actuator in the pump-down function of the air-conditioning apparatus according to Embodiment 3 of the present invention.

[0055] The above-described pump-down function is a function that is performed when refrigerant leakage is detected by refrigerant leakage detectors provided in the indoor units 2a, 2b, and 2c, the indoor spaces air-conditioned by the indoor units 2a, 2b, and 2c, or the like or from measurement values of various measurement sensors provided in the air-conditioning apparatus 100. That is, the pump-down function is a function to reduce an amount of the refrigerant leaking to the indoor space when the refrigerant leaks at a part of the refrigerant main pipe 5 or the refrigerant branch pipes 3a, 3b, and 3c, the part being other than a part which is located in the indoor units 2a, 2b, and 2c and the section between the first valve devices 71a, 71b and 71c and the second valve devices 71a, 71b and 71c.

[0056] For example, when refrigerant leakage is detected by the refrigerant leakage detector during the heating operation mode, the controller 30 switches the refrigerant flow path switching device 11 to a flow path for the cooling operation mode (step A1). When refrigerant leakage is detected during the cooling operation mode, switching of the refrigerant flow path switching device 11 is not performed, and the current state is maintained.

[0057] Next, the controller 30 sets the frequency of the compressor 10 to a predetermined value (step A2), opens the bypass valve device 15 from a closed state and also fully closes the first expansion device 13 (step A3, step A4), and sets the rotation speed of the outdoor

fan 16 to a predetermined value (step A5). The first expansion device 13 is fully closed, but the opening degree of the first expansion device 13 may be set to an opening degree close to full closing.

[0058] At this time, a pump-down operation is performed in which the refrigerant in the refrigerant main pipe 5 and the refrigerant branch pipes 3a, 3b, and 3c that connect the outdoor unit 1 and the first valve devices 70a, 70b, and 70c in a closed state and the outdoor unit 1 and the second valve devices 71a, 71b, and 71c in a closed state, is collected in the heat source side heat exchanger 12 and the accumulator 14. The timing at which the first valve devices 70a, 70b, and 70c and the second valve devices 71a, 71b, and 71c are changed from an opened state to a closed state is not shown in Fig. 6, and is, for example, between step A1 and step A2.

[0059] The operation order from step A1 to step A5 shown in Fig. 6 is not limited, and the same pump-down operation as described above is performed even when the operation order from step A1 to step A5 is changed.

[0060] When the predetermined value set for the frequency of the compressor 10 in step A2 is set to a high frequency, the pressure of the refrigeration cycle rapidly changes, so that there is a risk of abnormal stop or the like. On the other hand, when such a predetermined value is set to a low frequency, the pump-down effect is diminished, and thus it is not so preferable to perform pump-down at a minimum allowable frequency of the compressor 10. Therefore, it is preferable to perform a pump-down operation at a frequency that is approximately half the sum of the minimum frequency and the maximum frequency. Instead, the frequency of the compressor 10 may be changed in accordance with the detection value of either the first pressure detection device 20 or the second pressure detection device 21.

[0061] The predetermined value set for the rotation speed of the outdoor fan 16 in step A5 is set to a maximum rotation speed. When the rotation speed of the outdoor fan 16 is higher, the refrigerant more easily condensates at the heat source side heat exchanger 12, so that it is possible to inhibit the discharge pressure of the compressor 10 from increasing. The rotation speed of the outdoor fan 16 is set to a maximum speed, but the rotation speed of the outdoor fan 16 may be set to a value lower than the maximum value.

[0062] When the pump-down operation is performed, the controller 30 determines an end state of the pump-down operation by using the detection value of either the first pressure detection device 20 or the second pressure detection device 21 (step A6). The controller 30 ends the pump-down operation when the pressure (detection value) detected by the first pressure detection device 20 is equal to or greater than a first threshold or the pressure (detection value) detected by the second pressure detection device 21 is equal to or less than a second threshold.

[0063] Regarding the threshold set for ending the pump-down operation in step A6, when the first threshold

at the high-pressure side is set to a value as low as possible and the second threshold at the low-pressure side is set to a value as high as possible, it is possible to move a lot of the refrigerant from the refrigerant main pipe 5 and the refrigerant branch pipes 3a, 3b, and 3c to the outdoor unit 1, so that more safety is achieved. Thus, in the case where the first pressure detection device 20 is used, the first threshold is preferably set to the maximum allowable pressure for the compressor 10 during operation or to a value close to the maximum pressure. In the case where the second pressure detection device 21 is used, the second threshold is preferably set to the minimum pressure that is allowable for the compressor 10 during operation or to a value close to the minimum pressure.

[0064] The end state of the pump-down operation is determined using the detection value of either the first pressure detection device 20 or the second pressure detection device 21, but the pump-down operation may be ended when the pressure (detection value) detected by the first pressure detection device 20 is equal to or greater than the first threshold and the pressure (detection value) detected by the second pressure detection device 21 is equal to or less than the second threshold.

[0065] Regarding the determination for ending the pump-down operation, the pump-down operation may be ended when a predetermined time has elapsed from start of the pump-down operation.

[0066] When end of the pump-down operation is confirmed, the controller 30 fully closes the bypass valve device 15 (step A7), switches the refrigerant flow path switching device 11 to a flow path for the heating operation mode (step A8), and finally stops the compressor 10 (step A9). Although the bypass valve device 15 is fully closed, the opening degree of the bypass valve device 15 may be set to an opening degree close to full closing.

[0067] By performing the operation shown in steps A7 to A9, it is possible to contain the refrigerant collected in the heat source side heat exchanger 12 and the accumulator 14 by the pump-down operation from steps A1 to A5, in the outdoor unit 1. Accordingly, the collected refrigerant does not move to the indoor units 2a, 2b, and 2c side. Thus, the amount of the refrigerant leaking to the indoor space is reduced, and the safety improves.

[0068] The operation order from step A7 to step A9 shown in Fig. 6 is not limited, and the same advantageous effects as described above are achieved even when the operation order is changed.

[0069] Embodiment 3 has been described in which the bypass pipe 6 and the bypass valve device 15 are specially added, but the present invention is not limited thereto. For example, a bypass may be provided which uses an internal heat exchanger having an effect of increasing the degree of supercooling of the refrigerant flowing in the refrigerant main pipe 5 and the refrigerant branch pipes 3a, 3b, and 3c and reducing pressure loss during the cooling operation mode. In this case, the pump-down function is effective without using the above-described

bypass pipe 6 and bypass valve device 15, and it is possible to achieve the same advantageous effects as described above.

[0070] The pump-down function described in Embodiment 3 is effective for the air-conditioning system in which the first valve device 70d is provided at a shared refrigerant path shared by the multiple indoor units 2a, 2b, and 2c as described in Embodiment 2, and the second valve device 71d is provided at a shared refrigerant path shared by the multiple indoor units 2a, 2b, and 2c as described in Embodiment 2, and it is possible to achieve the same advantageous effects as described above.

Embodiment 4

[0071] Fig. 7 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 4 of the present invention. In Embodiment 4, only the differences from Embodiment 3 will be described.

[0072] In Embodiment 4, the second valve devices 71a, 71b, and 71c are provided only at the refrigerant branch pipes 3a, 3b, and 3c at the refrigerant flow path switching device 11 side, among the refrigerant branch pipes 3a, 3b, and 3c connected to the indoor units 2a, 2b, and 2c. In addition, although described later, the controller 30 has a pump-down function different from that in Embodiment 3. Flow of the refrigerant and control during the cooling operation mode and the heating operation mode are the same as in Embodiment 3 except that only operation of the first valve devices 70a, 70b, and 70c is not present.

[0073] The pump-down function of the controller 30 in Embodiment 4 will be described with reference to Fig. 8. Fig. 8 is a flowchart showing operation of an actuator in the pump-down function of the air-conditioning apparatus according to Embodiment 4 of the present invention.

[0074] For example, similar to Embodiment 3, when refrigerant leakage is detected by the refrigerant leakage detector during the heating operation mode, the controller 30 switches the refrigerant flow path switching device 11 to the flow path for the cooling operation mode (step B1). When the refrigerant leakage is detected during the cooling operation, switching of the refrigerant flow path switching device 11 is not performed, and the current state is maintained. In addition, when refrigerant leakage is detected by the refrigerant leakage detector, the second valve devices 71a, 71b, and 71c switch from an opened state to a closed state.

[0075] Next, the controller 30 sets the frequency of the compressor 10 to a predetermined value (step B2), and opens the bypass valve device 15 and also fully closes the first expansion device 13 (step B3, step B4). Then, the controller 30 fully closes the second expansion devices 41a, 41b, and 41c (step B5) and sets the rotation speed of the outdoor fan 16 to a predetermined value (step B6).

[0076] At this time, a pump-down operation is per-

formed in which the refrigerant in the refrigerant main pipe 5 and the refrigerant branch pipes 3a, 3b, and 3c that connect the outdoor unit 1 and the second expansion devices 41a, 41b, and 41c in a closed state and the outdoor unit 1 and the second valve devices 71a, 71b, and 71c in a closed state, is collected in the heat source side heat exchanger 12 and the accumulator 14.

[0077] The operation order from step B1 to step B6 shown in Fig. 8 is not limited, and it is possible to perform the same pump-down operation as described above even when the operation order from step B1 to step B6 is changed.

[0078] When the pump-down operation is performed, the controller 30 determines an end state of the pump-down operation by using the detection value of either the first pressure detection device 20 or the second pressure detection device 21 (step B7). The controller 30 ends the pump-down operation when the pressure (detection value) detected by the first pressure detection device 20 is equal to or greater than a first threshold or the pressure (detection value) detected by the second pressure detection device 21 is equal to or less than a second threshold.

[0079] The end state of the pump-down operation is determined using the detection value of either the first pressure detection device 20 or the second pressure detection device 21, but the pump-down operation may be ended when the pressure (detection value) detected by the first pressure detection device 20 is equal to or greater than the first threshold and the pressure (detection value) detected by the second pressure detection device 21 is equal to or less than the second threshold.

[0080] Regarding the determination for ending the pump-down operation, the pump-down operation may be ended when a predetermined time has elapsed from start of the pump-down operation.

[0081] When end of the pump-down operation is confirmed, the controller 30 fully closes the bypass valve device 15 (step B8), switches the refrigerant flow path switching device 11 to the flow path for the heating operation mode (step B9), and finally stops the compressor 10 (step B10).

[0082] By performing the operation shown in steps B8 to B10, it is possible to enclose the refrigerant collected in the heat source side heat exchanger 12 and the accumulator 14 by the pump-down operation from steps B1 to B6, in the outdoor unit 1. Accordingly, the collected refrigerant does not move to the indoor units 2a, 2b, and 2c side. Thus, the amount of the refrigerant leaking to the indoor space is reduced, and the safety improves.

[0083] The operation order from step B8 to step B10 shown in Fig. 8 is not limited, and the same advantageous effects as described above are achieved even when the operation order is changed.

[0084] In Embodiment 4, since only the second valve devices 71a, 71b, and 71c are provided at the refrigerant flow path switching device 11 side, a risk of refrigerant leakage to the indoor space increases, but by performing

the pump-down function with the second expansion devices 41a, 41b, and 41c, it is possible to realize an inexpensive air-conditioning apparatus in which the first valve devices 70a, 70b, and 70c are not used but safety is maintained.

Embodiment 5

[0085] Fig. 9 is a schematic configuration diagram of a refrigerant circuit showing an example of an air-conditioning apparatus according to Embodiment 5 of the present invention. In Embodiment 5, only the differences from Embodiment 4 will be described.

[0086] The air-conditioning apparatus 100 according to Embodiment 5 is configured such that an outdoor unit 1 and a heat medium relay device 60 are connected to each other by the refrigerant main pipe 5 to form a refrigerant circuit and the heat medium relay device 60 and indoor units 2a and 2b are connected to each other by heat medium pipes 64a and 64b to form a heat medium cycle circuit. The outdoor unit 1 in Embodiment 5 has the same configuration as in Embodiment 4, and thus the description thereof is omitted.

[Configurations of indoor units 2a and 2b]

[0087] The indoor units 2a and 2b in Embodiment 5 each have the same configuration as in Embodiment 4 except that the second expansion devices provided at the refrigerant branch pipes are removed and the pipes connecting the respective components are changed from the refrigerant branch pipes to the heat medium pipes 64a and 64b. In Fig. 9, an example in which the two indoor units 2a and 2b are connected is shown, but the number of indoor units is not limited thereto, and one or three or more indoor units may be provided.

[Configuration of heat medium relay device 60]

[0088] The heat medium relay device 60 includes a heat medium heat exchanger 61, a pump 62 that transfers a heat medium such as water or a brine, and heat medium flow control devices 63a and 63b that adjust the flow rate of the heat medium flowing in the heat medium pipe 64. These components are connected to each other by the heat medium pipe 64. The heat medium relay device 60 is provided in a space such as a machine chamber or a space above a ceiling. The number of heat medium relay devices 60 is one in Fig. 9, but is not limited thereto, and two or more heat medium relay devices 60 may be provided in parallel.

[0089] The heat medium heat exchanger 61 is, for example, a plate-type heat exchanger or another heat exchanger that exchanges heat between the refrigerant and the heat medium such as water or a brine. A fifth temperature detection device 65 and a sixth temperature detection device 66 are provided at an outlet and an inlet at the refrigerant side of the heat medium heat exchanger

61, and a seventh temperature detection device 67 and an eighth temperature detection device 68 are provided at an outlet and an inlet at the heat medium side of the heat medium heat exchanger 61.

[0090] Hereinafter, regarding the air-conditioning apparatus 100 according to Embodiment 5, operation during the cooling operation mode will be initially described with reference to Fig. 10, and operation during the heating operation mode will be described next with reference to Fig. 11.

[Cooling operation mode]

[0091] Fig. 10 is a refrigerant circuit diagram showing flow of the refrigerant and the heat medium during the cooling operation mode of the air-conditioning apparatus according to Embodiment 5 of the present invention. Fig. 10 illustrates the cooling operation mode in the case where cooling energy loads have been generated in the load side heat exchangers 40a and 40b, solid arrows in the drawing indicate the direction of flow of the refrigerant, and broken arrows indicate the direction of flow of the heat medium.

[0092] During the cooling operation mode, the low-temperature and low-pressure refrigerant is compressed into high-temperature, high-pressure gas refrigerant by the compressor 10 and discharged therefrom. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows into the heat source side heat exchanger 12 owing to the refrigerant flow path switching device 11. The high-temperature, high-pressure gas refrigerant flowing into the heat source side heat exchanger 12 condenses into high-pressure liquid refrigerant while rejecting heat to outdoor air. Then, the high-pressure liquid refrigerant having flowed out from the heat source side heat exchanger 12 is reduced in pressure by the first expansion device 13 into intermediate-pressure two-phase gas-liquid refrigerant, flows out from the outdoor unit 1, and flows through the refrigerant main pipe 5 into the heat medium relay device 60.

[0093] The intermediate-pressure two-phase gas-liquid refrigerant flowing into the heat medium relay device 60 is reduced in pressure by a second expansion device 41 into low-temperature and low-pressure two-phase gas-liquid refrigerant, then flows into the heat medium heat exchanger 61 that acts as an evaporator, and removes heat from the heat medium to cool the heat medium, thereby becoming low-temperature and low-pressure gas refrigerant. The low-temperature and low-pressure gas refrigerant flows out from the heat medium relay device 60 and flows through the refrigerant main pipe 5 into the outdoor unit 1. The low-temperature and low-pressure gas refrigerant flowing into the outdoor unit 1 flows to the accumulator 14 owing to the refrigerant flow path switching device 11 and is sucked into the compressor 10.

[0094] Meanwhile, the controller 30 controls the opening degree of the second expansion device 41 such that

superheat (degree of superheat) obtained on the basis of the difference between the temperature detected by the fifth temperature detection device 65 and the temperature detected by the sixth temperature detection device 66. In addition, the controller 30 controls the opening degree of a second valve device 71 such that flow of the refrigerant during the cooling operation mode is not blocked. By also closing the bypass valve device 15, bypassing unwanted refrigerant is inhibited.

[0095] Next, operation of the heat medium side circuit during the cooling operation mode will be described.

[0096] First, the heat medium discharged by the pump 62 for circulating the heat medium in the heat medium circuit flows into the heat medium heat exchanger 61 and is cooled by receiving cooling energy from the low-temperature and low-pressure gas refrigerant flowing in the refrigerant side circuit. The cooled heat medium is adjusted by the heat medium flow control devices 63a and 63b into a flow rate corresponding to a heat load required by each of the indoor units 2a and 2b, and flows out from the heat medium relay device 60.

[0097] The heat medium having flowed out from the heat medium relay device 60 flows through the heat medium pipes 64a and 64b into the indoor units 2a and 2b and exchanges heat with indoor air at the load side heat exchangers 40a and 40b to be heated, thereby cooling the indoor air. Meanwhile, the heat medium heated by the indoor air flows out from the indoor units 2a and 2b, flows through the heat medium pipes 64a and 64b into the heat medium relay device 60 again, and is sucked into the pump 62.

[0098] Meanwhile, the controller 30 controls the pump 62 such that the temperature difference between the temperature detected by the seventh temperature detection device 67 and the temperature detected by the eighth temperature detection device 68 becomes a predetermined value. By so controlling, it is possible to supply cooling energy corresponding to heat loads that have been generated in the indoor units 2a and 2b, so that it is possible to reduce energy consumption.

[0099] The controller 30 also controls the opening degrees of the heat medium flow control devices 63a and 63b such that the temperature differences between the temperatures detected by the second temperature detection devices 50a and 50b and the temperatures detected by the third temperature detection devices 51a and 51b each become a predetermined value. By so controlling, it is possible to supply cooling energy corresponding to heat loads that have been generated in the respective indoor units 2a and 2b, so that it is possible to reduce energy consumption.

[Heating operation mode]

[0100] Fig. 11 is a refrigerant circuit diagram showing flow of the refrigerant and the heat medium during the heating operation mode of the air-conditioning apparatus according to Embodiment 5 of the present invention. Fig.

11 illustrates the heating operation mode in the case where heating energy loads have been generated in the load side heat exchangers 40a and 40b, solid arrows in the drawing indicate the direction of flow of the refrigerant, and broken arrows indicate the direction of flow of the heat medium.

[0101] During the heating operation mode, the low-temperature and low-pressure refrigerant is compressed into high-temperature, high-pressure gas refrigerant by the compressor 10 and discharged therefrom. The high-temperature, high-pressure gas refrigerant discharged from the compressor 10 flows out from the outdoor unit 1 owing to the refrigerant flow path switching device 11, and flows through the refrigerant main pipe 5 into the heat medium relay device 60. The high-temperature, high-pressure gas refrigerant flowing into the heat medium relay device 60 rejects heat to the heat medium at the heat medium heat exchanger 61 to become high-pressure liquid refrigerant, and flows into the second expansion device 41. Then, the high-pressure liquid refrigerant is reduced in pressure by the second expansion device 41 into low-temperature and low-pressure two-phase gas-liquid refrigerant, then flows out from the heat medium relay device 60, and flows through the refrigerant main pipe 5 into the outdoor unit 1.

[0102] The low-temperature and low-pressure two-phase gas-liquid refrigerant flowing into the outdoor unit 1 passes through the first expansion device 13 that has been opened, removes heat from outdoor air at the heat source side heat exchanger 12 thereby to evaporate into low-temperature and low-pressure two-phase gas-liquid refrigerant having higher quality. The low-temperature and low-pressure two-phase gas-liquid refrigerant having flowed out from the heat source side heat exchanger 12 flows to the accumulator 14 owing to the refrigerant flow path switching device 11 and is separated into gas refrigerant and liquid refrigerant, and only the gas refrigerant is sucked into the compressor 10.

[0103] Meanwhile, the controller 30 controls the opening degree of the second expansion device 41 such that subcooling (degree of supercooling) obtained on the basis of the difference between the saturated liquid temperature of the refrigerant calculated from the pressure detected by the first pressure detection device 20 and the temperature detected by the sixth temperature detection device 66 is constant.

[0104] In the case where the first expansion device 13 is a device whose opening degree is adjustable such as an electronic expansion valve, the opening degree of the first expansion device 13 during the heating operation mode is set to such an opening degree that the operating state (for example, heating capacity, etc.) of the refrigeration cycle is not adversely affected (for example, full opening). In addition, the second valve device 71 is opened such that flow of the refrigerant is not blocked. By also closing the bypass valve device 15, bypassing unwanted refrigerant is inhibited.

[0105] Next, operation of the heat medium side circuit

during the heating operation mode will be described.

[0106] First, the heat medium discharged by the pump 62 for circulating the heat medium in the heat medium circuit flows into the heat medium heat exchanger 61 and is heated by receiving heating energy from the high-temperature refrigerant flowing in the refrigerant side circuit. Thereafter, the heated heat medium is adjusted by the heat medium flow control device 63 into a flow rate corresponding to a heat load required by each of the indoor units 2a and 2b, and flows out from the heat medium relay device 60.

[0107] The heat medium having flowed out from the heat medium relay device 60 flows through the heat medium pipes 64a and 64b into the indoor units 2a and 2b and exchanges heat with indoor air at the load side heat exchangers 40a and 40b to be cooled, thereby heating the indoor air. Meanwhile, the heat medium cooled by the indoor air flows out from the indoor units 2a and 2b, flows through the heat medium pipes 64a and 64b into the heat medium relay device 60 again, and is sucked into the pump 62.

[0108] Meanwhile, the controller 30 controls the pump 62 such that the temperature difference between the temperature detected by the seventh temperature detection device 67 and the temperature detected by the eighth temperature detection device 68 becomes a predetermined value. By so controlling, it is possible to supply cooling energy corresponding to heat loads that have been generated in the indoor units 2a and 2b, so that it is possible to reduce energy consumption.

[0109] The controller 30 also controls the opening degree of the heat medium flow control device 63 such that the temperature differences between the temperatures detected by the second temperature detection devices 50a and 50b and the temperatures detected by the third temperature detection devices 51a and 51b each become a predetermined value. By so controlling, it is possible to supply cooling energy corresponding to heat loads that have been generated in the respective indoor units 2a and 2b, so that it is possible to reduce energy consumption.

[0110] Next, the pump-down function of the controller 30 in Embodiment 5 will be described.

[0111] For example, similar to Embodiment 3, when refrigerant leakage is detected by the refrigerant leakage detector during the heating operation mode, the controller 30 switches the refrigerant flow path switching device 11 to the flow path for the cooling operation mode. When the refrigerant leakage is detected during the cooling operation, switching of the refrigerant flow path switching device 11 is not performed, and the current state is maintained. In addition, when refrigerant leakage is detected by the refrigerant leakage detector, the second valve device 71 changes from an opened state to a closed state.

[0112] Next, the controller 30 sets the frequency of the compressor 10 to a predetermined value, and opens the bypass valve device 15 and also fully closes the first expansion device 13. Then, the controller 30 fully closes

the second expansion device 41 and sets the rotation speed of the outdoor fan 16 to a predetermined value.

[0113] At this time, a pump-down operation is performed in which the refrigerant in the refrigerant main pipe 5 that connects the outdoor unit 1 and the second expansion device 41 in a closed state and the outdoor unit 1 and the second valve device 71 in a closed state, and in the refrigerant branch pipes 3a, 3b, and 3c is collected in the heat source side heat exchanger 12 and the accumulator 14.

[0114] When the pump-down operation is performed, the controller 30 determines an end state of the pump-down operation by using the detection value of either the first pressure detection device 20 or the second pressure detection device 21. The controller 30 ends the pump-down operation when the pressure (detection value) detected by the first pressure detection device 20 is equal to or greater than a first threshold or the pressure (detection value) detected by the second pressure detection device 21 is equal to or less than a second threshold.

[0115] The end state of the pump-down operation is determined using the detection value of either the first pressure detection device 20 or the second pressure detection device 21, but the pump-down operation may be ended when the pressure (detection value) detected by the first pressure detection device 20 is equal to or greater than the first threshold and the pressure (detection value) detected by the second pressure detection device 21 is equal to or less than the second threshold.

[0116] Regarding the determination for ending the pump-down operation, the pump-down operation may be ended when a predetermined time has elapsed from start of the pump-down operation.

[0117] When end of the pump-down operation is confirmed, the controller 30 fully closes the bypass valve device 15, switches the refrigerant flow path switching device 11 to the flow path for the heating operation mode, and finally stops the compressor 10.

[0118] By fully closing the bypass valve device 15, switching the refrigerant flow path switching device 11 to the flow path for the heating operation mode, and stopping the compressor 10 as described above, it is possible to enclose the refrigerant collected in the heat source side heat exchanger 12 and the accumulator 14 by the above-described pump-down operation, in the outdoor unit 1. Accordingly, the collected refrigerant does not move to the heat medium relay device 60 side, and thus the amount of the refrigerant leaking to the space in which the heat medium relay device 60 is provided is reduced, and the safety improves.

[0119] When refrigerant leakage is detected by the refrigerant leakage detection device, the controller 30 closes the second expansion device 41 and also closes the second valve device 71. Thus, it is also possible to inhibit leakage of the refrigerant to the space in which the heat medium relay device 60 is provided.

[0120] Since the heat medium relay device 60 is present between the outdoor unit 1 and the indoor units

2a and 2b, an valve device does not have to be provided at each of the refrigerant branch pipes connected to the front and the rear of the indoor units 2b and 2c. Thus, it is possible to reduce the number of used valve devices, and it is possible to provide an inexpensive air-conditioning system.

[0121] In the air-conditioning systems described in Embodiment 1 to Embodiment 4, the two-phase gas-liquid refrigerant flows into the indoor units 2a, 2b, and 2c provided in the indoor spaces or in the vicinities of the indoor spaces, so that there is a problem that loud sound is likely to occur, for example, when the refrigerant passes through the second expansion device 41.

[0122] On the other hand, with the configuration as described in Embodiment 5, it is possible to locate a noise occurrence source at a distance away from the indoor space, and it is also possible to reduce a risk of refrigerant leakage to the indoor space since the heat medium flows in the indoor units 2a and 2b and the refrigerant does not flows therein.

[0123] In the air-conditioning apparatus 100 using the heat medium, it is possible to reduce the amount of the used refrigerant by an amount corresponding to the refrigerant branch pipes connected to the indoor units 2a and 2b. In addition, since the amount of the entire refrigerant used in the air-conditioning apparatus 100 is reduced, the risk involved when refrigerant leakage occurs in the heat medium relay device 60 can be reduced.

[0124] In Embodiment 5, the controller 30 provided in the outdoor unit 1 is used to control the actuator provided in the heat medium relay device 60, but the present invention is not limited thereto. For example, another controller may be provided in the heat medium relay device 60 to control the actuator, or a controller provided in a unit of the indoor units 2a and 2b, a remote controller, or another device may be used to control the actuator.

[0125] Fig. 9 shows an example in which the air-conditioning apparatus 100 according to Embodiment 4 is changed to an air-conditioning system using a heat medium, but an air-conditioning apparatus 100 similarly having improved noise reduction and safety is obtained even when any of the air-conditioning apparatuses 100 according to Embodiment 1 to Embodiment 3 is changed to an air-conditioning system using a heat medium.

[0126] In the air-conditioning apparatuses 100 according to Embodiment 3 to Embodiment 5 described above, the bypass pipe 6 and the bypass valve device 15 are located in the outdoor unit 1, but the present invention is not limited thereto. The bypass pipe 6 and the bypass valve device 15 may be provided outside the outdoor unit 1, and it is possible to achieve the same advantageous effects as described above.

[0127] The case where the number of outdoor units 1 is one has been described as an example in Embodiment 1 to Embodiment 5, but the number of outdoor units 1 is not limited to one. A plurality of outdoor units may perform the operation specified in each Embodiment, and it is possible to achieve the same advantageous effects.

[0128] Regarding an air-conditioning system in which a plurality of indoor units are connected, Embodiment 1 to Embodiment 5 may be applied not only to an air-conditioning system in which all connected indoor units perform cooling or heating operation, but also to an air-conditioning system in which cooling operation and heating operation are simultaneously performed in accordance with indoor units.

[0129] In Embodiment 1 to Embodiment 5, the case where one compressor 10 is connected to the outdoor unit 1 has been described as an example, but an outdoor unit 1 in which two or more compressors 10 are connected may be provided. Reference Signs List

[0130] 1 outdoor unit 2a, 2b, 2c indoor unit 3a, 3b, 3c refrigerant branch pipe, 4 refrigerant pipe 5 refrigerant main pipe 6 bypass pipe 10 compressor 11 refrigerant flow path switching device 12 heat source side heat exchanger 13 first expansion device 14 accumulator 15 bypass valve device 16 outdoor fan 20 first pressure detection device 21 second pressure detection device 22 first temperature detection device 23 third pressure detection device 30 controller 40a, 40b, 40c load side heat exchanger 41, 41a, 41b, 41c second expansion device 42a, 42b, 42c indoor fan 50a, 50b, 50c second temperature detection device 51a, 51b, 51c third temperature detection device 52a, 52b, 52c fourth temperature detection device 60 heat medium relay device 61 heat medium heat exchanger 62 pump 63a, 63b heat medium flow control device 64, 64a, 64b heat medium pipe 65 fifth temperature detection device 66 sixth temperature detection device 67 seventh temperature detection device 68 eighth temperature detection device 70a, 70b, 70c first valve device 71, 71a, 71b, 71c second valve device 100 air-conditioning apparatus

Claims

1. An air-conditioning apparatus comprising:

an outdoor unit and an indoor unit, the outdoor unit having at least a compressor, a refrigerant flow path switching device, a heat source side heat exchanger, and a first expansion device, the indoor unit having at least a load side heat exchanger and a second expansion device, the compressor, the refrigerant flow path switching device, the heat source side heat exchanger, the first expansion device, the load side heat exchanger and the second expansion device being connected by refrigerant pipes to form a refrigerant circuit a first valve device provided at a refrigerant pipe of the refrigerant pipes, the refrigerant pipe connecting between the first expansion device and the second expansion device;

a second valve device provided at a refrigerant pipe of the refrigerant pipes, the refrigerant pipe

- connecting between the refrigerant flow path switching device and the load side heat exchanger; and
 a controller configured to control the first expansion device during a cooling operation mode to expand, into a two-phase gas-liquid state, refrigerant flowing through the first expansion device to the refrigerant pipe between the first expansion device and the second expansion device, wherein
 the first valve device and the second valve device are closed when leakage of the refrigerant is detected.
2. The air-conditioning apparatus of claim 1, wherein a plurality of the indoor units are connected to the outdoor unit, and the first valve device and the second valve device are provided for each of the indoor units.
3. The air-conditioning apparatus of claim 1, wherein a plurality of the indoor units are connected to the outdoor unit, and the second valve device is provided at a shared refrigerant path shared among at least some of the plurality of the indoor units.
4. The air-conditioning apparatus of claim 3, wherein the first valve device is provided at a shared refrigerant path shared among at least some of the plurality of the indoor units.
5. The air-conditioning apparatus of any one of claims 1 to 4, wherein the first valve device and the second valve device are provided at such positions that a refrigerant concentration during assumed refrigerant leakage is less than a predetermined value, the refrigerant concentration during assumed refrigerant leakage being calculated from
 a sum of a weight of the refrigerant in the indoor unit connected to the outdoor unit and a weight of the refrigerant calculated from a diameter of part of the refrigerant pipe of the refrigerant pipes, the refrigerant pipe being connected to the indoor unit, and
 a volume of an indoor space having a smallest volume from among indoor spaces that are air-conditioned by a plurality of indoor units.
6. The air-conditioning apparatus of any one of claims 1 to 5, further comprising:
 an accumulator provided at a suction side of the compressor;
 a bypass pipe branching from the refrigerant pipe between the first expansion device and the second expansion device during a cooling operation mode and connected to a refrigerant pipe of the refrigerant pipes, the refrigerant pipe connecting between the refrigerant flow path switching device and the accumulator; and
 a bypass valve device provided at the bypass pipe, wherein
 the controller is configured to perform a pump-down operation using both or either one of the first expansion device and the bypass valve device when refrigerant leakage occurs.
7. The air-conditioning apparatus of claim 6, wherein the controller is configured to, when performing the pump-down operation, switch the refrigerant flow path switching device to a direction for the cooling operation mode, fully close the first expansion device or change an opening degree of the first expansion device to an opening degree close to full closing, open the bypass valve device, and operate the compressor.
8. The air-conditioning apparatus of claim 6 or 7, wherein
 the outdoor unit has a fan increasing an amount of heat exchanged in the heat source side heat exchanger, and
 the controller is configured to set a rotation speed of the fan to a maximum value or a value close to the maximum value during the pump-down operation.
9. The air-conditioning apparatus of any one of claims 6 to 8, further comprising both or any one of a first pressure detection device detecting a pressure at a discharge side of the compressor and a second pressure detection device detecting a pressure at the suction side of the compressor, wherein
 the controller is configured to end the pump-down operation when the pressure detected by the first pressure detection device is equal to or greater than a first threshold and the pressure detected by the second pressure detection device is equal to or less than a second threshold, or when the pressure detected by the first pressure detection device is equal to or greater than the first threshold or the pressure detected by the second pressure detection device is equal to or less than the second threshold.
10. The air-conditioning apparatus of claim 9, wherein the controller is configured to, when ending the pump-down operation, switch the refrigerant flow path switching device to a direction for a heating operation mode and make the bypass valve device into a full closing state or a state close to full closing.
11. The air-conditioning apparatus of any one of claims 7 to 10, wherein
 only the second valve device, from among the first valve device and the second valve device, is provided, and
 the controller is configured to, when performing the

pump-down operation, fully close the second expansion device.

12. The air-conditioning apparatus of any one of claims 1 to 11, comprising a heat medium heat exchange device forming a refrigerant circuit with the outdoor unit in place of the indoor unit and forming a heat medium cycle circuit with the indoor unit having the load side heat exchanger, wherein the heat medium heat exchange device includes

a heat medium heat exchanger exchanging heat between the refrigerant flowing in the refrigerant circuit and the heat medium flowing in the heat medium cycle circuit, and a pump configured to transfer the heat medium in the heat medium cycle circuit to the load side heat exchanger and circulate the heat medium.

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FIG. 1

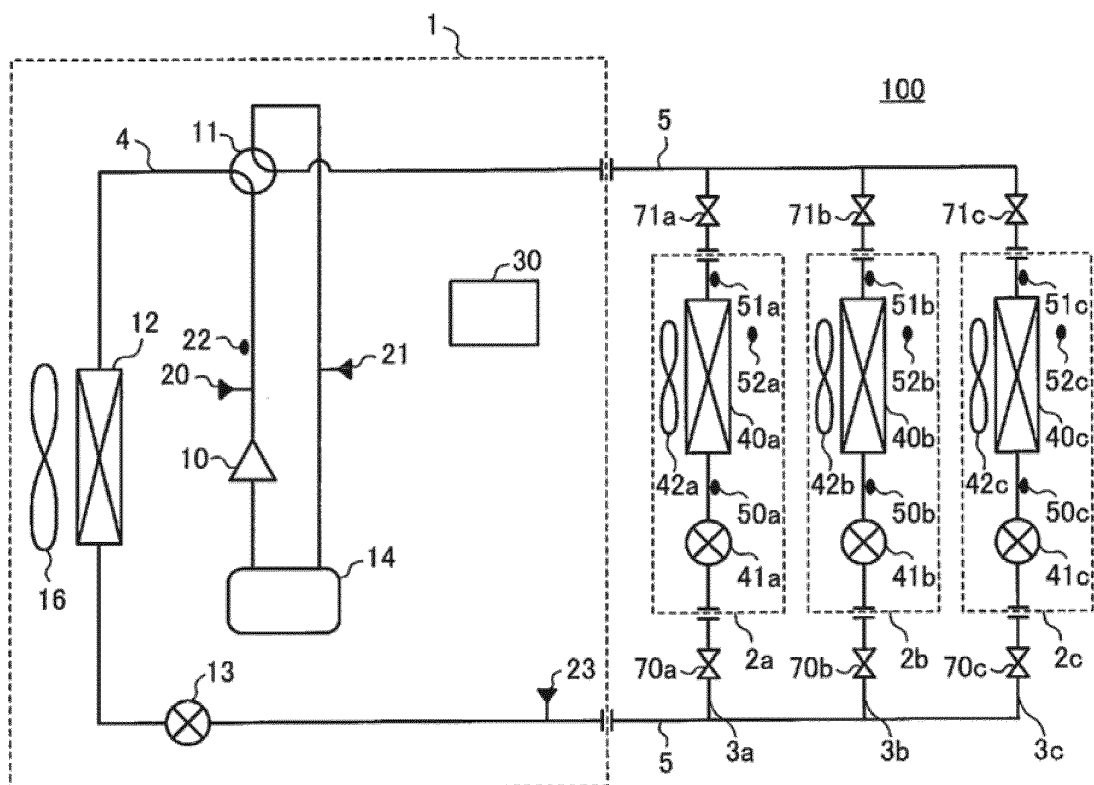


FIG. 2

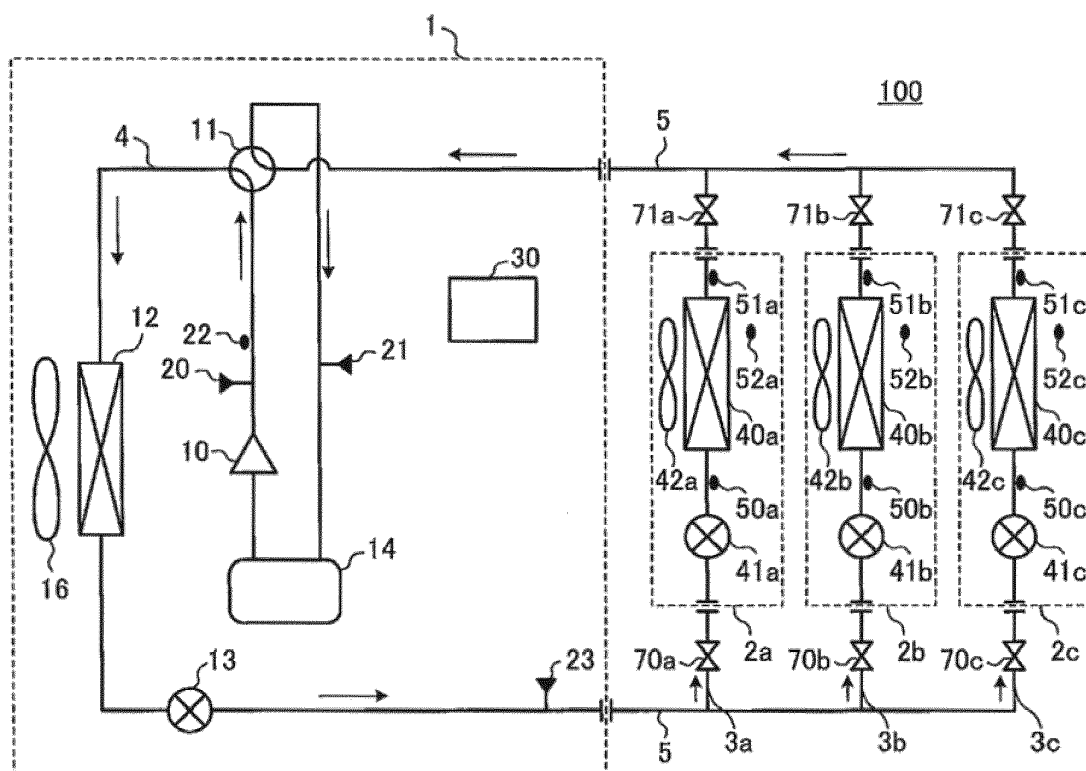


FIG. 3

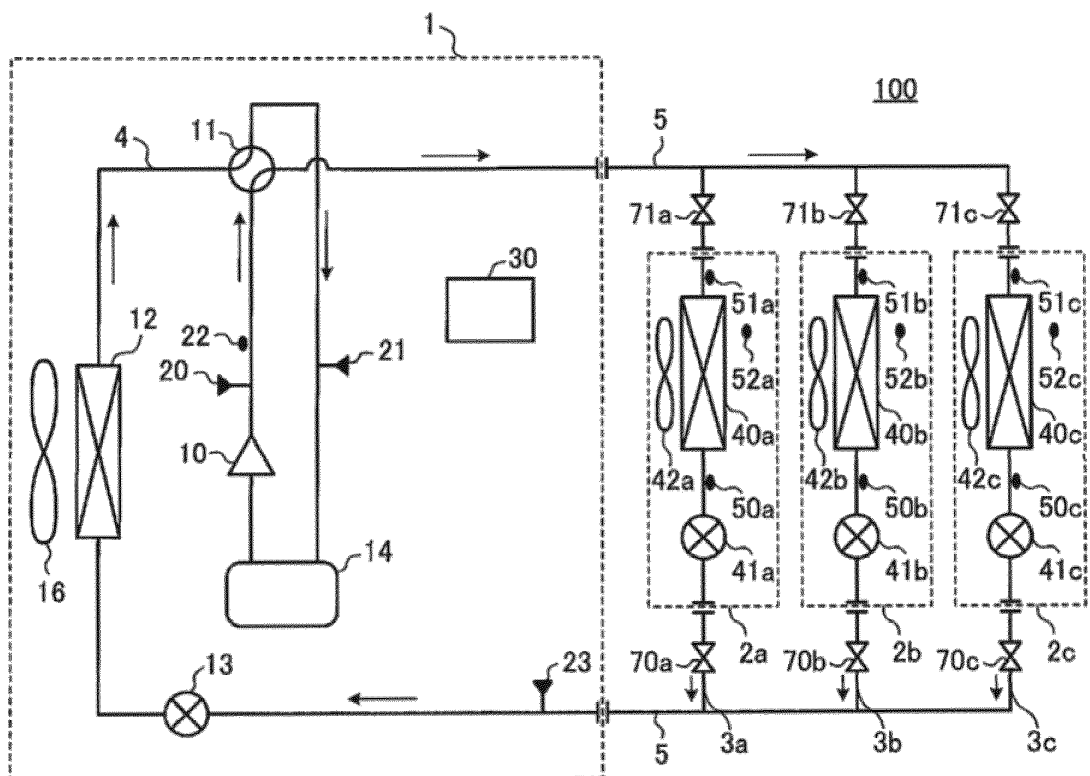


FIG. 4

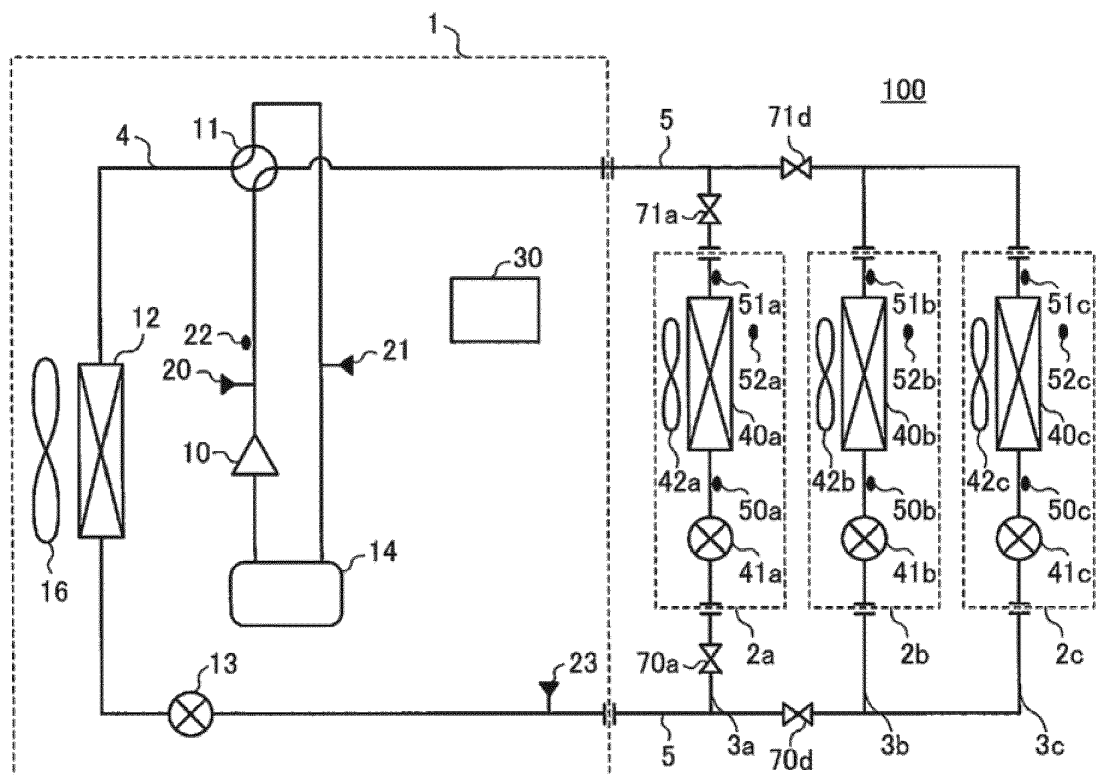


FIG. 5

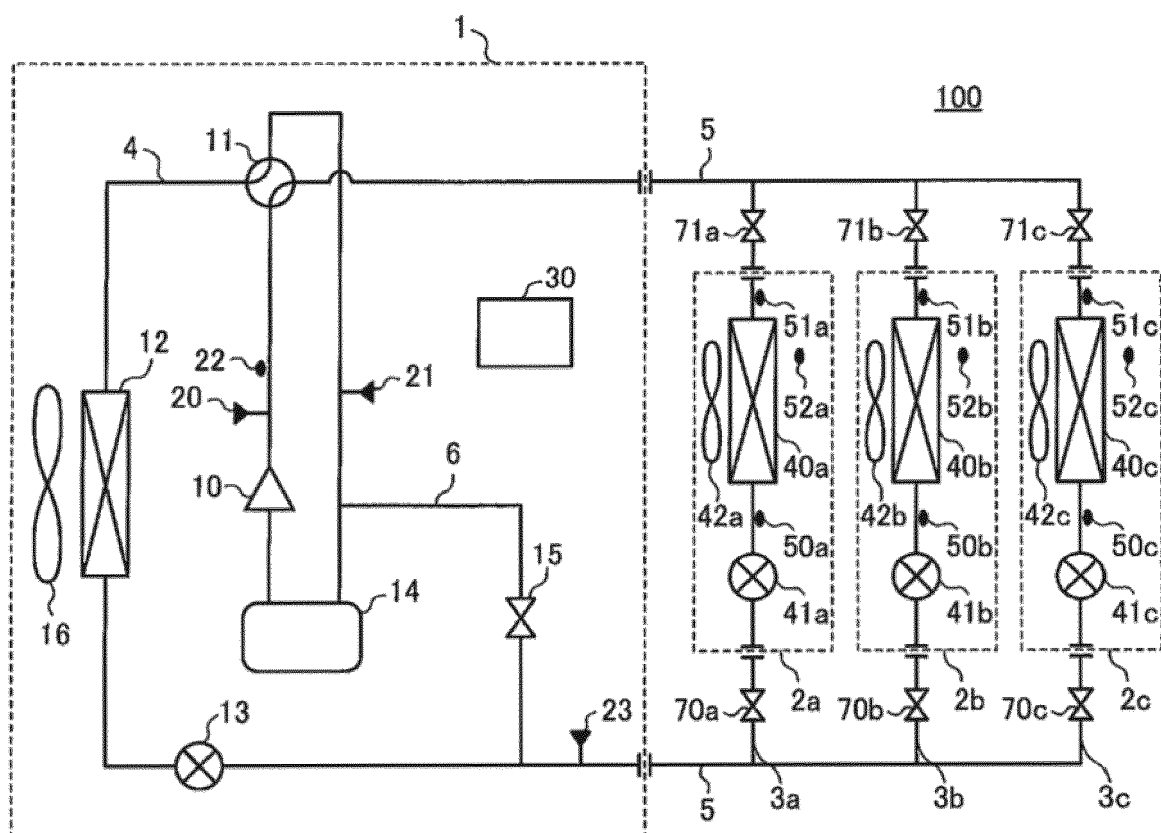


FIG. 6

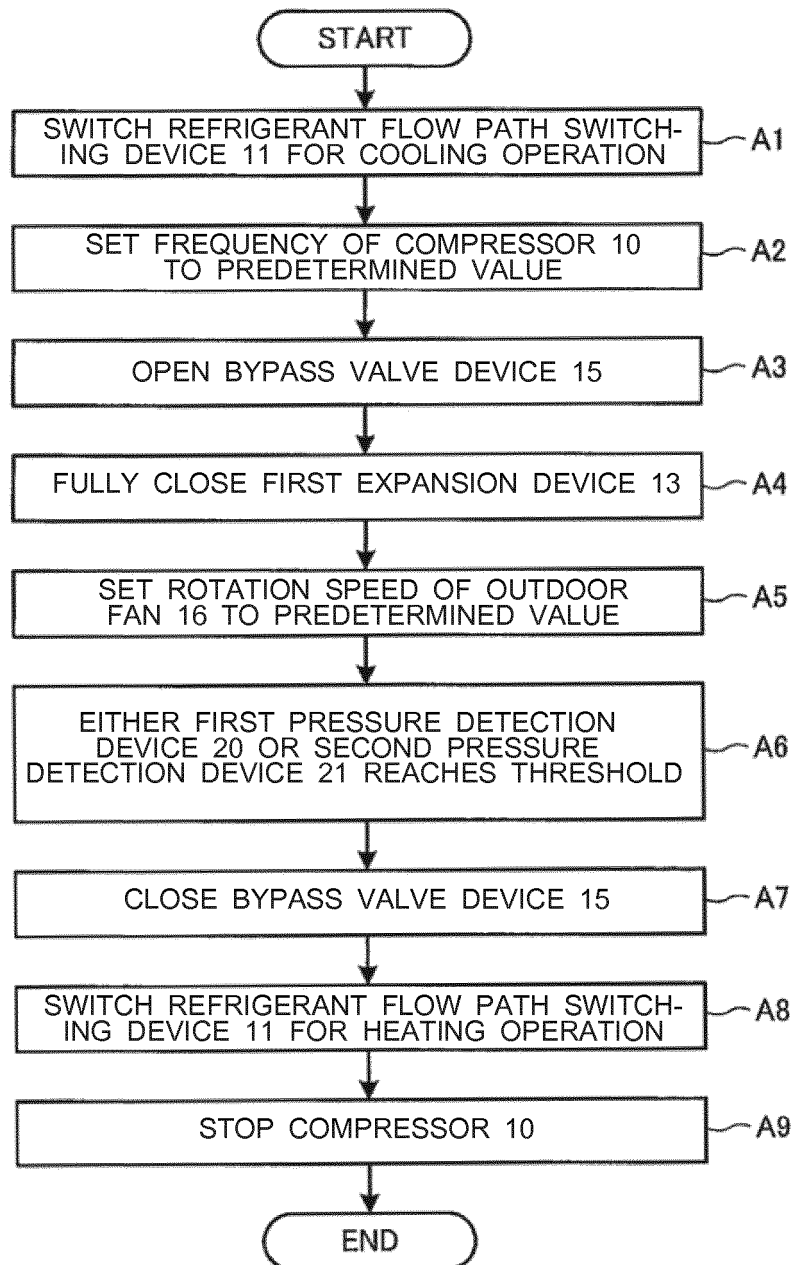


FIG. 7

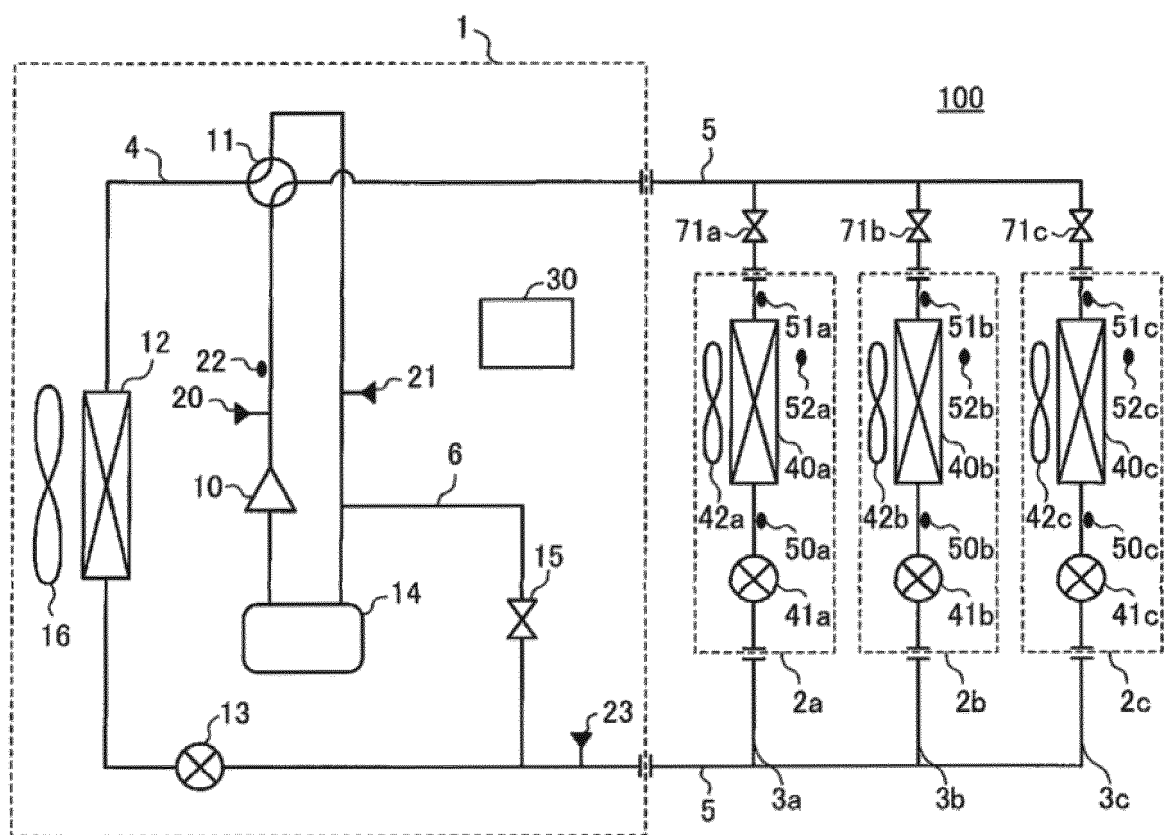


FIG. 8

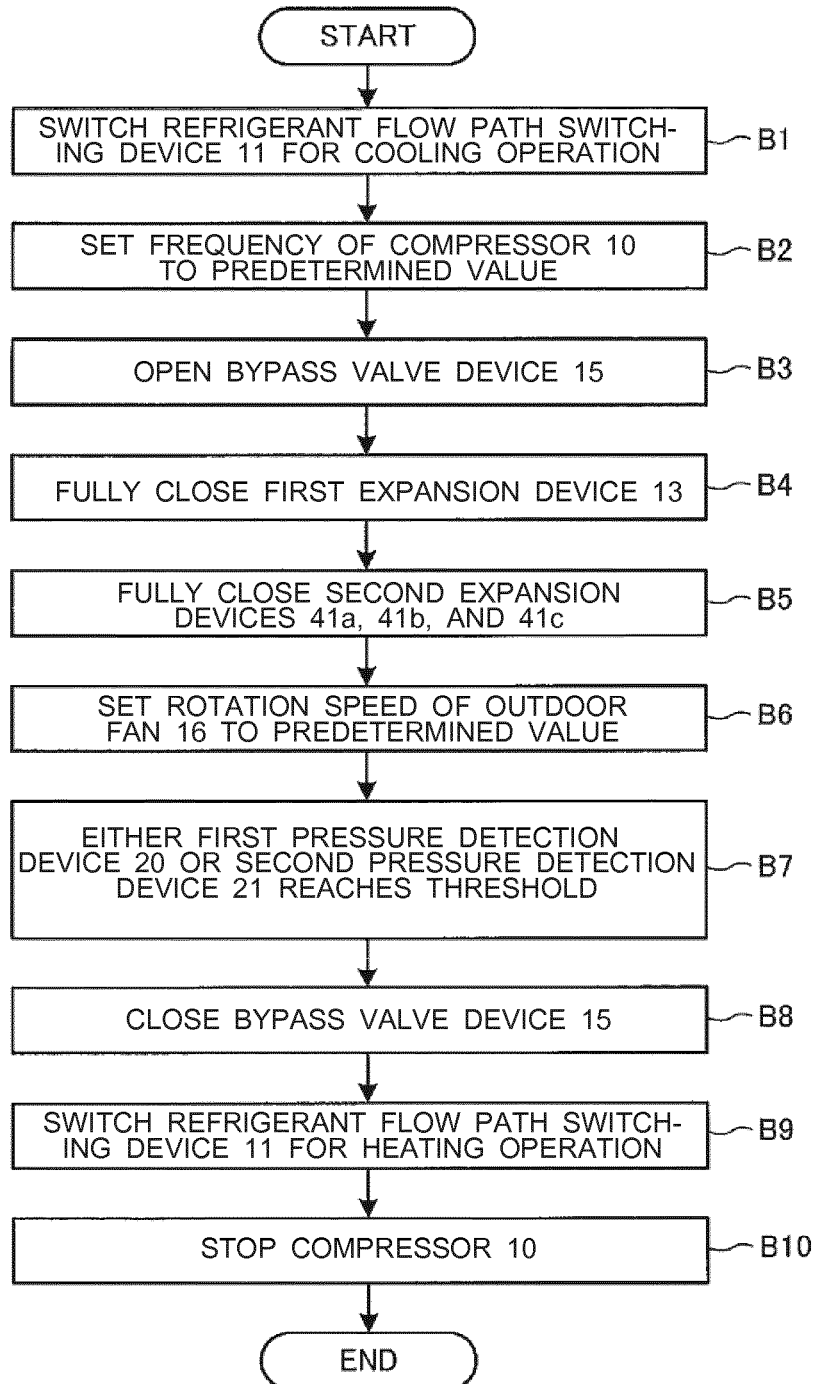


FIG. 9

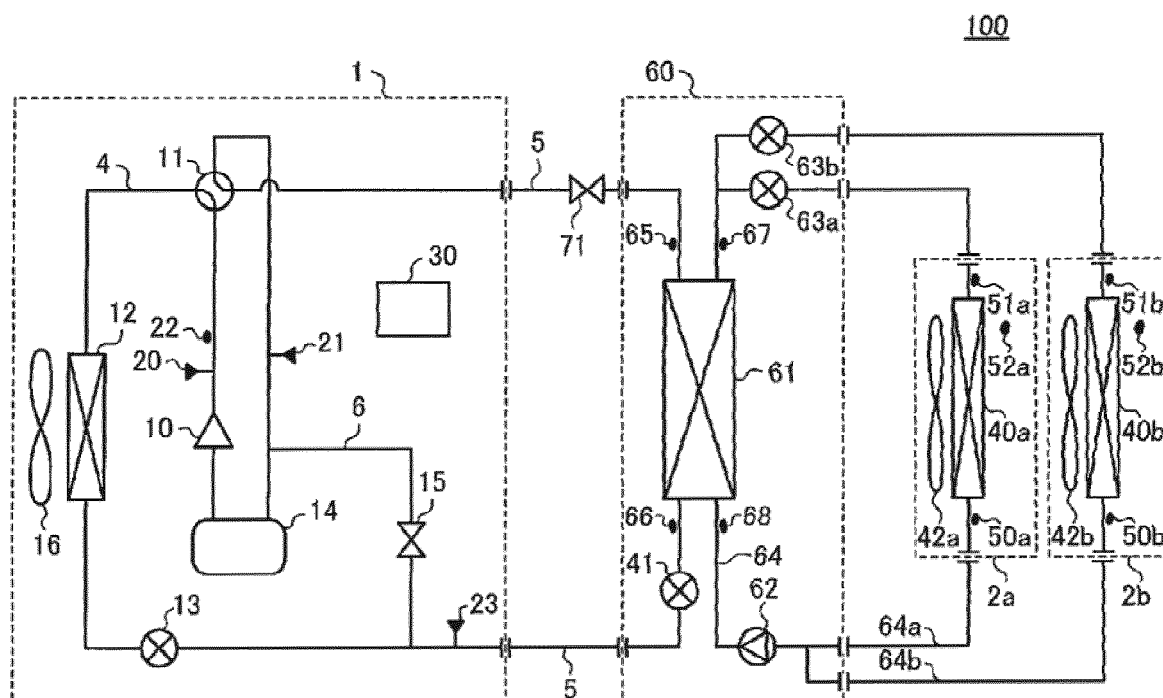


FIG. 10

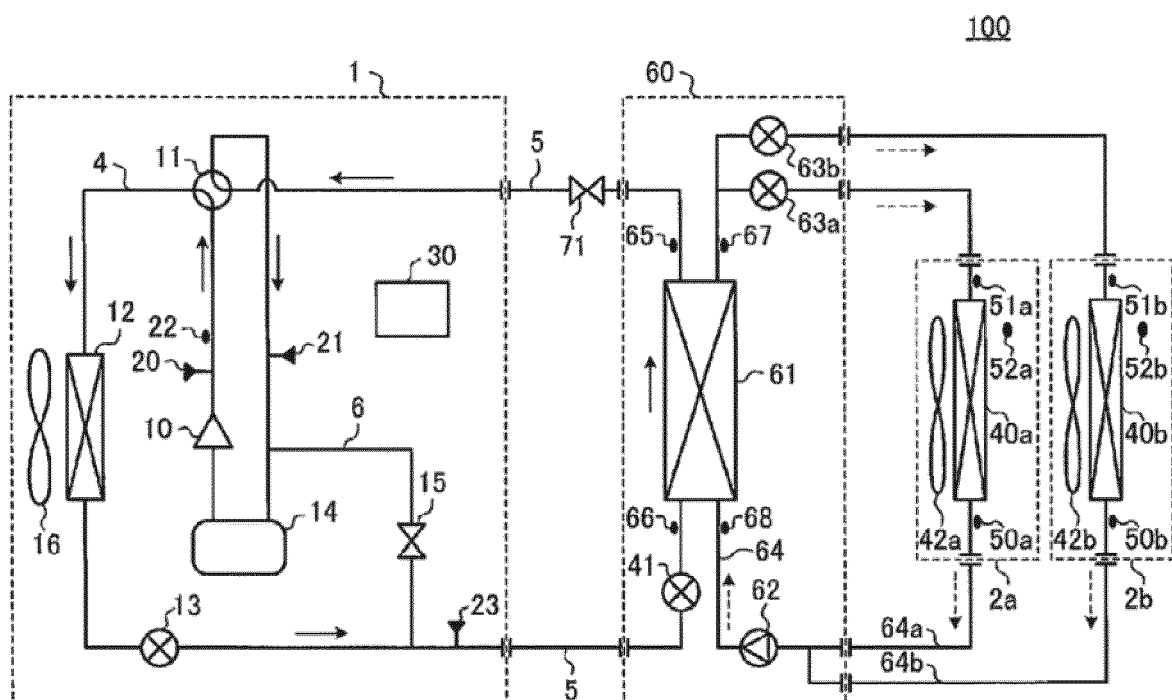
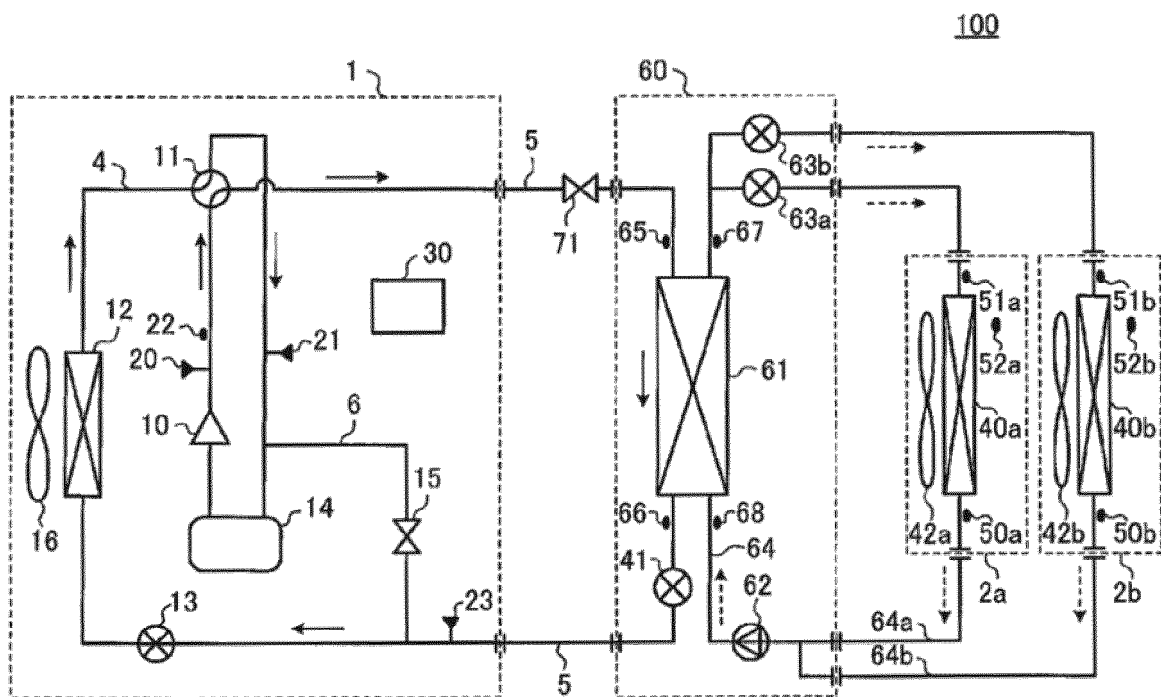


FIG. 11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/065326

A. CLASSIFICATION OF SUBJECT MATTER

F25B49/02(2006.01)i, F24F11/02(2006.01)i, F25B1/00(2006.01)i, F25B13/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B49/02, F24F11/02, F25B1/00, F25B13/00

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 1996-2016

Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2014/118953 A1 (Mitsubishi Electric Corp.), 07 August 2014 (07.08.2014), claims; paragraphs [0015] to [0016], [0026]; fig. 1, 6 & GB 2525791 A	1-9, 11-12 10
Y	JP 02-052967 A (Sanyo Electric Co., Ltd.), 22 February 1990 (22.02.1990), claims; fig. 1 to 2 (Family: none)	1-2, 6-9, 11-12
Y	WO 2011/099063 A1 (Mitsubishi Electric Corp.), 18 August 2011 (18.08.2011), claims; fig. 1, 7 & US 2012/0272672 A1 & EP 2535653 A1 & CN 102753898 A	1-4, 6-9, 11-12

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

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Date of the actual completion of the international search
28 July 2016 (28.07.16)

Date of mailing of the international search report
09 August 2016 (09.08.16)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/065326

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2011/099058 A1 (Mitsubishi Electric Corp.), 18 August 2011 (18.08.2011), claims; paragraphs [0053], [0134] to [0137]; fig. 1, 7 (Family: none)	1-9, 11-12
Y	WO 2012/160598 A1 (Mitsubishi Electric Corp.), 29 November 2012 (29.11.2012), claims; paragraphs [0054] to [0081]; fig. 2, 9 & US 2014/0033754 A1 & GB 2504036 A	1, 3-9, 11-12
Y	WO 2016/017643 A1 (Mitsubishi Electric Corp.), 04 February 2016 (04.02.2016), claims; paragraphs [0061] to [0066]; fig. 8A (Family: none)	1, 3-4, 6-9, 11-12
Y	WO 2012/098584 A1 (Mitsubishi Electric Corp.), 26 July 2012 (26.07.2012), claims; fig. 2 & US 2013/0227977 A1 & EP 2631571 A1	1, 3-9, 11-12
Y	JP 2013-122364 A (Mitsubishi Electric Corp.), 20 June 2013 (20.06.2013), claims; paragraphs [0033] to [0038], [0103]; fig. 1, 18 (Family: none)	6-9, 11
Y	JP 2015-206518 A (Daikin Industries, Ltd.), 19 November 2015 (19.11.2015), paragraphs [0082] to [0087]; fig. 1, 3 (Family: none)	8
A	JP 2012-013339 A (Hitachi Appliances, Inc.), 19 January 2012 (19.01.2012), entire text; all drawings (Family: none)	1-12
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A	WO 2015/152163 A1 (Mitsubishi Electric Corp.), 08 October 2015 (08.10.2015), entire text; all drawings (Family: none)	1-12

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REFERENCES CITED IN THE DESCRIPTION

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