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heat source-side heat exchanger acts as an evaporator. The control unit includes a first controller that, in response to detection of refrigerant leakage by the leakage detection unit, switches the flow switching device to connect the discharge side of the compressor with the heat source-side heat exchanger, closes the expansion unit, and opens the bypass opening and closing device, and a second controller that, after the end of operation of the first controller, switches the flow switching device to connect the discharge side of the compressor with the load-side heat exchanger, and stops the compressor.

The diagram illustrates a control system for a refrigeration cycle. It consists of the following components and connections:

- 31**: DISCHARGE PRESSURE DETECTION UNIT
- 32**: SUCTION PRESSURE DETECTION UNIT
- 40**: FIRST CONTROLLER
- 41**: SECOND CONTROLLER
- 14a, 14b**: EXPANSION UNIT
- 11**: FLOW SWITCHING DEVICE
- 21**: BYPASS OPENING AND CLOSING DEVICE
- 13**: HEAT SOURCE-SIDE AIR-SENDING DEVICE
- 10**: COMPRESSOR

Connections:

- Units **31** and **32** are connected to both controllers **40** and **41**.
- Controller **40** is connected to units **14a, 14b**, **11**, **21**, **13**, and **10**.
- Controller **41** is connected to units **11**, **21**, **13**, and **10**.

Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus that reduces leakage of refrigerant into the indoor space.

Background Art

[0002] Known examples of existing air-conditioning apparatuses include building multi-air-conditioning apparatuses having a plurality of indoor units connected to an outdoor unit. For air-conditioning apparatuses such as building multi-air-conditioning apparatuses, the total length of the refrigerant pipe that connects the outdoor unit with each indoor unit is as long as several hundreds of meters in some cases. Consequently, the refrigerant pipe of such an air-conditioning apparatus tends to be filled with an extremely large amount of refrigerant. In this case, leakage of refrigerant out of such an air-conditioning apparatus may cause, for example, a large amount of refrigerant to flow out into a single room.

[0003] In recent years, from the viewpoint of preventing global warming, there has been a growing demand for replacing refrigerants traditionally used in air-conditioning apparatuses by refrigerants with low global warming potentials. Refrigerants with low global warming potentials tend to have flammability. Consequently, as refrigerants traditionally used in air-conditioning apparatuses will increasingly be replaced by refrigerants with low global warming potentials for years to come, further attention will need to be paid to safety. With a view to reducing leakage of refrigerant into the indoor space upon detection of refrigerant leakage, Patent Literature 1 discloses an air-conditioning apparatus including a flow cutoff device that cuts off the flow of refrigerant, and refrigerant leakage detection device that detects refrigerant leakage. According to Patent Literature 1, when refrigerant leakage is detected by the refrigerant leak detection device, an electromagnetic expansion valve provided to the outdoor unit is closed, and refrigerant flowing in the indoor unit is collected into the outdoor unit. Then, the flow cutoff device is closed to thereby hold the refrigerant in the outdoor unit. Patent Literature 1 employs the above-mentioned configuration in an attempt to reduce leakage of refrigerant into the indoor space.

Citation List

Patent Literature

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

Summary of Invention

Technical Problem

[0005] With the air-conditioning apparatus as disclosed in Patent Literature 1, if an accumulator is disposed at the suction side of the compressor, even when the electromagnetic expansion valve is closed, refrigerant flowing in the indoor unit is mainly collected into an outdoor heat exchanger located upstream of the electromagnetic expansion valve, rather than into the accumulator. Generally, the accumulator has a greater volume for storing refrigerant than the outdoor heat exchanger. For this reason, it is not possible to sufficiently collect refrigerant flowing in the indoor unit without utilizing the volume of the accumulator. It is thus desired to make full use of the volume of the accumulator in collecting refrigerant.

[0006] The present invention has been made to solve the above-mentioned problem, and provides an air-conditioning apparatus that makes full use of the volume of the accumulator in collecting refrigerant.

Solution to Problem

[0007] An air-conditioning apparatus according to an embodiment of the present invention includes a circuit formed by connecting, by a pipe, a compressor that compresses refrigerant, a flow switching device, a heat source-side heat exchanger, an expansion unit, a load-side heat exchanger, and an accumulator, a bypass pipe that connects a position between the heat source-side heat exchanger and the expansion unit, with the upstream side of the accumulator, a bypass opening and closing device provided to the bypass pipe to control a flow rate of refrigerant flowing in the bypass pipe, a leakage detection unit that detects refrigerant leakage, and a control unit that switches the flow switching device to switch between a cooling operation and a heating operation, the cooling operation being an operation in which the heat source-side heat exchanger acts as a condenser, the heating operation being an operation in which the heat source-side heat exchanger acts as an evaporator. The control unit includes a first controller that, in response to detection of refrigerant leakage by the leakage detection unit, switches the flow switching device to connect the discharge side of the compressor with the heat source-side heat exchanger, closes the expansion unit, and opens the bypass opening and closing device, and a second controller that, after operation of the first controller ends, switches the flow switching device to connect the discharge side of the compressor with the load-side heat exchanger, and stops the compressor.

Advantageous Effects of Invention

[0008] According to an embodiment of the present invention, the first controller switches the flow switching

device to change the flow of refrigerant to the flow of refrigerant in cooling operation, closes the expansion unit, and opens the bypass opening and closing device. Consequently, refrigerant flowing in the indoor unit is collected into the accumulator. Subsequently, the second controller switches the flow switching device to change the flow of refrigerant to the flow of refrigerant in heating operation. This causes the upstream side of the accumulator to be connected with the heat source-side heat exchanger. This ensures that refrigerant does not flow toward the load-side heat exchanger from the upstream side of the accumulator. Further, the second controller stops the compressor. This ensures that refrigerant does not pass through the compressor from the downstream side of the accumulator. Consequently, a large amount of refrigerant can be trapped mainly within the accumulator. The above-mentioned configuration makes it possible to make full use of the volume of the accumulator in collecting refrigerant.

Brief Description of Drawings

[0009]

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

Fig. 2 is a block diagram illustrating a control unit 40 of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention.

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

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

Fig. 5 is a flowchart illustrating operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention.

Fig. 6 is a flowchart illustrating operation of a first controller 41 during cooling operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention.

Fig. 7 is a flowchart illustrating operation of a second controller 42 of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention.

Fig. 8 is a flowchart illustrating the operation of the first controller 41 during heating operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention.

Fig. 9 is a circuit diagram illustrating an air-conditioning apparatus 100 according to a modification of Embodiment 1 of the present invention.

Fig. 10 is a circuit diagram illustrating an air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

Fig. 11 is a block diagram illustrating a control unit 240 of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

Fig. 12 is a circuit diagram illustrating the flow of refrigerant during cooling operation of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

Fig. 13 is a flowchart illustrating operation of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

Fig. 14 is a flowchart illustrating operation of a later-stage controller 241b of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention.

Fig. 15 is a circuit diagram illustrating an air-conditioning apparatus 300 according to Embodiment 3 of the present invention.

Description of Embodiments

Embodiment 1

[0010] Hereinafter, embodiments of an air-conditioning apparatus according to the present invention will be described with reference to the drawings. Fig. 1 is a circuit diagram illustrating an air-conditioning apparatus 1 according to Embodiment 1 of the present invention. The air-conditioning apparatus 1 will be described below with reference to Fig. 1. As illustrated in Fig. 1, the air-conditioning apparatus 1 includes, for example, a single outdoor unit 2 and two indoor units 3a and 3b. The outdoor unit 2 is connected with each of the two indoor units 3a and 3b by a refrigerant main pipe 8. The air-conditioning apparatus 1 is, for example, a building multi-air-conditioning apparatus that utilizes a refrigeration cycle to perform air conditioning. The air-conditioning apparatus 1 has, for example, a cooling operation mode in which the two indoor units 3a and 3b both perform cooling operation, and a heating operation mode in which the two outdoor units 2 both perform heating operation. One of these two modes is selected. Although a single outdoor unit 2 is illustrated to be provided, two or more outdoor units may be provided. Although two indoor units 3a and 3b are illustrated to be provided, a single indoor unit, or three or more indoor units may be provided.

(Outdoor Unit 2 and Indoor Units 3a and 3b)

[0011] The outdoor unit 2 is installed outdoors. The outdoor unit 2 includes a compressor 10, a flow switching device 11, a heat source-side heat exchanger 12, a heat source-side air-sending device 13, an accumulator 17, a bypass pipe 20, a bypass opening and closing device 21, a leakage detection unit 30, a discharge temperature detection unit 33, and a control unit 40. The indoor unit 3a includes an expansion unit 14a, a load-side heat exchanger 15a, a load-side air-sending device 16a, a first heat-exchange-temperature detection unit 34a, a second

heat-exchange-temperature detection unit 35a, and an indoor temperature detection unit 36a. The indoor unit 3b includes an expansion unit 14b, a load-side heat exchanger 15b, a load-side air-sending device 16b, a first heat-exchange-temperature detection unit 34b, a second heat-exchange-temperature detection unit 35b, and an indoor temperature detection unit 36b. The compressor 10, the flow switching device 11, the heat source-side heat exchanger 12, the expansion units 14a and 14b, the load-side heat exchangers 15a and 15b, and the accumulator 17 are connected by a pipe 5 to form a refrigerant circuit 4 in which refrigerant flows. The refrigerant circuit 4 corresponds to "circuit" according to the present invention.

(Compressor 10 and Flow Switching Device 11)

[0012] The compressor 10 sucks in refrigerant that is in a low-temperature, low-pressure state, compresses the sucked refrigerant into a high-temperature, high-pressure state, and discharges the resulting refrigerant. The compressor 10 is, for example, an inverter compressor whose capacity can be controlled. Two or more compressors 10 may be provided. The flow switching device 11 connects the following portions of a refrigerant pipe 7: a portion of the refrigerant pipe 7 connected to the discharge side of the compressor 10; a portion of the refrigerant pipe 7 connected to the accumulator 17; a portion of the refrigerant pipe 7 connected to the heat source-side heat exchanger 12; and a portion of the refrigerant pipe 7 connected to the refrigerant main pipe 8, which is connected to each of the load-side heat exchangers 15a and 15b. The flow switching device 11 switches the directions of refrigerant flow in the refrigerant circuit 4. The flow switching device 11 is, for example, a four-way valve. The flow switching device 11 switches whether the refrigerant discharged from the compressor 10 flows to the heat source-side heat exchanger 12 (as indicated by a solid line in Fig. 1) or to each of the load-side heat exchangers 15a and 15b (as indicated by a dashed line in Fig. 1). This switching action makes it possible to perform both cooling operation and heating operation.

(Heat Source-side Heat Exchanger 12 and Heat Source-side Air-sending Device 13)

[0013] The heat source-side heat exchanger 12 is connected to a portion of the refrigerant pipe 7 between the flow switching device 11 and each of the expansion units 14a and 14b. The heat source-side heat exchanger 12 exchanges heat between, for example, outdoor air and refrigerant. The heat source-side heat exchanger 12 acts as a condenser during cooling operation, and acts as an evaporator during heating operation. The heat source-side air-sending device 13 is a fan disposed near the heat source-side heat exchanger 12 to send outdoor air to the heat source-side heat exchanger 12. The accumu-

lator 17 is connected to a portion of the refrigerant pipe 7 located at the suction side of the compressor 10. The accumulator 17 is used to store the liquid part of the refrigerant sucked into the compressor 10 so that only the gaseous part of the refrigerant is allowed to enter the compressor 10.

(Bypass Pipe 20 and Bypass Opening and Closing Device 21)

[0014] The bypass pipe 20 is a pipe that connects a position between the heat source-side heat exchanger 12 and the expansion units 14a and 14b, with the upstream side of the accumulator 17. The bypass opening and closing device 21 is provided to the bypass pipe 20 to control the flow rate of refrigerant flowing in the bypass pipe 20. The bypass opening and closing device 21 is, for example, a solenoid valve with a non-adjustable opening degree. Alternatively, the bypass opening and closing device 21 may be an electronic expansion valve with a refrigerant passage (not illustrated) whose opening area is varied to adjust the opening degree of the bypass opening and closing device 21. Although Embodiment 1 is directed to a case in which the refrigerant pipe 7 and the bypass pipe 20 are connected at a position inside the outdoor unit 2, the refrigerant pipe 7 and the bypass pipe 20 may be connected at a position outside the outdoor unit 2.

(Expansion Units 14a and 14b)

[0015] The expansion units 14a and 14b are respectively connected to portions of the refrigerant main pipe 8 between the heat source-side heat exchanger 12 and the load-side heat exchangers 15a and 15b. Each of the expansion units 14a and 14b is a pressure-reducing valve or expansion valve that causes refrigerant to be reduced in pressure and expand. Each of the expansion units 14a and 14b is, for example, an electronic expansion valve whose opening degree is adjusted.

(Load-side Heat Exchangers 15a and 15b and Load-side Air-sending Devices 16a and 16b)

[0016] The load-side heat exchangers 15a and 15b are respectively connected to portions of the refrigerant main pipe 8 between the expansion units 14a and 14b and the flow switching device 11. The load-side heat exchangers 15a and 15b exchange heat between, for example, indoor air and refrigerant. The load-side heat exchangers 15a and 15b each act as an evaporator during cooling operation, and act as a condenser during heating operation. The load-side air-sending devices 16a and 16b are fans respectively disposed near the load-side heat exchangers 15a and 15b to send indoor air to the load-side heat exchangers 15a and 15b.

(Leakage detection unit 30)

[0017] The leakage detection unit 30 detects refrigerant leakage in the refrigerant circuit 4. In Embodiment 1, the leakage detection unit 30 includes a discharge pressure detection unit 31 and a suction pressure detection unit 32. As the leakage detection unit 30, various sensors other than the discharge pressure detection unit 31 and the suction pressure detection unit 32 may be used. Examples of such sensors include a gas sensor.

(Discharge Pressure Detection Unit 31 and Suction Pressure Detection Unit 32)

[0018] The discharge pressure detection unit 31 is provided to a portion of the refrigerant pipe 7 that connects the discharge side of the compressor 10 with the flow switching device 11. The discharge pressure detection unit 31 detects the pressure of high-temperature, high-pressure refrigerant that is compressed by and discharged from the compressor 10. The suction pressure detection unit 32 is provided to a portion of the refrigerant pipe 7 that connects the accumulator 17 with the flow switching device 11. The suction pressure detection unit 32 detects the pressure of low-temperature, low-pressure refrigerant that is sucked into the compressor 10. If refrigerant leaks, the amount of refrigerant flowing through the pipe 5 decreases. This causes a problem with the proper operation of the compressor 10 and the expansion units 14a and 14b. Consequently, the discharge pressure at which refrigerant is discharged from the compressor 10 decreases, and the suction pressure at which refrigerant is sucked by the compressor 10 increases. That is, refrigerant leakage is determined to have occurred if the discharge pressure detected by the discharge pressure detection unit 31 is below a discharge pressure threshold. Further, refrigerant leakage is determined to have occurred if the suction pressure detected by the suction pressure detection unit 32 is above a suction pressure threshold.

(Discharge Temperature Detection Unit 33)

[0019] The discharge temperature detection unit 33 is provided to a portion of the refrigerant pipe 7 that connects the discharge side of the compressor 10 with the flow switching device 11. The discharge temperature detection unit 33 detects the temperature of high-temperature, high-pressure refrigerant that is compressed by and discharged from the compressor 10. The discharge temperature detection unit 33 is, for example, a thermistor.

(First Heat-exchange-temperature Detection Units 34a and 34b)

[0020] The first heat-exchange-temperature detection units 34a and 34b are respectively provided to portions of the refrigerant main pipe 8 that connect the expansion

units 14a and 14b with the load-side heat exchangers 15a and 15b. The first heat-exchange-temperature detection units 34a and 34b each detect the temperature of refrigerant flowing in the refrigerant main pipe 8. That is, the first heat-exchange-temperature detection units 34a and 34b respectively detect the temperatures of refrigerant entering the load-side heat exchangers 15a and 15b during cooling operation, and detect the temperatures of refrigerant exiting the load-side heat exchangers 15a and 15b during heating operation. The first heat-exchange-temperature detection units 34a and 34b are, for example, thermistors.

(Second Heat-exchange-temperature Detection Units 35a and 35b)

[0021] The second heat-exchange-temperature detection units 35a and 35b are respectively provided to portions of the refrigerant main pipe 8 that connect the load-side heat exchangers 15a and 15b with the flow switching device 11. The second heat-exchange-temperature detection units 35a and 35b each detect the temperature of refrigerant flowing in the refrigerant main pipe 8. That is, the second heat-exchange-temperature detection units 35a and 35b respectively detect the temperatures of refrigerant exiting the load-side heat exchangers 15a and 15b during cooling operation, and detect the temperatures of refrigerant entering the load-side heat exchangers 15a and 15b during heating operation. The second heat-exchange-temperature detection units 35a and 35b are, for example, thermistors.

(Indoor Temperature Detection Units 36a and 36b)

[0022] The indoor temperature detection units 36a and 36b are disposed at the respective air inlets (not illustrated) of the load-side heat exchangers 15a and 15b. The indoor temperature detection units 36a and 36b respectively detect the temperatures of indoor air sucked into the load-side heat exchangers 15a and 15b. The indoor temperature detection units 36a and 36b are, for example, thermistors.

(Refrigerant)

[0023] The refrigerant flowing in the refrigerant circuit 4 may be a natural refrigerant such as carbon dioxide, hydrocarbon, or helium, or may be R410A, R32, R407C, R404A, or HFO1234yf.

(Control Unit 40)

[0024] The control unit 40 controls the entire air-conditioning apparatus 1. Examples of the control unit 40 include a microcomputer and a driver. Based on the results of detection by the discharge pressure detection unit 31, the suction pressure detection unit 32, the discharge temperature detection unit 33, the first heat-ex-

change-temperature detection units 34a and 34b, the second heat-exchange-temperature detection units 35a and 35b, and the indoor temperature detection units 36a and 36b, and an instruction from a remote controller (not illustrated), the control unit 40 controls the driving frequency of the compressor 10, the rotation speed of the heat source-side air-sending device 13, the rotation speed of each of the load-side air-sending devices 16a and 16b, the switching operation of the flow switching device 11, the opening degree of each of the expansion units 14a and 14b, and the opening and closing operation of the bypass opening and closing device 21. Either a cooling operation mode or heating operation mode is thus carried out. Although the control unit 40 is illustrated to be disposed in the outdoor unit 2, the control unit 40 may be disposed in both the outdoor unit 2 and the indoor units 3a and 3b on a unit-by-unit basis, or may be disposed only in the indoor units 3a and 3b.

[0025] During cooling operation, the control unit 40 controls the opening degree of each of the expansion units 14a and 14b to maintain a constant degree of superheat, which is obtained as the difference between the temperature detected by the first heat-exchange-temperature detection unit 34a or 34b and the temperature detected by the second heat-exchange-temperature detection unit 35a or 35b. During heating operation, the control unit 40 controls the opening degree of each of the expansion units 14a and 14b to maintain a constant degree of subcooling, which is obtained as the difference between the saturated liquid temperature of refrigerant calculated from the discharge pressure detected by the discharge pressure detection unit 31, and the temperature detected by the first heat-exchange-temperature detection unit 34a or 34b.

[0026] Fig. 2 is a block diagram illustrating the control unit 40 of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. As illustrated in Fig. 2, the control unit 40 includes a first controller 41 and a second controller 42.

(First Controller 41)

[0027] The first controller 41 performs the following control in response to detection of refrigerant leakage by the leakage detection unit 30. That is, at this time, the first controller 41 switches the flow switching device 11 to connect the discharge side of the compressor 10 with the heat source-side heat exchanger 12, closes the expansion units 14a and 14b, and opens the bypass opening and closing device 21. As described above, the first controller 41 has a pump-down function, whereby refrigerant staying in the indoor units 3a and 3b is collected into the outdoor unit 2. Switching the flow switching device 11 to connect the discharge side of the compressor 10 with the heat source-side heat exchanger 12 as described above means switching the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in cooling operation.

[0028] As described above, the leakage detection unit 30 includes the discharge pressure detection unit 31 and the suction pressure detection unit 32, and refrigerant leakage is detected by means of the discharge pressure detection unit 31 and the suction pressure detection unit 32. In this regard, the first controller 41 may detect refrigerant leakage based on an external signal or a detection result obtained from a sensor other than the discharge pressure detection unit 31 and the suction pressure detection unit 32. The expansion units 14a and 14b may not necessarily be fully closed but may be set to an opening degree close to the fully closed position.

[0029] The first controller 41 sets the operating frequency of the compressor 10 to a frequency below the maximum operating frequency at which the compressor 10 operates during cooling operation. If the compressor 10 is being operated at a high frequency at the time when the expansion units 14a and 14b are closed, this causes an abrupt change in the pressure of the refrigeration cycle, potentially leading to an abnormal stop or other problems. For this reason, the operating frequency of the compressor 10 is set to a frequency below the maximum operating frequency at which the compressor 10 operates during cooling operation to ensure that the pressure of the refrigeration cycle does not increase excessively.

[0030] Further, the first controller 41 controls the operating frequency of the compressor 10 such that the discharge pressure of the compressor 10 becomes a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation. A low operating frequency of the compressor 10 leads to reduced pump-down effect, and consequently reduced flow rate at which refrigerant flows to the outdoor unit 2 from the indoor units 3a and 3b. For this reason, it is preferable that the compressor 10 be operated at a somewhat high frequency. By controlling the operating frequency of the compressor 10 such that the discharge pressure of the compressor 10 becomes a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation, it is possible to minimize an excessive increase in the high-side pressure of the refrigeration cycle.

[0031] The first controller 41 controls the rotation speed of the heat source-side air-sending device 13 to a preset rotation speed. The preset rotation speed is preferably equal or close to the maximum rotation speed of the heat source-side air-sending device 13. A high rotation speed of the heat source-side air-sending device 13 facilitates condensation of refrigerant in the heat source-side heat exchanger 12, thus minimizing an increase in the discharge pressure of the compressor 10.

[0032] Further, operation of the first controller 41 ends if the discharge pressure detected by the discharge pressure detection unit 31 becomes greater than or equal to a preset discharge pressure threshold. The discharge

pressure threshold at this time is preferably equal or close to the maximum pressure allowed during operation of the compressor 10. Setting the discharge pressure threshold to the highest possible value as described above ensures that a large amount of refrigerant moves from the indoor units 3a and 3b to the outdoor unit 2 during operation of the first controller 41. This makes it possible to reduce the amount of refrigerant leaking indoors from the indoor units 3a and 3b.

[0033] Operation of the first controller 41 ends also if the suction pressure detected by the suction pressure detection unit 32 becomes less than or equal to a preset suction pressure threshold. The suction pressure threshold is preferably equal or close to the minimum pressure allowed during operation of the compressor 10. Setting the suction pressure threshold to the lowest possible value as described above ensures that a large amount of refrigerant moves from the indoor units 3a and 3b to the outdoor unit 2 during operation of the first controller 41. This makes it possible to reduce the amount of refrigerant leaking indoors from the indoor units 3a and 3b. For cases where the operating frequency of the compressor 10 is controlled such that the discharge pressure becomes a target discharge pressure, operation of the first controller 41 ends only if the suction pressure becomes less than or equal to a suction pressure threshold. The first controller 41 may be configured to end operation if the time elapsed after detection of refrigerant leakage becomes greater than or equal to a preset time threshold.

(Second Controller 42)

[0034] The second controller 42 is a controller that, after the end of operation of the first controller 41, switches the flow switching device 11 to connect the discharge side of the compressor 10 with the load-side heat exchangers 15a and 15b, and stops the compressor 10. The second controller 42 has a function to trap, within the outdoor unit 2, the refrigerant collected into the outdoor unit 2 by the first controller 41. Switching the flow switching device 11 to connect the discharge side of the compressor 10 with the load-side heat exchangers 15a and 15b as described above means switching the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in heating operation.

[0035] The second controller 42 also closes the bypass opening and closing device 21 at a time after switching of the flow switching device 11 and before stopping of the compressor 10. The second controller 42 fully closes the expansion units 14a and 14b if the expansion units 14a and 14b are open. Further, the second controller 42 stops the heat source-side air-sending device 13.

[0036] If refrigerant leakage is detected by the leakage detection unit 30, the control unit 40 continues operation of the load-side air-sending devices 16a and 16b until the second controller 42 stops the compressor 10. At this time, the control unit 40 sets the rotation speed of each of the load-side air-sending devices 16a and 16b equal

or close to the maximum rotation speed. When refrigerant leakage is being detected, the respective load-side heat exchangers 15a and 15b within the indoor units 3a and 3b are at extremely low pressure. Consequently, moisture in the air is cooled. This can potentially lead to freezing of the respective load-side heat exchangers 15a and 15b within the indoor units 3a and 3b and freezing of the pipe 5 within the indoor units 3a and 3b. Such freezing can potentially lead to formation of an enlarged pinhole in the pipe 5 that causes refrigerant leakage, and also to the occurrence of a new leak. By setting the rotation speed of each of the load-side air-sending devices 16a and 16b equal or close to the maximum rotation speed, the control unit 40 reduces the risk of freezing within the indoor units 3a and 3b, thus reducing the occurrence of a new refrigerant leak.

(Operation Modes)

[0037] Next, operation modes of the air-conditioning apparatus 1 will be described. As described above, operation modes of the air-conditioning apparatus 1 include a cooling operation mode and a heating operation mode. In cooling operation, refrigerant flows through the compressor 10, the flow switching device 11, the heat source-side heat exchanger 12, each of the expansion units 14a and 14b, each of the load-side heat exchangers 15a and 15b, the flow switching device 11, and the accumulator 17 in this order. As heat is exchanged between indoor air and refrigerant in each of the load-side heat exchangers 15a and 15b, the corresponding indoor space is cooled. In heating operation, refrigerant flows through the compressor 10, the flow switching device 11, each of the load-side heat exchangers 15a and 15b, each of the expansion units 14a and 14b, the heat source-side heat exchanger 12, the flow switching device 11, and the accumulator 17 in this order. As heat is exchanged between indoor air and refrigerant in each of the load-side heat exchangers 15a and 15b, the corresponding indoor space is heated.

(Cooling Operation)

[0038] Fig. 3 is a circuit diagram illustrating the flow of refrigerant during cooling operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. The following describes how the air-conditioning apparatus 1 operates in each operation mode. First, cooling operation will be described. In cooling operation, the discharge side of the compressor 10 is connected with the heat source-side heat exchanger 12 by the flow switching device 11, and the bypass opening and closing device 21 is closed. If the bypass opening and closing device 21 is an electronic expansion valve, the bypass opening and closing device 21 is set to such an opening degree that does not affect the operational state of the refrigeration cycle, for example, the cooling capacity. For example, the bypass opening and closing

device 21 is set to the fully closed position or to an opening degree close to the fully closed position. As indicated by solid arrows in Fig. 3, in cooling operation, the refrigerant sucked into the compressor 10 is compressed by the compressor 10 and leaves the compressor 10 as high-temperature, high-pressure refrigerant in a gaseous state. Upon leaving the compressor 10, the high-temperature, high-pressure refrigerant in a gaseous state passes through the flow switching device 11 into the heat source-side heat exchanger 12 acting as a condenser. In the heat source-side heat exchanger 12, the refrigerant is made to exchange heat with the outdoor air sent by the heat source-side air-sending device 13. This causes the refrigerant to condense and liquefy. The condensed refrigerant in a liquid state flows into each of the indoor units 3a and 3b.

[0039] In the indoor units 3a and 3b, the refrigerant flows into the corresponding expansion units 14a and 14b. In each of the expansion units 14a and 14b, the refrigerant is expanded and reduced in pressure. This causes the refrigerant to turn into low-temperature, low-pressure refrigerant in a two-phase gas-liquid state. The refrigerant in a two-phase gas-liquid state then flows into each of the load-side heat exchangers 15a and 15b acting as evaporators. In each of the load-side heat exchangers 15a and 15b, the refrigerant is made to exchange heat with the indoor air sent by the load-side air-sending device 16a or 16b. This causes the refrigerant to evaporate and gasify. At this time, the indoor air is cooled, and thus cooling is performed in the corresponding indoor space. The evaporated low-temperature, low-pressure refrigerant in a gaseous state passes through the flow switching device 11 into the accumulator 17. Of the refrigerant having entered the accumulator 17, refrigerant in a liquid state is stored into the accumulator 17, and refrigerant in a gaseous state is sucked into the compressor 10.

(Heating Operation)

[0040] Fig. 4 is a circuit diagram illustrating the flow of refrigerant during heating operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. Next, heating operation will be described. In heating operation, the accumulator 17 is connected with each of the load-side heat exchangers 15a and 15b by the flow switching device 11, and the bypass opening and closing device 21 is closed. If the bypass opening and closing device 21 is an electronic expansion valve, the bypass opening and closing device 21 is set to such an opening degree that does not affect the operational state of the refrigeration cycle, for example, the cooling capacity of the refrigeration cycle. For example, the bypass opening and closing device 21 is set to the fully closed position or to an opening degree close to the fully closed position. As indicated by solid arrows in Fig. 4, in heating operation, the refrigerant sucked into the compressor 10 is compressed by the compressor 10 and

leaves the compressor 10 as high-temperature, high-pressure refrigerant in a gaseous state. Upon leaving the compressor 10, the high-temperature, high-pressure refrigerant in a gaseous state passes through the flow switching device 11 into each of the indoor units 3a and 3b. In each of the indoor units 3a and 3b, the refrigerant flows into the corresponding load-side heat exchanger 15a or 15b acting as a condenser. In each of the load-side heat exchangers 15a and 15b, the refrigerant is made to exchange heat with the indoor air sent by the load-side air-sending device 16a or 16b. This causes the refrigerant to condense and liquefy. At this time, the indoor air is heated, and thus heating is performed in the corresponding indoor space.

[0041] The condensed refrigerant in a liquid state is expanded and reduced in pressure in each of the expansion units 14a and 14b. This causes the refrigerant to turn into low-temperature, low-pressure refrigerant in a two-phase gas-liquid state. The refrigerant in a two-phase gas-liquid state then flows into the heat source-side heat exchanger 12 acting as an evaporator. In the heat source-side heat exchanger 12, the refrigerant is made to exchange heat with the indoor air sent by the heat source-side air-sending device 13. This causes the refrigerant to evaporate and gasify. The evaporated low-temperature, low-pressure refrigerant in a gaseous state passes through the flow switching device 11 into the accumulator 17. Of the refrigerant entering the accumulator 17, refrigerant in a liquid state is stored into the accumulator 17, and refrigerant in a gaseous state is sucked into the compressor 10.

(Operation upon Refrigerant Leakage)

[0042] Fig. 5 is a flowchart illustrating operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. The following describes how the air-conditioning apparatus 1 operates when refrigerant leakage occurs. As illustrated in Fig. 5, first, it is determined whether refrigerant leakage has been detected by the leakage detection unit 30 (step ST1). If refrigerant leakage has not been detected (step ST1: No), the control ends. If refrigerant leakage has been detected (step ST1: Yes), the first controller 41, which has a pump-down function to collect refrigerant staying in each of the indoor units 3a and 3b into the outdoor unit 2, is executed (step ST2). The execution of the first controller 41 is then followed by execution of the second controller 42, which has a function to trap the refrigerant collected into the outdoor unit 2 within the outdoor unit 2 (step ST3).

[0043] Now, the operation of the first controller 41 during cooling will be described with reference to Fig. 6, and the operation of the second controller 42 during cooling will be described below with reference to Fig. 7. Further, the operation of the first controller 41 during heating will be described with reference to Fig. 8, and the operation of the second controller 42 during heating will be described below with reference to Fig. 7. Furthermore, the

operation of the first controller 41 when the air-conditioning apparatus 1 is stopped will be described with reference to Fig. 8, and the operation of the second controller 42 when the air-conditioning apparatus 1 is stopped will be described below with reference to Fig. 7.

(Operation during Cooling)

[0044] Fig. 6 is a flowchart illustrating the operation of the first controller 41 during cooling operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. The following describes the operation of the air-conditioning apparatus 1 when refrigerant leaks during cooling operation. When refrigerant leakage is detected, operation of the first controller 41 starts. As illustrated in Fig. 6, the flow switching device 11 is maintained in the current state without being switched (step ST11). Although operation of the compressor 10 is continued at this time (step ST12), the operating frequency of the compressor 10 is controlled such that the operating frequency is below the maximum operating frequency at which the compressor 10 operates during cooling operation, and that the discharge pressure of the compressor 10 becomes a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation.

[0045] Next, the expansion units 14a and 14b are fully closed (step ST13). At this time, the expansion units 14a and 14b may not necessarily be fully closed but may be set to an opening degree close to the fully closed position. Then, the bypass opening and closing device 21 is opened (step ST14). Subsequently, the rotation speed of the heat source-side air-sending device 13 is controlled to a preset rotation speed (step ST15). If the discharge pressure detected by the discharge pressure detection unit 31 is less than a discharge pressure threshold, the suction pressure detected by the suction pressure detection unit 32 is less than a suction pressure threshold, and the time elapsed from the detection of refrigerant leakage is less than a time threshold (step ST16: No), the process returns to step ST16. By contrast, operation of the first controller 41 ends if one of the following conditions is satisfied: the discharge pressure detected by the discharge pressure detection unit 31 is greater than or equal to a discharge pressure threshold; the suction pressure detected by the suction pressure detection unit 32 is greater than or equal to a suction pressure threshold; and the time elapsed from the detection of refrigerant leakage is greater than or equal to a time threshold (step ST16: Yes). It is to be noted that steps ST11 to ST15 are in no particular order.

[0046] As the expansion units 14a and 14b are fully closed, the refrigerant staying in each of the load-side heat exchangers 15a and 15b or other components that are located downstream of the expansion units 14a and 14b in cooling operation flows into the outdoor unit 2, and is stored into the accumulator 17. At this time, the bypass

opening and closing device 21 is open. Consequently, the refrigerant tends to be stored into the accumulator 17 through the bypass pipe 20 than to be stored into the heat source-side heat exchanger 12. Since the expansion units 14a and 14b are in their fully closed state at this time, hardly any of the refrigerant having passed through the heat source-side heat exchanger 12 enters the indoor units 3a and 3b. Instead, the refrigerant mainly flows into the bypass pipe 20. As a result, most of the refrigerant is stored into the accumulator 17, and a portion of the refrigerant is stored into the heat source-side heat exchanger 12. As described above, the first controller 41 makes it possible to reduce the amount of liquid refrigerant staying in the load-side heat exchangers 15a and 15b and in the refrigerant main pipe 8 located at the low-pressure side, thus reducing the amount of refrigerant leaking indoors.

[0047] Fig. 7 is a flowchart illustrating operation of the second controller 42 of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. As illustrated in Fig. 7, after the operation of the first controller 41 illustrated in Fig. 6 ends, the flow switching device 11 is switched to change the flow of refrigerant to the flow of refrigerant in heating operation (step ST21). If the flow switching device 11 is a four-way valve or any other such device that is driven by a pressure difference within the refrigerant circuit 4, this switching operation of the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in heating operation needs to be performed before the compressor 10 is stopped. Then, if the expansion units 14a and 14b are open, the expansion units 14a and 14b are set to the fully closed position (step ST22). Subsequently, the bypass opening and closing device 21 is closed (step ST23). Then, the compressor 10 is stopped (step ST24), and the heat source-side air-sending device 13 is stopped (step ST25). Stopping the heat source-side air-sending device 13 after stopping the compressor 10 as described above makes it possible to minimize an excessive increase in high-side pressure that occurs as a result of reduced heat exchange in the heat source-side heat exchanger 12. Then, operation of the second controller 42 ends. It is to be noted that steps ST22 to ST24 are in no particular order.

[0048] As the flow switching device 11 is switched to change the flow of refrigerant to the flow of refrigerant in heating operation, the upstream side of the accumulator 17 is connected with the heat source-side heat exchanger 12. This ensures that refrigerant does not flow toward the load-side heat exchangers 15a and 15b from the upstream side of the accumulator 17. Further, since the compressor 10 is stopped at this time, refrigerant does not pass through the compressor 10 from the downstream side of the accumulator 17. As a result, a large amount of refrigerant can be trapped within the accumulator 17. At this time, a portion of refrigerant is trapped within the refrigerant pipe 7 of the outdoor unit 2 and within the refrigerant main pipe 8 located at the high-pressure side. This configuration makes it possible to

further reduce the amount of refrigerant leaking indoors.

(Operation during Heating)

[0049] Fig. 8 is a flowchart illustrating the operation of the first controller 41 during heating operation of the air-conditioning apparatus 1 according to Embodiment 1 of the present invention. The following describes the operation of the air-conditioning apparatus 1 when refrigerant leaks during heating operation. When refrigerant leakage is detected, operation of the first controller 41 starts. As illustrated in Fig. 8, the flow switching device 11 is switched to change the flow of refrigerant to the flow of refrigerant in cooling operation (step ST31). If the flow switching device 11 is a four-way valve or any other such device that is driven by a pressure difference within the refrigerant circuit 4, this switching operation of the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in cooling operation needs to be performed while the compressor 10 is in operation. Although operation of the compressor 10 is continued at this time (step ST32), the operating frequency of the compressor 10 is controlled such that the operating frequency is below the maximum operating frequency at which the compressor 10 operates during cooling operation, and that the discharge pressure of the compressor 10 becomes a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation.

[0050] Next, the expansion units 14a and 14b are fully closed (step ST33). At this time, the expansion units 14a and 14b may not necessarily be fully closed but may be set to an opening degree close to the fully closed position. Then, the bypass opening and closing device 21 is opened (step ST34). Subsequently, the rotation speed of the heat source-side air-sending device 13 is controlled to a preset rotation speed (step ST35). If the discharge pressure detected by the discharge pressure detection unit 31 is less than a discharge pressure threshold, the suction pressure detected by the suction pressure detection unit 32 is less than a suction pressure threshold, and the time elapsed from the detection of refrigerant leakage is less than a time threshold (step ST36: No), the process returns to step ST36. By contrast, operation of the first controller 41 ends if one of the following conditions is satisfied: the discharge pressure detected by the discharge pressure detection unit 31 is greater than or equal to a discharge pressure threshold; the suction pressure detected by the suction pressure detection unit 32 is greater than or equal to a suction pressure threshold; and the time elapsed from the detection of refrigerant leakage is greater than or equal to a time threshold (step ST36: Yes). It is to be noted that steps ST32 to ST35 are in no particular order.

[0051] As the expansion units 14a and 14b are fully closed, the refrigerant staying in each of the load-side heat exchangers 15a and 15b or other components that

are located downstream of the expansion units 14a and 14b in cooling operation flows into the outdoor unit 2, and is stored into the accumulator 17. At this time, the bypass opening and closing device 21 is open. Consequently, the refrigerant is more likely to be stored into the accumulator 17 through the bypass pipe 20 than to be stored into the heat source-side heat exchanger 12. Since the expansion units 14a and 14b are in their fully closed state at this time, hardly any of the refrigerant having passed through the heat source-side heat exchanger 12 enters the indoor units 3a and 3b. Instead, the refrigerant mainly flows into the bypass pipe 20. As a result, most of the refrigerant is stored into the accumulator 17, and a portion of the refrigerant is stored into the heat source-side heat exchanger 12. As described above, also when heating is being executed, the flow switching device 11 is switched by the first controller 41 to change the flow of refrigerant to the flow of refrigerant in cooling operation. As a result, as with when cooling is being executed, the amount of liquid refrigerant staying in the load-side heat exchangers 15a and 15b and in the refrigerant main pipe 8 located at the low-pressure side can be reduced, thus reducing the amount of refrigerant leaking indoors.

[0052] After the operation of the first controller 41 illustrated in Fig. 8 ends, operation of the second controller 42 starts. The operation of the second controller 42 in this case is identical or similar to the operation of the second controller 42 during cooling illustrated in Fig. 7, and thus will not be described in further detail.

(Operation in Stop Mode)

[0053] The following describes how the air-conditioning apparatus 1 operates in response to refrigerant leakage in stop mode in which the air-conditioning apparatus 1 is stopped. When refrigerant leakage is detected, operation of the first controller 41 starts. The operation of the first controller 41 in this case is identical or similar to the operation of the first controller 41 during heating illustrated in Fig. 8, and thus will not be described in further detail. In stop mode, the compressor 10 is stopped and the pressure within the refrigerant circuit 4 is constant. Therefore, operation of a device driven by utilizing a differential pressure needs to be performed after the compressor 10 is activated to create a pressure difference within the refrigerant circuit 4.

[0054] In stop mode, the location where liquid refrigerant stays within the air-conditioning apparatus is not fixed to a specific area, as this location depends on factors such as the outdoor and indoor temperature conditions and the time elapsed from the stoppage of the air-conditioning apparatus. By executing the operation of the first controller 41 illustrated in Fig. 8, at least the proportion of liquid refrigerant contained in the load-side heat exchangers 15a and 15b can be reduced. This makes it possible to reduce the amount of refrigerant leaking indoors. After the operation of the first controller 41 illustrated in Fig. 8 ends, operation of the second controller

42 starts. The operation of the second controller 42 in this case is identical or similar to the operation of the second controller 42 during cooling illustrated in Fig. 7, and thus will not be described in further detail. It is to be noted that an operation identical or similar to the operation in stop mode is executed also in a thermo-off state, in which the indoor units 3a and 3b has reached a thermo-off set temperature and the compressor 10 is stopped. Consequently, an effect identical or similar to the effect obtained in stop mode can be obtained also in the thermo-off state.

[0055] In Embodiment 1, the first controller 41 switches the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in cooling operation, closes the expansion units 14a and 14b, and opens the bypass opening and closing device 21. Consequently, refrigerant flowing in the indoor units 3a and 3b is collected into the accumulator 17. Subsequently, the second controller 42 switches the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in heating operation. Consequently, the upstream side of the accumulator 17 is connected with the heat source-side heat exchanger 12. This ensures that refrigerant does not flow toward the load-side heat exchangers 15a and 15b from the upstream side of the accumulator 17. Further, the second controller 42 stops the compressor 10. This ensures that refrigerant does not pass through the compressor 10 from the downstream side of the accumulator 17. Consequently, a large amount of refrigerant can be trapped mainly within the accumulator 17. The above-mentioned configuration makes it possible to make full use of the volume of the accumulator 17 in collecting refrigerant. Generally, the accumulator 17 has a volume such that the accumulator 17 is able to store about twice as much refrigerant as the heat source-side heat exchanger 12. According to Embodiment 1, the volume of the accumulator 17 can be fully utilized, thus increasing the amount of refrigerant to be collected.

(Modification)

[0056] Fig. 9 is a circuit diagram illustrating an air-conditioning apparatus 100 according to a modification of Embodiment 1 of the present invention. The following describes the air-conditioning apparatus 100 according to a modification of Embodiment 1. This modification differs from Embodiment 1 in that an internal heat exchanger 101 is provided. As illustrated in Fig. 9, the internal heat exchanger 101 allows heat exchange between the refrigerant flowing in a portion of the pipe 5 that connects the heat source-side heat exchanger 12 with the expansion units 14a and 14b, and the refrigerant flowing in the bypass pipe 20. The internal heat exchanger 101 serves to increase the degree of subcooling of the refrigerant exiting the outdoor unit 2 during cooling operation. The internal heat exchanger 101 is disposed at a position that is located downstream of the heat source-side heat exchanger 12 in cooling operation. The internal heat ex-

changer 101 is formed by using a portion of the bypass pipe 20 that branches off from a position downstream of the internal heat exchanger 101.

[0057] The bypass opening and closing device 21 is disposed at a position on the bypass pipe 20 upstream of the internal heat exchanger 101. The bypass opening and closing device 21 is an electronic expansion valve with a refrigerant passage (not illustrated) whose opening area is varied to adjust the opening degree of the bypass opening and closing device 21. This configuration makes it possible to control the subcooling of refrigerant flow at the outlet side of the internal heat exchanger 101. Although the internal heat exchanger 101 is illustrated to be installed inside the outdoor unit 2, the internal heat exchanger 101 may be installed outside the outdoor unit 2 as long as the internal heat exchanger 101 is located between the heat source-side heat exchanger 12 and the expansion units 14a and 14b.

[0058] A portion of high-pressure liquid refrigerant generated in the heat source-side heat exchanger 12 during cooling operation flows into the bypass pipe 20. Upon entering the bypass pipe 20, the refrigerant is reduced in pressure by the bypass opening and closing device 21 and turns into low-temperature, low-pressure two-phase refrigerant. The internal heat exchanger 101 causes heat to be exchanged between the liquid refrigerant flowing in the refrigerant pipe 7, and the low-temperature, low-pressure two-phase refrigerant flowing in the bypass pipe 20, thus allowing refrigerant with a large amount of subcooling to exit to the refrigerant main pipe 8. An effect identical or similar to Embodiment 1 is thus obtained even if the internal heat exchanger 101 is provided as in this modification.

Embodiment 2

[0059] Fig. 10 is a circuit diagram illustrating an air-conditioning apparatus 200 according to Embodiment 2 of the present invention. Embodiment 2 differs from the above-mentioned modification of Embodiment 1 in that an opening and closing device 222 is provided. In Embodiment 2, portions of the air-conditioning apparatus 200 identical to those in Embodiment 1 will be designated by the same reference signs and will not be described in further detail. The following description will mainly focus on differences from Embodiment 1.

[0060] As illustrated in Fig. 10, the opening and closing device 222 is disposed in a portion of the pipe 5 connecting between the heat source-side heat exchanger 12 and each of the expansion units 14a and 14b. The opening and closing device 222 controls the flow rate of refrigerant. The opening and closing device 222 is, for example, a solenoid valve with a non-adjustable opening degree. Alternatively, the opening and closing device 222 may be an electronic expansion valve with a refrigerant passage (not illustrated) whose opening area is varied to adjust the opening degree of the opening and closing device 222. Although the opening and closing device 222

is illustrated to be installed inside the outdoor unit 2, the opening and closing device 222 may be installed outside the outdoor unit 2 as long as opening and closing device 222 is located between the heat source-side heat exchanger 12 and the expansion units 14a and 14b.

[0061] Fig. 11 is a block diagram illustrating a control unit 240 of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention. As illustrated in Fig. 11, a first controller 241 includes a pre-stage controller 241a and a later-stage controller 241b. The operation of the second controller 42 is identical or similar to the operation in Embodiment 1, and thus will not be described in further detail.

(Pre-stage controller 241a)

[0062] The pre-stage controller 241a switches the flow switching device 11 to connect the discharge side of the compressor 10 with the heat source-side heat exchanger 12, closes the expansion units 14a and 14b, and opens the bypass opening and closing device 21. As described above, the pre-stage controller 241a has a pump-down function whereby refrigerant staying in the indoor units 3a and 3b is collected into the outdoor unit 2. Switching the flow switching device 11 to connect the discharge side of the compressor 10 with the heat source-side heat exchanger 12 as described above means switching the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in cooling operation. The pre-stage controller 241a has a function identical or similar to the function of the first controller 41 according to Embodiment 1.

(Later-stage Controller 241b)

[0063] The later-stage controller 241b closes the opening and closing device 222 after operation of the pre-stage controller 241a ends. As described above, the later-stage controller 241b has an additional pump-down function whereby refrigerant staying in the refrigerant main pipe 8 located at the high-pressure side in cooling operation is collected into the outdoor unit 2. The later-stage controller 241b also sets the operating frequency of the compressor 10 to a frequency below the maximum operating frequency at which the compressor 10 operates during cooling operation. If the compressor 10 is operating at a high frequency at the time when the expansion units 14a and 14b are closed, the pressure of the refrigeration cycle changes abruptly, potentially leading to an abnormal stop or other problems. For this reason, the operating frequency of the compressor 10 is set to a frequency below the maximum operating frequency at which the compressor 10 operates during cooling operation to ensure that the pressure of the refrigeration cycle does not increase excessively.

[0064] Further, the later-stage controller 241b controls the operating frequency of the compressor 10 such that the discharge pressure of the compressor 10 becomes

a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation. A low operating frequency of the compressor 10 leads to reduced pump-down effect, and consequently reduced flow rate at which refrigerant flows to the outdoor unit 2 from the indoor units 3a and 3b. For this reason, it is preferable that the compressor 10 be operated at a somewhat high frequency. By controlling the operating frequency of the compressor 10 such that the discharge pressure of the compressor 10 becomes a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation, it is possible to minimize an excessive increase in the high-side pressure of the refrigeration cycle.

[0065] The later-stage controller 241b controls the rotation speed of the heat source-side air-sending device 13 to a preset rotation speed. The preset rotation speed is preferably equal or close to the maximum rotation speed of the heat source-side air-sending device 13. A high rotation speed of the heat source-side air-sending device 13 facilitates condensation of refrigerant in the heat source-side heat exchanger 12, thus minimizing an increase in the discharge pressure of the compressor 10.

[0066] Further, operation of the later-stage controller 241b ends if the discharge pressure detected by the discharge pressure detection unit 31 becomes greater than or equal to a preset discharge pressure threshold. The discharge pressure threshold at this time is preferably equal or close to the maximum pressure allowed during operation of the compressor 10. Setting the discharge pressure threshold to the highest possible value as described above ensures that a large amount of refrigerant moves from the indoor units 3a and 3b to the outdoor unit 2 during operation of the first controller 41. This makes it possible to reduce the amount of refrigerant leaking indoors from the indoor units 3a and 3b.

[0067] Operation of the later-stage controller 241b ends also if the suction pressure detected by the suction pressure detection unit 32 becomes less than or equal to a preset suction pressure threshold. The suction pressure threshold at this time is preferably equal or close to the minimum pressure allowed during operation of the compressor 10. Setting the suction pressure threshold to the lowest possible value as described above ensures that a large amount of refrigerant moves from the indoor units 3a and 3b to the outdoor unit 2 during operation of the first controller 41. This makes it possible to reduce the amount of refrigerant leaking indoors from the indoor units 3a and 3b. For cases where the operating frequency of the compressor 10 is controlled such that the discharge pressure becomes a target discharge pressure, operation of the later-stage controller 241b ends only if the suction pressure becomes less than or equal to a suction pressure threshold. The later-stage controller 241b may

be configured to end operation if the time elapsed after detection of refrigerant leakage becomes greater than or equal to a preset time threshold.

(Operation Modes)

[0068] Next, operation modes of the air-conditioning apparatus 200 will be described. In cooling operation, refrigerant flows through the compressor 10, the flow switching device 11, the heat source-side heat exchanger 12, the opening and closing device 222, the internal heat exchanger 101, each of the expansion units 14a and 14b, each of the load-side heat exchangers 15a and 15b, the flow switching device 11, and the accumulator 17 in this order. As heat is exchanged between indoor air and refrigerant in each of the load-side heat exchangers 15a and 15b, the corresponding indoor space is cooled. A portion of the refrigerant exiting the internal heat exchanger 101 flows into the bypass pipe 20, and travels through the bypass opening and closing device 21, the internal heat exchanger 101, and the accumulator 17 in this order. In heating operation, refrigerant flows through the compressor 10, the flow switching device 11, each of the load-side heat exchangers 15a and 15b, each of the expansion units 14a and 14b, the internal heat exchanger 101, the opening and closing device 222, the heat source-side heat exchanger 12, the flow switching device 11, and the accumulator 17 in this order. As heat is exchanged between indoor air and refrigerant in each of the load-side heat exchangers 15a and 15b, the corresponding indoor space is heated.

(Cooling Operation)

[0069] Fig. 12 is a circuit diagram illustrating the flow of refrigerant during cooling operation of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention. The following describes how the air-conditioning apparatus 200 operates in each operation mode. First, cooling operation will be described. In cooling operation, the discharge side of the compressor 10 is connected with the heat source-side heat exchanger 12 by the flow switching device 11, the opening and closing device 222 is open, and the bypass opening and closing device 21 is open at a predetermined opening degree. As indicated by solid arrows in Fig. 12, in cooling operation, the refrigerant sucked into the compressor 10 is compressed by the compressor 10 and leaves the compressor 10 as high-temperature, high-pressure refrigerant in a gaseous state. Upon leaving the compressor 10, the high-temperature, high-pressure refrigerant in a gaseous state passes through the flow switching device 11 into the heat source-side heat exchanger 12 acting as a condenser. In the heat source-side heat exchanger 12, the refrigerant is made to exchange heat with the outdoor air sent by the heat source-side air-sending device 13. This causes the refrigerant to condense and liquefy. The condensed refrigerant in a liquid state passes through

the opening and closing device 222, and then undergoes heat exchange in the internal heat exchanger 101 with the refrigerant flowing in the bypass pipe 20. This increases subcooling of the refrigerant. The resulting refrigerant flows into each of the indoor units 3a and 3b. The opening and closing device 222 is open at this time, and thus does not hinder refrigerant flow.

[0070] In the indoor units 3a and 3b, the refrigerant flows into the corresponding expansion units 14a and 14b. In each of the expansion units 14a and 14b, the refrigerant is expanded and reduced in pressure. This causes the refrigerant to turn into low-temperature, low-pressure refrigerant in a two-phase gas-liquid state. The refrigerant in a two-phase gas-liquid state then flows into each of the load-side heat exchangers 15a and 15b acting as evaporators. In each of the load-side heat exchangers 15a and 15b, the refrigerant is made to exchange heat with the indoor air sent by the load-side air-sending device 16a or 16b. This causes the refrigerant to evaporate and gasify. At this time, the indoor air is cooled, and thus cooling is performed in the corresponding indoor space. The evaporated low-temperature, low-pressure refrigerant in a gaseous state passes through the flow switching device 11 into the accumulator 17. Of the refrigerant entering the accumulator 17, refrigerant in a liquid state is stored into the accumulator 17, and refrigerant in a gaseous state is sucked into the compressor 10. At this time, a portion of the refrigerant exiting the internal heat exchanger 101 flows into the bypass pipe 20, undergoes pressure reduction in the bypass opening and closing device 21, and then enters the internal heat exchanger 101. Upon entering the internal heat exchanger 101, the refrigerant is made to exchange heat in the internal heat exchanger 101 with the refrigerant flowing in the refrigerant pipe 7. The resulting refrigerant then flows into the accumulator.

(Heating Operation)

[0071] Next, heating operation will be described. In heating operation, the accumulator 17 is connected with each of the load-side heat exchangers 15a and 15b by the flow switching device 11, the opening and closing device 222 is open, and the bypass opening and closing device 21 is closed. That is, the heating operation in this case is identical or similar to the heating operation in Embodiment 1, and thus will not be described in further detail.

(Operation upon Refrigerant Leakage)

[0072] Fig. 13 is a flowchart illustrating operation of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention. The following describes how the air-conditioning apparatus 200 operates when refrigerant leakage occurs. As illustrated in Fig. 13, first, it is determined whether refrigerant leakage has been detected by the leakage detection unit 30 (step ST41). If refrigerant

erant leakage has not been detected (step ST41: No), the control ends. If refrigerant leakage has been detected (step ST41: Yes), the pre-stage controller 241a of the first controller 241, which has a pump-down function to collect refrigerant staying in each of the indoor units 3a and 3b into the outdoor unit 2, is executed (step ST42). The execution of the pre-stage controller 241a is then followed by execution of the later-stage controller 241b of the first controller 241, which has an additional pump-down function to collect, into the outdoor unit 2, the refrigerant staying in the refrigerant main pipe 8 that is located at the high-pressure side in cooling operation (step ST43). The execution of the later-stage controller 241b is then followed by execution of the second controller 42, which has a function to trap the refrigerant collected into the outdoor unit 2 within the outdoor unit 2 (step ST44).

[0073] The operation of the pre-stage controller 241a of the first controller 241 during cooling will be described below with reference to Fig. 6, the operation of the later-stage controller 241b of the first controller 241 during cooling will be described below with reference to Fig. 14, and the operation of the second controller 42 during cooling will be described below with reference to Fig. 7. The operation of the pre-stage controller 241a of the first controller 241 during heating will be described below with reference to Fig. 8, the operation of the later-stage controller 241b of the first controller 241 during heating will be described below with reference to Fig. 14, and the operation of the second controller 42 during heating will be described below with reference to Fig. 7. Further, the operation of the pre-stage controller 241a of the first controller 241 when the air-conditioning apparatus 200 is stopped will be described below with reference to Fig. 8, the operation of the later-stage controller 241b of the first controller 241 when the air-conditioning apparatus 200 is stopped will be described below with reference to Fig. 14, and the operation of the second controller 42 when the air-conditioning apparatus 200 is stopped will be described below with reference to Fig. 7.

(Operation during Cooling)

[0074] First, the operation of the air-conditioning apparatus 200 when refrigerant leaks during cooling will be described. When refrigerant leakage is detected, operation of the pre-stage controller 241a of the first controller 241 starts. The operation of the pre-stage controller 241a in this case is identical or similar to the operation of the first controller 41 during cooling according to Embodiment 1 illustrated in Fig. 6, and thus will not be described in further detail.

[0075] Fig. 14 is a flowchart illustrating operation of the later-stage controller 241b of the air-conditioning apparatus 200 according to Embodiment 2 of the present invention. As illustrated in Fig. 14, after the operation of the pre-stage controller 241a illustrated in Fig. 6 ends, the flow switching device 11 is maintained in the current state without being switched (step ST51). Although op-

eration of the compressor 10 is continued at this time (step ST52), the operating frequency of the compressor 10 is controlled such that the operating frequency is below the maximum operating frequency at which the compressor 10 operates during cooling operation, and that the discharge pressure of the compressor 10 becomes a target discharge pressure determined by a target condensing temperature that is based on the temperature of air with which the heat source-side heat exchanger 12 exchanges heat during cooling operation.

[0076] Next, the opening and closing device 222 is fully closed (step ST53). Further, the bypass opening and closing device 21 is kept open (step ST54). Subsequently, the rotation speed of the heat source-side air-sending device 13 is controlled to a preset rotation speed (step ST55). If the discharge pressure detected by the discharge pressure detection unit 31 is less than a discharge pressure threshold, the suction pressure detected by the suction pressure detection unit 32 is less than a suction pressure threshold, and the time elapsed from the detection of refrigerant leakage is less than a time threshold (step ST56: No), the process returns to step ST56. By contrast, the operation of the first controller 241 ends if one of the following conditions is satisfied: the discharge pressure detected by the discharge pressure detection unit 31 is greater than or equal to a discharge pressure threshold; the suction pressure detected by the suction pressure detection unit 32 is greater than or equal to a suction pressure threshold; and the time elapsed from the detection of refrigerant leakage is greater than or equal to a time threshold (step ST56: Yes). It is to be noted that steps ST51 to ST55 are in no particular order.

[0077] As the opening and closing device 222 is fully closed, the refrigerant staying in a portion of the refrigerant main pipe 8 between the opening and closing device 222 and the expansion units 14a and 14b passes through the bypass pipe 20 and is stored into the accumulator 17. By means of the pre-stage controller 241a, refrigerant staying in a portion of the refrigerant main pipe 8 between the opening and closing device 222 and the expansion units 14a and 14b is collected into the accumulator 17 and the heat source-side heat exchanger 12 to some degree. The opening and closing device 222 is then fully closed by means of the later-stage controller 241b. As a result, refrigerant staying in a portion of the refrigerant main pipe 8 between the opening and closing device 222 and the expansion units 14a and 14b is collected intensively.

[0078] After the operation of the later-stage controller 241b illustrated in Fig. 14 ends, operation of the second controller 42 starts. The operation of the second controller 42 in this case is identical or similar to the operation of the second controller 42 during cooling according to Embodiment 1 illustrated in Fig. 7, and thus will not be described in further detail.

(Operation during Heating)

[0079] The following describes the operation of the air-conditioning apparatus 200 when refrigerant leaks during heating operation. When refrigerant leakage is detected, operation of the pre-stage controller 241a of the first controller 241 starts. The operation of the pre-stage controller 241a in this case is identical or similar to the operation of the first controller 241 during heating according to Embodiment 1 illustrated in Fig. 8, and thus will not be described in further detail. After the operation of the pre-stage controller 241a illustrated in Fig. 8 ends, operation of the later-stage controller 241b starts. The operation of the later-stage controller 241b in this case is identical or similar to the operation of the later-stage controller 241b during cooling illustrated in Fig. 14, and thus will not be described in further detail. After the operation of the later-stage controller 241b illustrated in Fig. 14 ends, operation of the second controller 42 starts. The operation of the second controller 42 in this case is identical or similar to the operation of the second controller 42 during cooling according to Embodiment 1 illustrated in Fig. 7, and thus will not be described in further detail.

(Operation in Stop Mode)

[0080] Next, the operation of the air-conditioning apparatus 200 when refrigerant leaks in stop mode will be described. When refrigerant leakage is detected, operation of the pre-stage controller 241a of the first controller 241 starts. The operation of the pre-stage controller 241a in this case is identical or similar to the operation of the first controller 241 during heating according to Embodiment 1 illustrated in Fig. 8, and thus will not be described in further detail. After the operation of the pre-stage controller 241a illustrated in Fig. 8 ends, operation of the later-stage controller 241b starts. The operation of the later-stage controller 241b in this case is identical or similar to the operation of the later-stage controller 241b during cooling illustrated in Fig. 14, and thus will not be described in further detail. After the operation of the later-stage controller 241b illustrated in Fig. 14 ends, operation of the second controller 42 starts. The operation of the second controller 42 in this case is identical or similar to the operation of the second controller 42 during cooling according to Embodiment 1 illustrated in Fig. 7, and thus will not be described in further detail.

[0081] In Embodiment 2, the pre-stage controller 241a of the first controller 241 switches the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in cooling operation, closes the expansion units 14a and 14b, and opens the bypass opening and closing device 21. Consequently, refrigerant flowing in the indoor units 3a and 3b is collected into the accumulator 17. Subsequently, the later-stage controller 241b of the first controller 241 closes the opening and closing device 222. Consequently, refrigerant staying in a portion of the refrigerant main pipe 8 between the opening and

closing device 222 and the expansion units 14a and 14b passes through the bypass pipe 20 and is stored into the accumulator 17. Subsequently, the second controller 42 switches the flow switching device 11 to change the flow of refrigerant to the flow of refrigerant in heating operation. Consequently, the upstream side of the accumulator 17 is connected with the heat source-side heat exchanger 12. This ensures that refrigerant does not flow toward the load-side heat exchangers 15a and 15b from the upstream side of the accumulator 17. Further, the second controller 42 stops the compressor 10. This ensures that refrigerant does not pass through the compressor 10 from the downstream side of the accumulator 17. Consequently, a large amount of refrigerant can be trapped mainly within the accumulator 17. The above-mentioned configuration makes it possible to make full use of the volume of the accumulator 17 in collecting refrigerant.

[0082] In Embodiment 2, after the pump-down operation by the pre-stage controller 241a is carried out, refrigerant staying in a portion of the refrigerant main pipe 8 between the opening and closing device 222 and the expansion units 14a and 14b is intensively collected by means of the later-stage controller 241b. This makes it possible to further increase the amount of refrigerant collected into the outdoor unit 2. If the later-stage controller 241b is executed without executing the pre-stage controller 241a, refrigerant is mainly collected into the heat source-side heat exchanger 12, which is located upstream of the opening and closing device 222 in cooling operation, rather than into the accumulator 17. In this case, it is necessary to add a separate connection pipe that connects a position between the heat source-side heat exchanger 12 and the opening and closing device 222 with the upstream side of the accumulator 17, so that the refrigerant that would be otherwise stored into the heat source-side heat exchanger 12 is stored into the accumulator 17.

[0083] By contrast, in Embodiment 2, with the opening and closing device 222 opened by means of the pre-stage controller 241a, refrigerant is collected mainly into the accumulator 17. Then, with the opening and closing device 222 closed by means of the later-stage controller 241b, the refrigerant that has not been fully collected is collected into the accumulator 17 and the heat source-side heat exchanger 12. This configuration eliminates the need to add a separate connection pipe that connects a position between the heat source-side heat exchanger 12 and the opening and closing device 222 with the upstream side of the accumulator 17. The above-mentioned configuration makes it possible to make full use of the volume of the accumulator 17 in collecting refrigerant, without changing the existing refrigerant circuit 4.

Embodiment 3

[0084] Fig. 15 is a circuit diagram illustrating an air-conditioning apparatus 300 according to Embodiment 3 of the present invention. Embodiment 3 differs from Em-

bodiment 2 in that a heat medium relay unit 350 is provided. In Embodiment 3, portions of the air-conditioning apparatus 300 identical to those in Embodiments 1 and 2 will be designated by the same reference signs and will not be described in further detail. The following description will mainly focus on differences from Embodiments 1 and 2.

(Heat Medium Relay Unit 350)

[0085] As illustrated in Fig. 15, the outdoor unit 2 is identical or similar to the outdoor unit 2 according to Embodiment 1, and thus will not be described in further detail. The indoor unit 3a differs from Embodiment 1 in that the indoor unit 3a is not provided with the expansion unit 14a. Although a single indoor unit 3a is illustrated to be provided, two or more indoor units 3a may be provided. The heat medium relay unit 350 includes a pump 352, the expansion unit 14a, a refrigerant-heat medium heat exchanger 353, and a heat medium flow control unit 354. The pump 352 pumps out a heat medium. The refrigerant-heat medium heat exchanger 353 allows heat exchange between refrigerant and the heat medium. The refrigerant-heat medium heat exchanger 353 is, for example, a plate heat exchanger. The heat medium flow control unit 354 controls the flow rate of the heat medium. The heat medium flow control unit 354 is, for example, an electronic expansion valve with a refrigerant passage (not illustrated) whose opening area is varied to adjust the opening degree of the heat medium flow control unit 354. The heat medium relay unit 350 is installed in a space such as a machine room or space above a ceiling. Although a single heat medium relay unit 350 is illustrated to be provided, two or more heat medium relay units may be provided.

[0086] The compressor 10, the flow switching device 11, the heat source-side heat exchanger 12, the expansion unit 14a, the refrigerant-heat medium heat exchanger 353, and the accumulator 17 are connected by the refrigerant pipe 7 to form the refrigerant circuit 4 in which refrigerant flows. Further, the pump 352, the refrigerant-heat medium heat exchanger 353, the heat medium flow control unit 354, and the load-side heat exchanger 15a are connected by a heat medium pipe 308 to form a heat medium circuit 351 in which the heat medium flows. The heat medium is water or brine. The control unit 240 controls the opening degree of the heat medium flow control unit 354 such that the difference between the temperature detected by the first heat-exchange-temperature detection unit 34a and the temperature detected by the second heat-exchange-temperature detection unit 35a is constant. Consequently, the cooling capacity or heating capacity is adjusted according to the indoor load.

(Operation Modes)

[0087] Next, operation modes of the air-conditioning apparatus 1 will be described. During cooling operation,

in the refrigerant circuit 4, refrigerant flows through the compressor 10, the flow switching device 11, the heat source-side heat exchanger 12, the opening and closing device 222, the internal heat exchanger 101, the expansion unit 14a, the refrigerant-heat medium heat exchanger 353, the flow switching device 11, and the accumulator 17 in this order. A portion of the refrigerant exiting the internal heat exchanger 101 flows into the bypass pipe 20, and travels through the bypass opening and closing device 21, the internal heat exchanger 101, and the accumulator 17 in this order. In the heat medium circuit 351, the heat medium flows through the pump 352, the refrigerant-heat medium heat exchanger 353, the heat medium flow control unit 354, and the load-side heat exchanger 15a in this order. In the load-side heat exchanger 15a, indoor air is made to exchange heat with refrigerant, and thus the indoor space is cooled.

[0088] During heating operation, in the refrigerant circuit 4, refrigerant flows through the compressor 10, the flow switching device 11, the refrigerant-heat medium heat exchanger 353, the expansion unit 14a, the internal heat exchanger 101, the opening and closing device 222, the heat source-side heat exchanger 12, the flow switching device 11, and the accumulator 17 in this order. In the heat medium circuit 351, the heat medium flows through the pump 352, the refrigerant-heat medium heat exchanger 353, the heat medium flow control unit 354, and the load-side heat exchanger 15a in this order. In the load-side heat exchanger 15a, indoor air is made to exchange heat with refrigerant, and thus the indoor space is heated.

[0089] The control unit 240 according to Embodiment 3 operates in a manner identical or similar to the control unit 240 according to Embodiment 2. This makes it possible for the air-conditioning apparatus 300 according to Embodiment 3 to provide an effect identical or similar to the effect provided by the air-conditioning apparatus 200 according to Embodiment 2. Further, even if the heat medium relay unit 350 is installed in a space such as a machine room or space above a ceiling, the amount of refrigerant leaking into the space such as a machine room or space above a ceiling can be reduced.

[0090] If a plurality of outdoor units 2 are provided, the control unit 40 executes the first controller 41 and the second controller 42 for each of the plurality of outdoor units 2. This makes it possible to collect refrigerant into the plurality of outdoor units 2.

[0091] Although the foregoing description of Embodiments 1 and 2 is directed to either the case in which all of the indoor units 3a and 3b perform a cooling operation or the case in which all of the indoor units 3a and 3b perform a heating operation, the control unit may cause the plurality of indoor units 3a and 3b to execute a cooling and heating mixed operation in which the plurality of indoor units 3a and 3b each perform a cooling operation or heating operation simultaneously. At this time, upon occurrence of refrigerant leakage, the operation of the first controller 41 in cooling and the operation of the sec-

ond controller 42 in cooling are executed in the case of a cooling only operation and a cooling main operation, in which the heat source-side heat exchanger 12 of the outdoor unit 2 acts as a condenser, and the operation of the first controller 41 in heating and the operation of the second controller 42 in heating are executed in the case of a heating only operation and a heating main operation, in which the heat source-side heat exchanger 12 of the outdoor unit 2 acts as an evaporator. As a result, an effect identical or similar to those of Embodiments 1 and 2 can be obtained.

Reference Signs List

[0092] 1 air-conditioning apparatus 2 outdoor unit 3a, 3b indoor unit 4 refrigerant circuit 5 pipe 7 refrigerant pipe 8 refrigerant main pipe 10 compressor 11 flow switching device 12 heat source-side heat exchanger 13 heat source-side air-sending device 14a, 14b expansion unit 15a, 15b load-side heat exchanger 16a, 16b load-side air-sending device 17 accumulator 20 bypass pipe 21 bypass opening and closing device 30 leakage detection unit 31 discharge pressure detection unit 32 suction pressure detection unit 33 discharge temperature detection unit 34a, 34b first heat-exchange-temperature detection unit 35a, 35b second heat-exchange-temperature detection unit 36a, 36b indoor temperature detection unit 40 control unit 41 first controller 42 second controller 100 air-conditioning apparatus 101 internal heat exchanger 200 air-conditioning apparatus 222 opening and closing device 240 controller 241 first controller 241a pre-stage controller 241b later-stage controller 300 air-conditioning apparatus 308 heat medium pipe 350 heat medium relay unit 351 heat medium circuit 352 pump 353 refrigerant-heat medium heat exchanger 354 heat medium flow control unit

Claims

1. An air-conditioning apparatus comprising:

a circuit formed by connecting, by a pipe, a compressor that compresses refrigerant, a flow switching device, a heat source-side heat exchanger, an expansion unit, a load-side heat exchanger, and an accumulator;
a bypass pipe that connects a position between the heat source-side heat exchanger and the expansion unit, with an upstream side of the accumulator;
a bypass opening and closing device provided to the bypass pipe to control a flow rate of refrigerant flowing in the bypass pipe;
a leakage detection unit that detects refrigerant leakage; and
a control unit configured to switch the flow switching device to switch between a cooling op-

eration and a heating operation, the cooling operation being an operation in which the heat source-side heat exchanger acts as a condenser, the heating operation being an operation in which the heat source-side heat exchanger acts as an evaporator,

wherein the control unit includes

a first controller configured to, in response to detection of refrigerant leakage by the leakage detection unit, switch the flow switching device to connect a discharge side of the compressor with the heat source-side heat exchanger, close the expansion unit, and open the bypass opening and closing device, and

a second controller configured to, after operation of the first controller ends, switch the flow switching device to connect the discharge side of the compressor with the load-side heat exchanger, and stop the compressor.

2. The air-conditioning apparatus of claim 1, further comprising an opening and closing device that controls a flow rate of refrigerant, the opening and closing device being provided to a pipe that connects the heat source-side heat exchanger with the expansion unit, wherein the first controller includes

a pre-stage controller configured to switch the flow switching device to connect the discharge side of the compressor with the heat source-side heat exchanger, close the expansion unit, and open the bypass opening and closing device, and

a later-stage controller configured to, after operation of the pre-stage controller ends, close the opening and closing device.

3. The air-conditioning apparatus of claim 1 or 2, further comprising an internal heat exchanger provided to a pipe that connects the heat source-side heat exchanger with the expansion unit, the internal heat exchanger allowing heat exchange between refrigerant flowing in the pipe that connects the heat source-side heat exchanger with the expansion unit, and refrigerant flowing in the bypass pipe.

4. The air-conditioning apparatus of any one of claims 1 to 3, further comprising a load-side air-sending device that sends air to the load-side heat exchanger, wherein if refrigerant leakage is detected by the leakage detection unit, the control unit continues operation of the load-side air-sending device until the second controller stops the compressor.

5. The air-conditioning apparatus of any one of claims

- 1 to 4,
wherein the second controller configured to switch the flow switching device to connect the discharge side of the compressor with the load-side heat exchanger, close the bypass opening and closing device, and stop the compressor. 5
6. The air-conditioning apparatus of any one of claims 1 to 5, further comprising
a discharge pressure detection unit that detects a discharge pressure at which refrigerant is discharged from the compressor, 10
wherein operation of the first controller ends if the discharge pressure detected by the discharge pressure detection unit becomes greater than or equal to a preset discharge pressure threshold. 15
7. The air-conditioning apparatus of any one of claims 1 to 6, further comprising
a suction pressure detection unit that detects a suction pressure at which refrigerant is sucked by the compressor, 20
wherein operation of the first controller ends if the suction pressure detected by the suction pressure detection unit becomes less than or equal to a preset suction pressure threshold. 25
8. The air-conditioning apparatus of any one of claims 1 to 7,
wherein operation of the first controller ends if a time elapsed from detection of refrigerant leakage becomes greater than or equal to a preset time threshold. 30
9. The air-conditioning apparatus of any one of claims 1 to 8,
wherein the first controller sets an operating frequency of the compressor to a frequency below a maximum operating frequency at which the compressor operates during the cooling operation. 35 40
10. The air-conditioning apparatus of any one of claims 1 to 9,
wherein the first controller controls an operating frequency of the compressor such that a discharge pressure of the compressor becomes a target discharge pressure, the target discharge pressure being determined by a target condensing temperature that is based on a temperature of air with which the heat source-side heat exchanger exchanges heat during the cooling operation. 45 50
11. The air-conditioning apparatus of any one of claims 1 to 10,
wherein the circuit includes 55
a refrigerant circuit in which refrigerant flows, the refrigerant circuit being formed by connecting, by a refrigerant pipe, the compressor, the flow switching device, the heat source-side heat exchanger, the expansion unit, and the accumulator, and
a heat medium circuit in which a heat medium flows, the heat medium circuit being formed by connecting, by a heat medium pipe, a pump that pumps out the heat medium, a heat medium heat exchanger that allows heat exchange between the heat medium and refrigerant, a heat medium flow control unit that controls a flow rate of the heat medium, and the load-side heat exchanger.
12. The air-conditioning apparatus of any one of claims 1 to 11, comprising
a plurality of outdoor units, the plurality of outdoor unit each accommodating the compressor, the flow switching device, the heat source-side heat exchanger, and the accumulator,
wherein the control unit executes, for each of the plurality of outdoor units, the first controller and the second controller.
13. The air-conditioning apparatus of any one of claims 1 to 12, comprising
a plurality of indoor units each accommodating the load-side heat exchanger,
wherein the control unit causes the plurality of indoor units to execute a cooling and heating mixed operation in which the plurality of indoor units each simultaneously perform the cooling operation or the heating operation.

FIG. 1

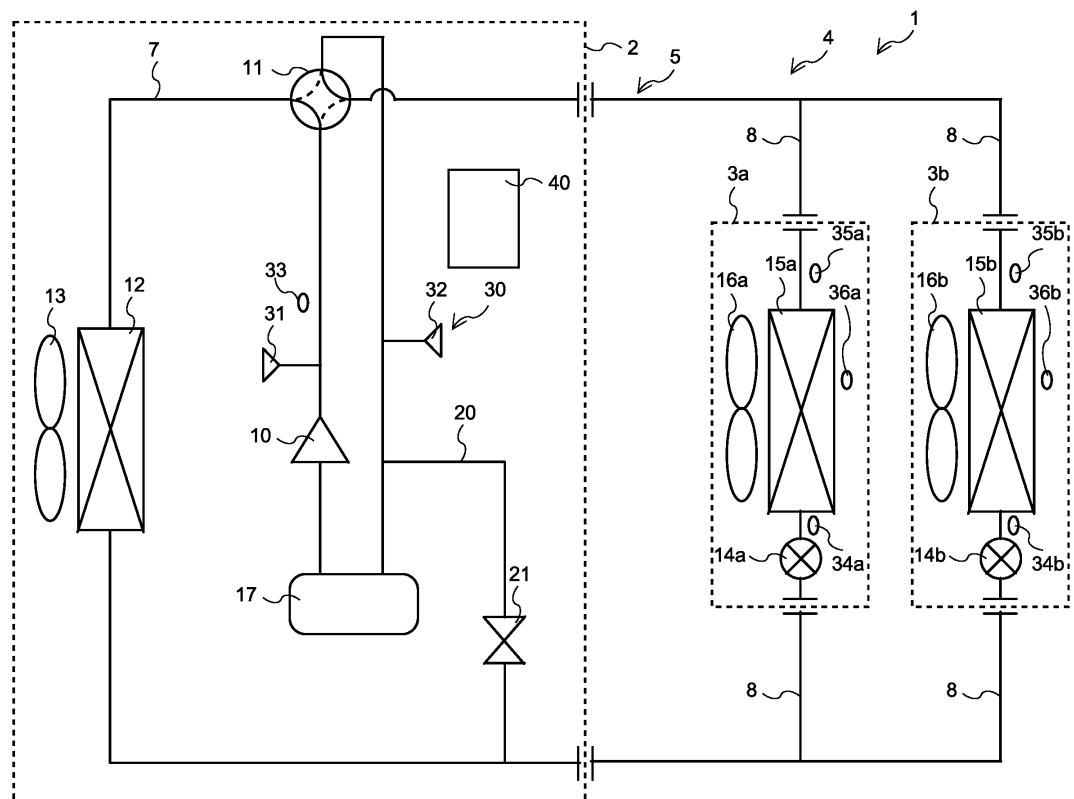
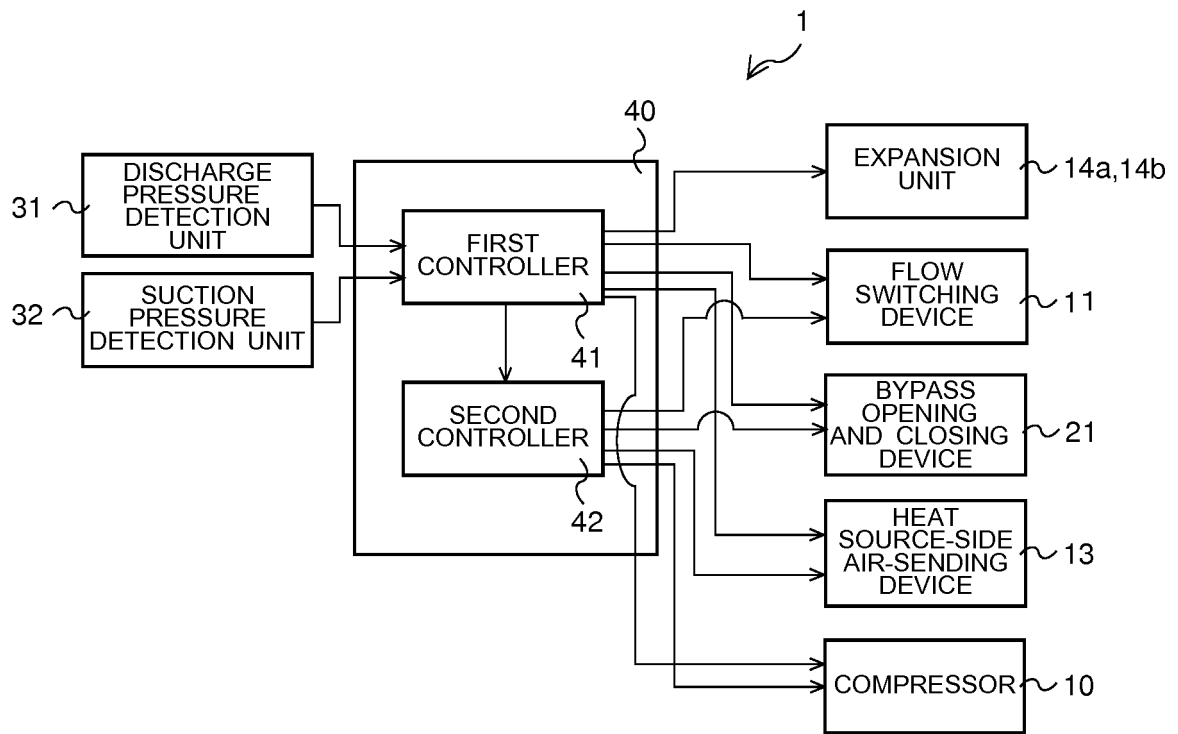


FIG. 2



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FIG. 3

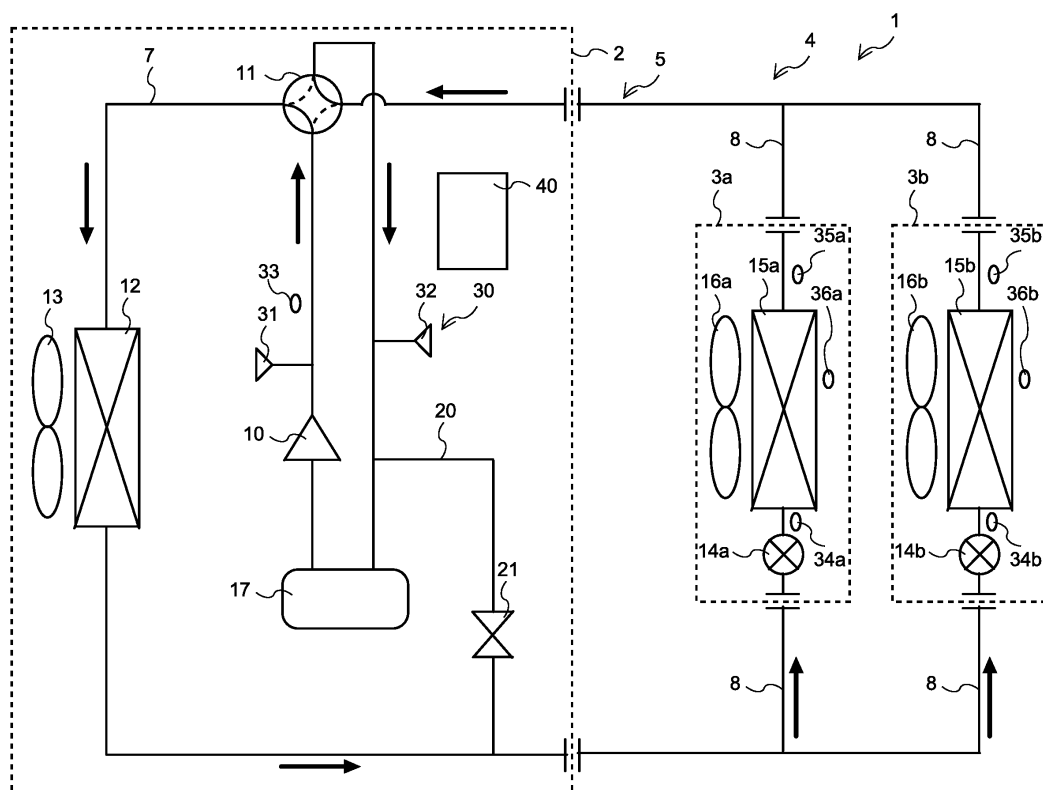


FIG. 4

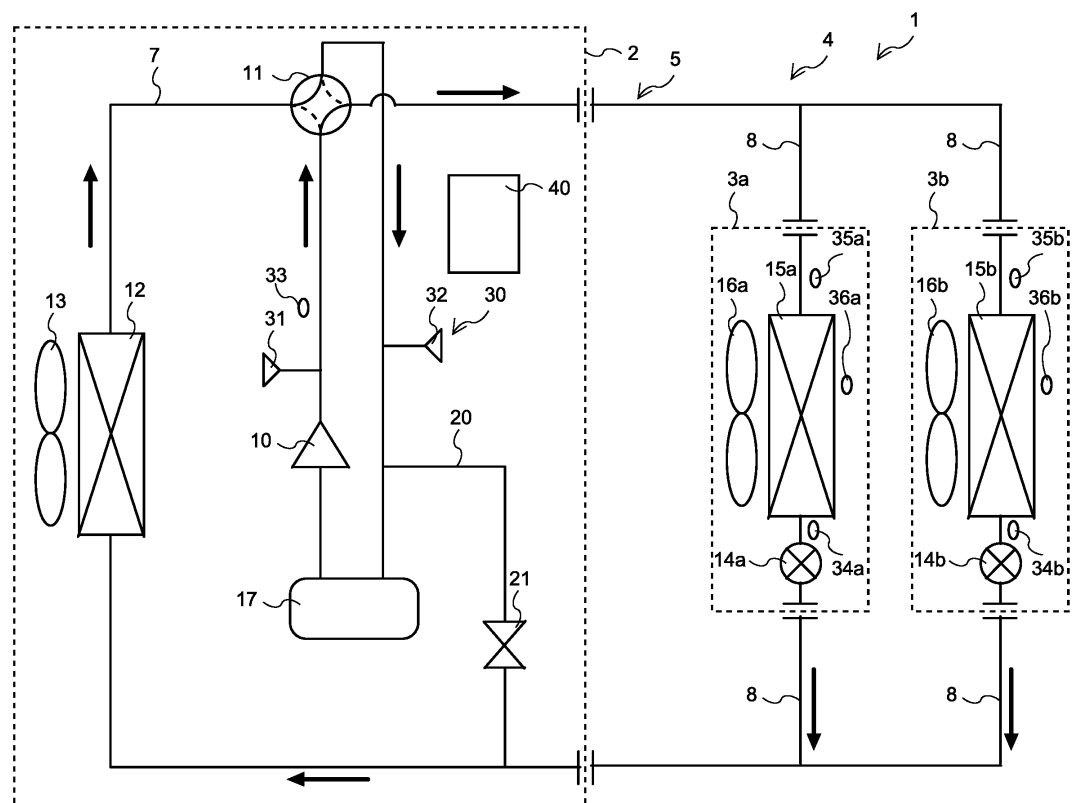


FIG. 5

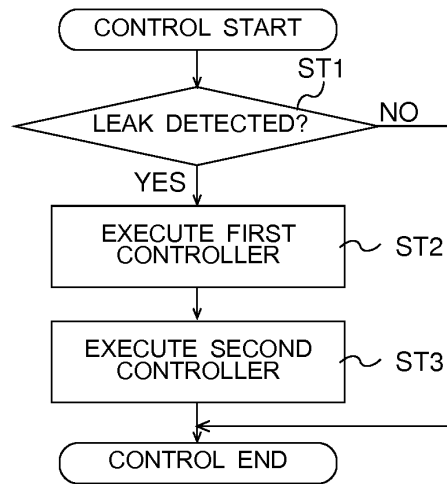


FIG. 6

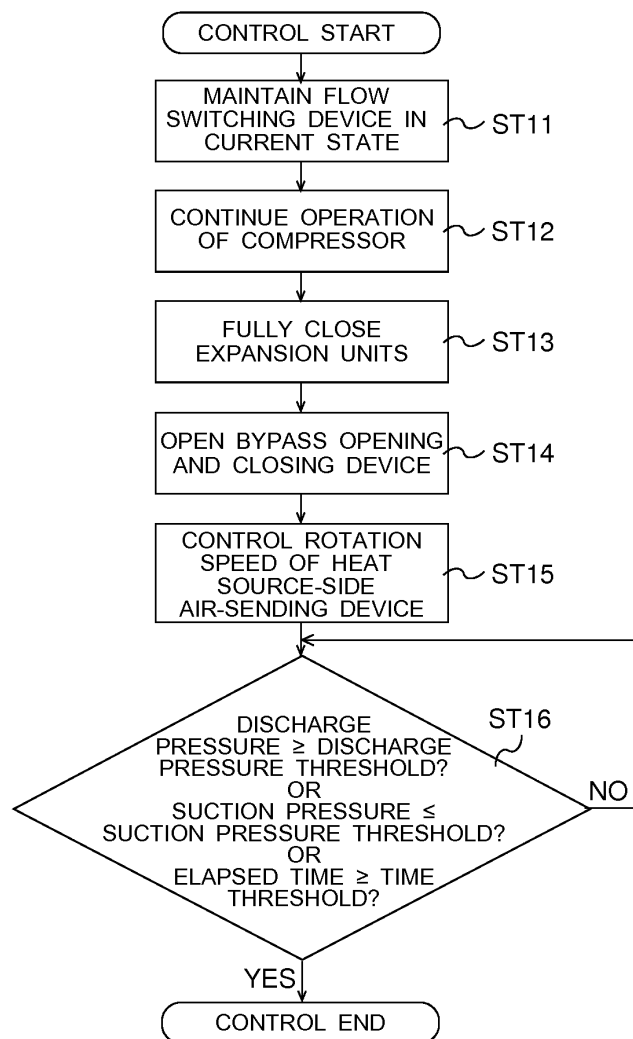


FIG. 7

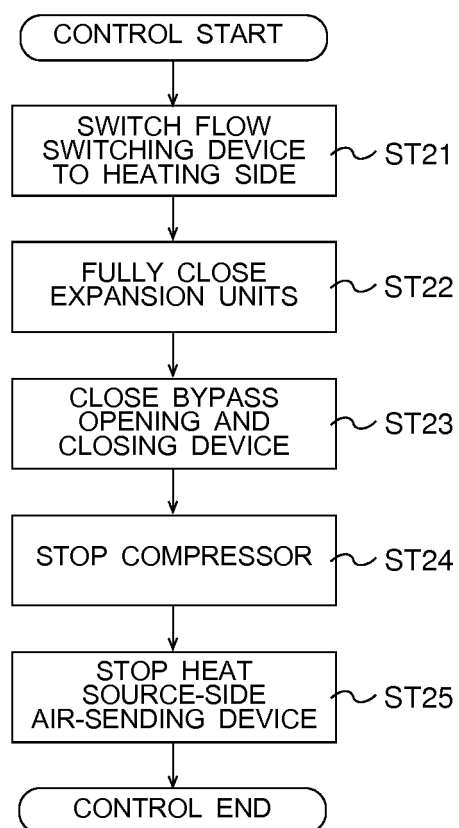


FIG. 8

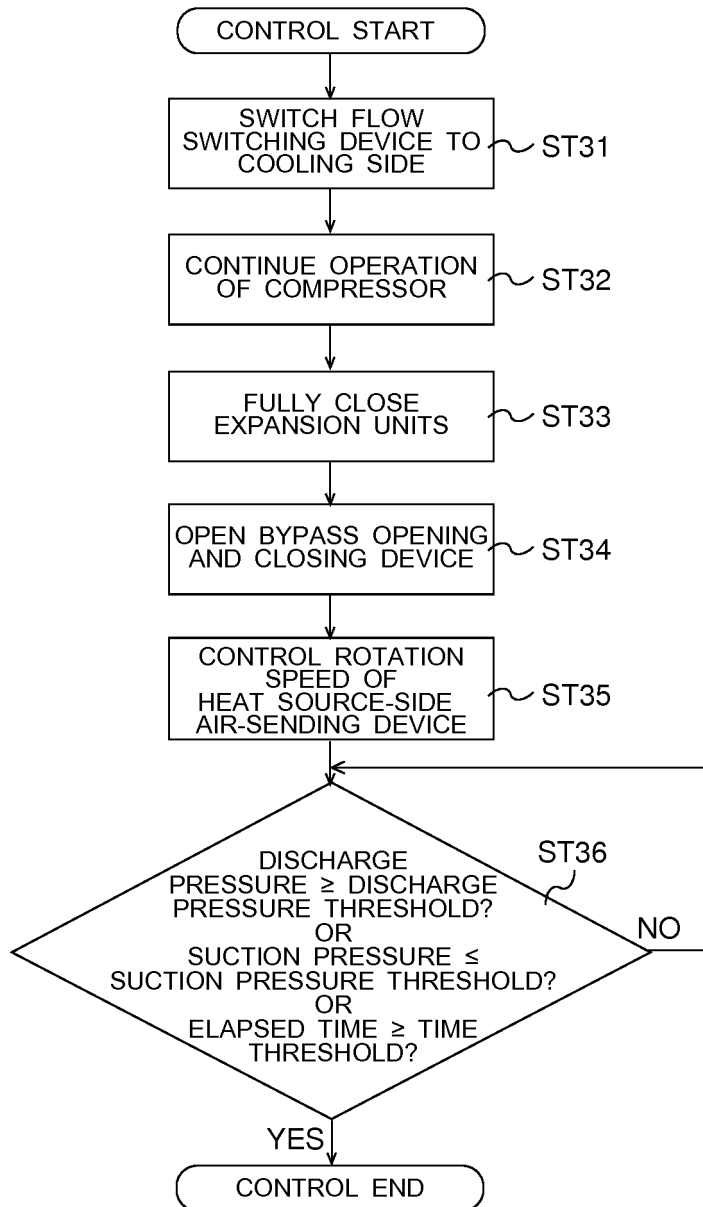


FIG. 9

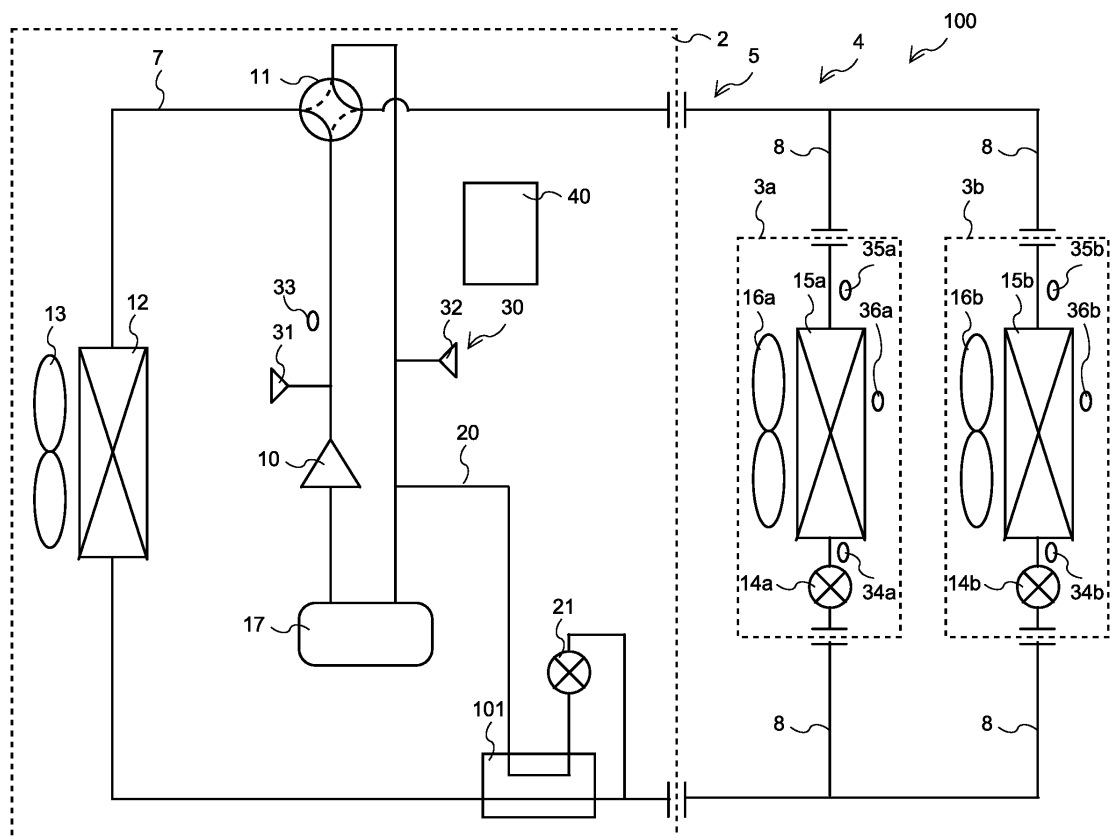


FIG. 10

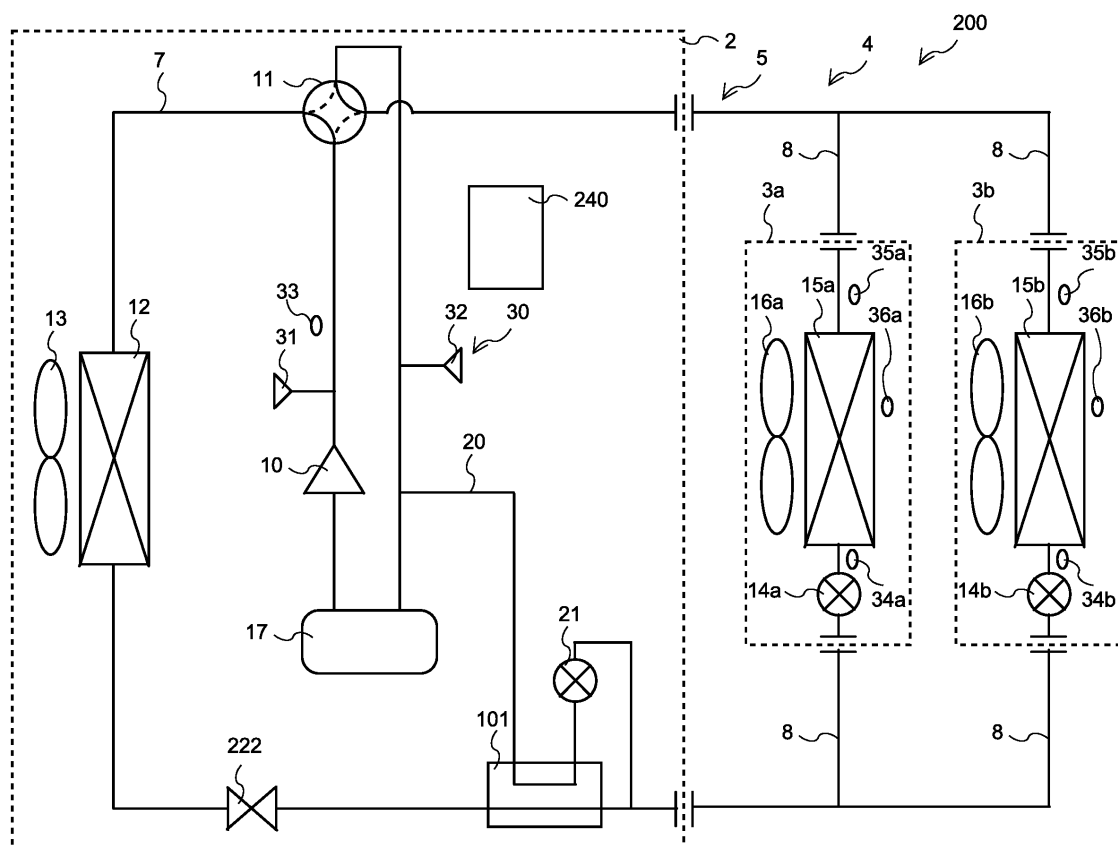


FIG. 11

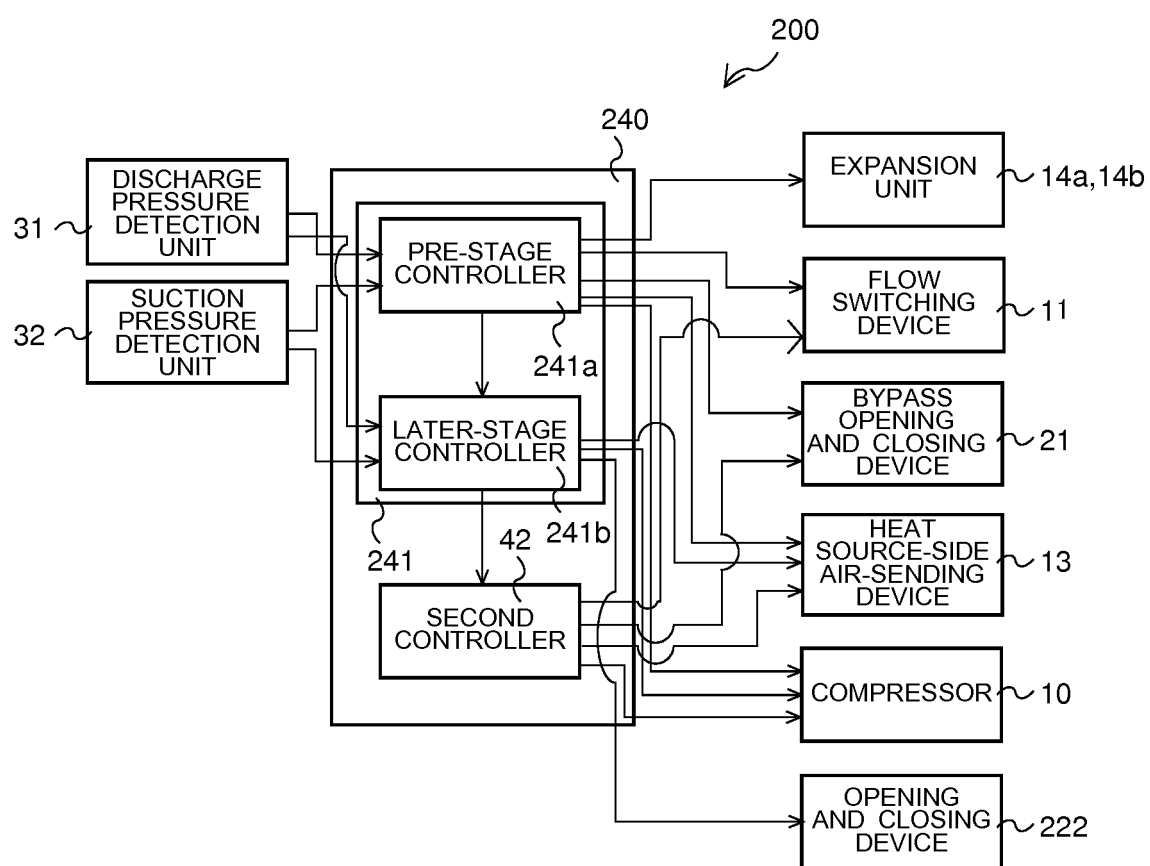


FIG. 12

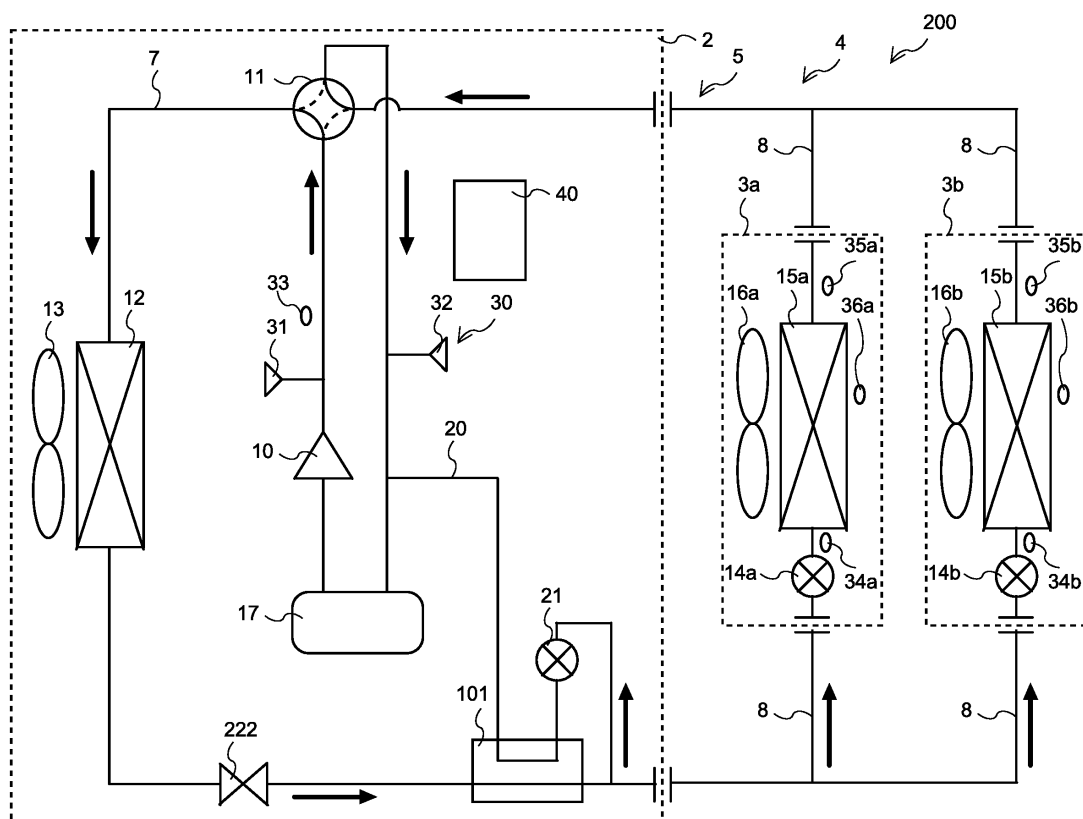


FIG. 13

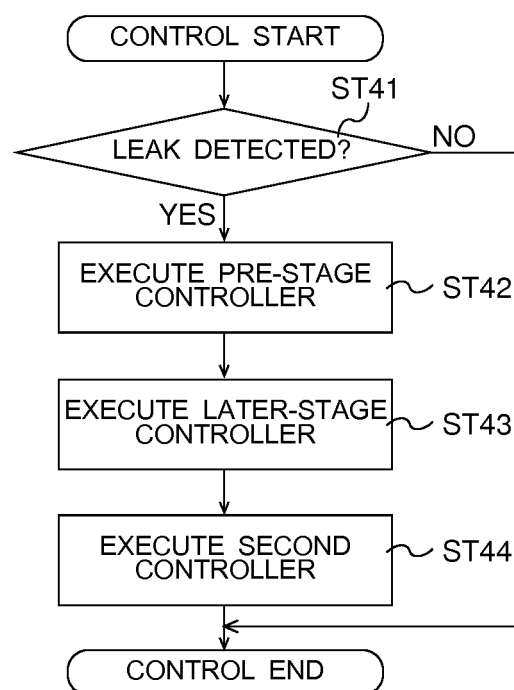


FIG. 14

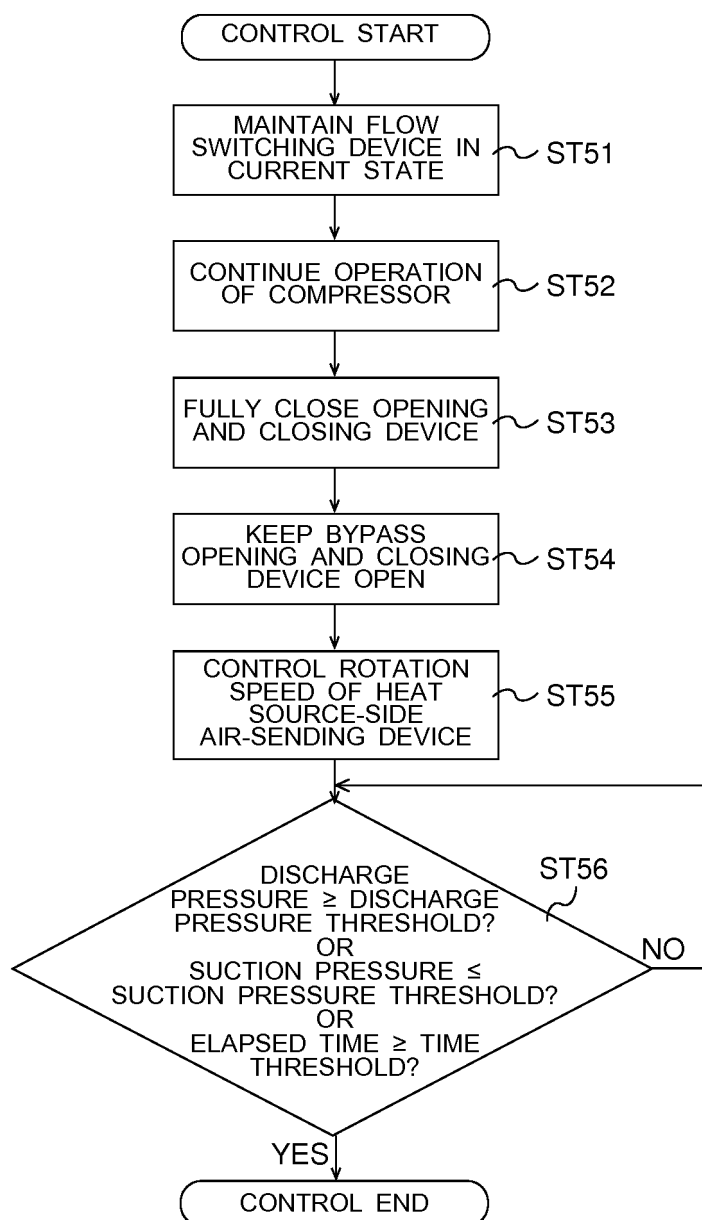
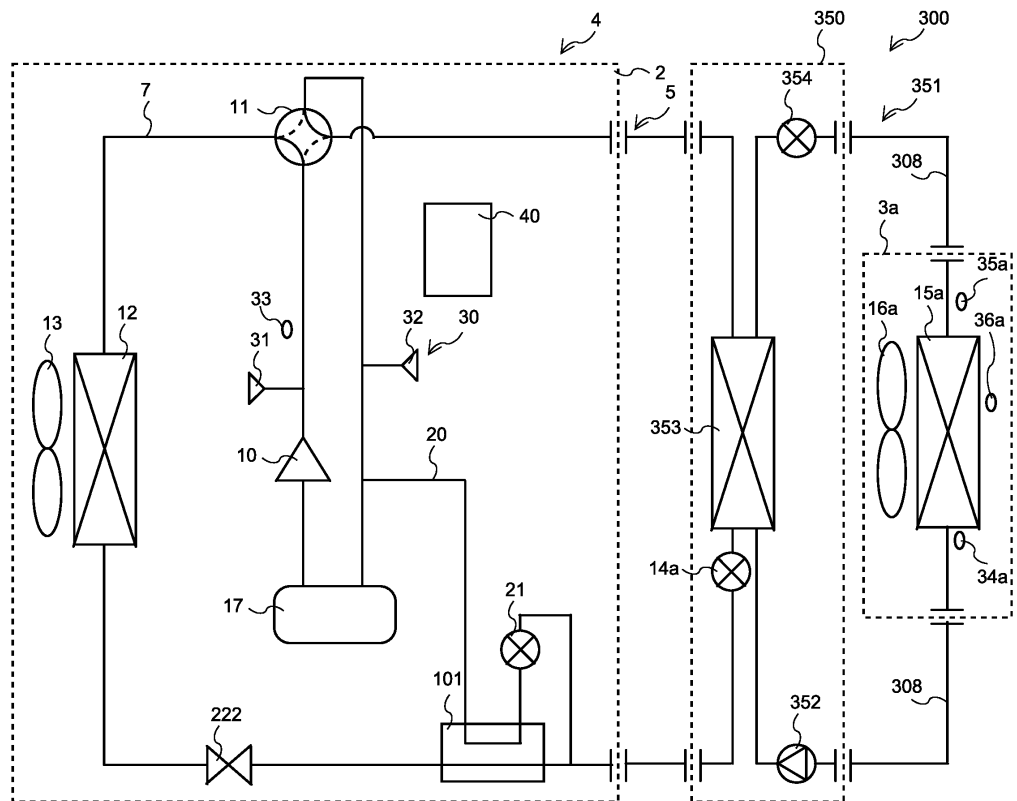


FIG. 15



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/084400

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(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)
F25B1/00

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 1996-2017
Kokai Jitsuyo Shinan Koho 1971-2017 Toroku Jitsuyo Shinan Koho 1994-2017

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2016/157519 A1 (Mitsubishi Electric Corp.), 06 October 2016 (06.10.2016), paragraphs [0011] to [0076]; fig. 1 to 10 (Family: none)	1, 3-13 2
Y	JP 2015-87071 A (Fujitsu General Ltd.), 07 May 2015 (07.05.2015), paragraphs [0033] to [0047], [0097]; fig. 1 to 3 (Family: none)	1, 3-13
Y	JP 2000-266444 A (Matsushita Refrigeration Co.), 29 September 2000 (29.09.2000), paragraph [0211] (Family: none)	10

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

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search
31 January 2017 (31.01.17)

Date of mailing of the international search report
07 February 2017 (07.02.17)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/084400

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 2015/132959 A1 (Mitsubishi Electric Corp.), 11 September 2015 (11.09.2015), entire text; all drawings & US 2017/0010030 A1 entire text; all drawings & EP 3115714 A1 & CN 106062490 A & KR 10-2016-0121581 A	1-13
A	JP 2011-80731 A (Toshiba Corp.), 21 April 2011 (21.04.2011), entire text; all drawings (Family: none)	1-13

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

REFERENCES CITED IN THE DESCRIPTION

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