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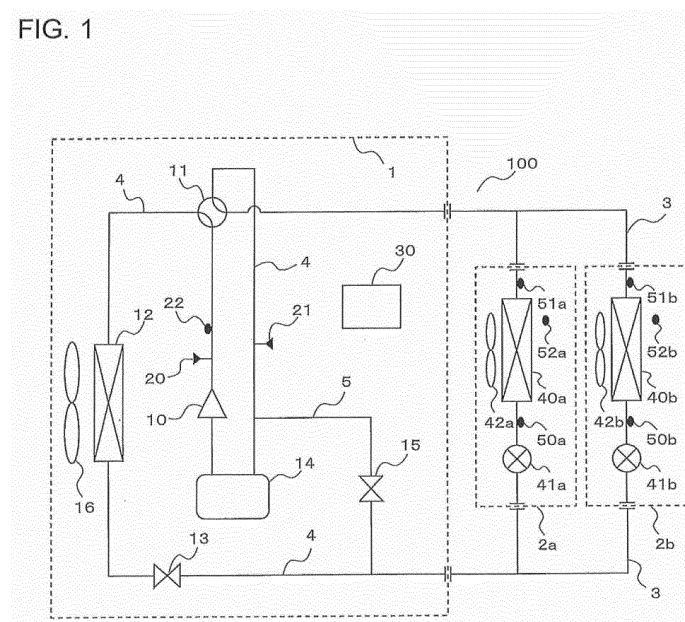
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(54) **AIR-CONDITIONING DEVICE**

(57) The present invention includes a controller 30 that performs a pump-down operation in which, when a leakage of refrigerant is detected, a flow switching device 11 is switched to a direction of a cooling operation so that refrigerant in a refrigerant main pipe 3 is recovered into a heat-side heat exchanger 12 and an accumulator 14, and in which a refrigerant shutoff device 13, a bypass opening-closing device 15 and operation of a compressor

10 are controlled, and then performs a refrigerant leakage amount reduction operation in which the flow switching device 11 is switched to a direction of a heating operation so that the recovered refrigerant is enclosed in the heat-side heat exchanger 12 and the accumulator 14, and in which the refrigerant shutoff device 13, the bypass opening-closing device 15 and operation of the compressor 10 are controlled.

FIG. 1



Description

Technical Field

[0001] The present invention relates to an air-conditioning apparatus that minimizes the amount of leakage of refrigerant.

Background Art

[0002] In a conventional air-conditioning apparatus such as a multi-air conditioner for a building, refrigerant pipes connecting an outdoor unit and a plurality of indoor units to each other may have a total length of several hundred meters, and as a result, a large amount of refrigerant is used. With such an air-conditioning apparatus, in a case when leakage of refrigerant occurs, a large amount of refrigerant may leak into a room.

[0003] In addition, in recent years, switching to refrigerants having a low global warming potential has been required in view of global warming, however, many of the refrigerants having a low global warming potential are flammable. If switching to refrigerants having a low global warming potential progresses in the future, further consideration of safety is necessary. To solve such a problem, a feature has been proposed in which a shutoff valve for closing the flow of refrigerant is provided in a refrigerant circuit to reduce the amount of leakage of the refrigerant in a case when the refrigerant leaks (see Patent Literature 1, for example).

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2000-97527 (Fig. 1, etc.)

Summary of Invention

[0005] Technical Problem

[0006] However, with the feature described in Patent Literature 1, the amount of leakage of the refrigerant can be reduced when the refrigerant leaks, but a large amount of the refrigerant may still leak depending on the position of the shutoff valve for closing the flow of the refrigerant or the location where leakage of the refrigerant occurs.

[0007] To solve the abovementioned problem, the present invention provides an air-conditioning apparatus that further reduces the amount of leakage of refrigerant when a leakage of refrigerant occurs regardless of the operation mode such as a cooling operation or a heating operation.

Solution to Problem

[0008] An air-conditioning apparatus according to the present invention having a refrigerant circuit formed by

connecting a compressor, a flow switching device, a first heat exchanger, a first expansion device, a second heat exchanger, and an accumulator by a pipe, the air-conditioning apparatus being configured to switch between a cooling operation in which the first heat exchanger serves as a condenser and the second heat exchanger serves as an evaporator and a heating operation in which the second heat exchanger serves as a condenser and the first heat exchanger serves as an evaporator by switching the flow switching device, the air-conditioning apparatus including a first opening-closing device provided on the pipe between the first heat exchanger and the expansion device, a bypass pipe branching from the pipe between the first opening-closing device and the expansion device and connected to the pipe between the flow switching device and the accumulator, a second opening-closing device provided on the bypass pipe, and a controller configured to perform a pump-down operation in which, when a leakage of refrigerant is detected, the flow switching device is switched to a direction of the cooling operation so that refrigerant in the pipes is recovered into the first heat exchanger and the accumulator, and in which the first and the second opening-closing devices and the compressor are controlled, and then perform a refrigerant leakage amount reduction operation in which the flow switching device is switched to a direction of the heating operation so that the recovered refrigerant is enclosed in the first heat exchanger and the accumulator, and in which the first and the second opening-closing devices and the compressor are controlled.

Advantageous Effects of Invention

[0009] According to the present invention, when a leakage of refrigerant is detected, the refrigerant inside the refrigerant circuit is recovered into the first heat exchanger and the accumulator and then the recovered refrigerant is enclosed in the first heat exchanger and the accumulator, and as a result, the amount of the refrigerant that would leak into a room space can be further reduced.

Brief Description of Drawings

[0010]

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

[Fig. 2] Fig. 2 is a diagram of refrigerant circuit illustrating the flow of refrigerant when the air-conditioning apparatus of Fig. 1 is in a cooling operation mode.

[Fig. 3] Fig. 3 is a diagram of refrigerant circuit illustrating the flow of refrigerant when the air-conditioning apparatus of Fig. 1 is in a heating operation mode.

[Fig. 4] Fig. 4 is a flowchart illustrating operations of refrigerant leakage prevention control in the air-conditioning apparatus of Fig. 1.

[Fig. 5] Fig. 5 is a flowchart illustrating a pump-down operation when the air-conditioning apparatus of Fig. 2 is in a cooling operation mode.

[Fig. 6] Fig. 6 is a flowchart illustrating a refrigerant leakage amount reduction operation when the air-conditioning apparatus of Fig. 5 is in a cooling operation mode.

[Fig. 7] Fig. 7 is a flowchart illustrating a pump-down operation of the air-conditioning apparatus of Fig. 3 in a heating operation mode and a pump-down operation in a stop mode.

[Fig. 8] Fig. 8 is a diagram of refrigerant circuit illustrating one example of the schematic configuration of an air-conditioning apparatus according to Embodiment 2 of the present invention.

[Fig. 9] Fig. 9 is a diagram of refrigerant circuit illustrating the flow of refrigerant when the air-conditioning apparatus of Fig. 8 is in a cooling operation mode.

[Fig. 10] Fig. 10 is a diagram of refrigerant circuit illustrating one example of the schematic configuration of an air-conditioning apparatus according to Embodiment 3 of the present invention.

Description of Embodiments

[0011] Embodiments of an air-conditioning apparatus according to the present invention will be explained below with reference to the accompanying drawings. Note that, configurations in the drawings are only exemplary and do not limit the present invention. In addition, in the drawings, the features denoted by the same signs are the same or corresponding features, and this applies throughout the specification. Furthermore, in the drawings, the dimensional relationships among the component members may differ from an actual case.

Embodiment 1

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

[0013] In Fig. 1, an air-conditioning apparatus 100 is a multi-air conditioner for a building, for example, provided with a refrigerant circuit composed of an outdoor unit 1 and two indoor units 2a, 2b connected to the outdoor unit 1 via a refrigerant main pipe 3. The air-conditioning apparatus 100 allows refrigerant to circulate in the refrigerant circuit to perform air conditioning by using the refrigeration cycle, and is configured in such a manner that a cooling only operation mode, in which both indoor units 2a, 2b perform cooling, or a heating only operation mode, in which both indoor units 2a, 2b perform heating, can be selected arbitrarily.

[Outdoor Unit 1]

[0014] The outdoor unit 1 includes a compressor 10,

a flow switching device 11 formed of a four-way valve or another valve, a heat-side heat exchanger 12, a refrigerant shutoff device 13, and an accumulator 14, and these components are connected by a refrigerant pipe 4. An outdoor fan 16 that sends air to the heat-side heat exchanger 12 is provided near the heat-side heat exchanger 12. Note that the heat-side heat exchanger 12 corresponds to the "first heat exchanger" of the present invention, the outdoor fan 16 corresponds to the "fan" of the present invention, and the refrigerant shutoff device 13 corresponds to the "first opening/closing device" of the present invention.

[0015] The compressor 10 sucks a low-temperature low-pressure gas refrigerant and compresses the gas refrigerant to a high-temperature high-pressure state, and is formed of, for example, an inverter compressor capable of controlling capacity. The flow switching device 11 switches between the flow of refrigerant in a cooling operation mode and the flow of refrigerant in a heating operation mode.

[0016] The heat-side heat exchanger 12 functions as a condenser in a cooling operation and functions as an evaporator in a heating operation, and exchanges heat between the air supplied from the outdoor fan 16 and the refrigerant. The refrigerant shutoff device 13 is formed of, for example, a solenoid valve that blocks the flow of the refrigerant circulating in the refrigerant pipe 4. Note that the refrigerant shutoff device 13 is formed of a solenoid valve, but may be formed of any feature that can block the flow of refrigerant.

[0017] The outdoor unit 1 also includes a bypass pipe 5 that branches from the refrigerant pipe 4 on the side of the refrigerant shutoff device 13, the refrigerant pipe 4 being connected to one terminal of the refrigerant main pipe 3, and that is connected to the refrigerant pipe 4 connecting the flow switching device 11 and the suction side of the compressor 10 to each other, and a bypass opening/closing device 15 provided along the bypass pipe 5. The bypass opening/closing device 15 corresponds to the "second opening/closing device" of the present invention, and is formed of, for example, a solenoid valve that blocks the flow of the refrigerant in the bypass pipe 5. Note that Fig. 1 shows an example in which the connection points of the bypass pipe 5 are located inside the outdoor unit 1, but the location is not limited thereto. In addition, the bypass opening/closing device 15 is formed of a solenoid valve, but may be formed of any feature that can block the flow of refrigerant.

[0018] Furthermore, the outdoor unit 1 is provided with a first pressure detection device 20 and a second pressure detection device 21. The first pressure detection device 20 is provided on the refrigerant pipe 4 connecting the discharge side of the compressor 10 and the flow switching device 11 to each other, and detects a pressure P1 of a high-temperature high-pressure gas refrigerant that is compressed by and discharged from the compressor 10. The second pressure detection device 21 is pro-

vided on the refrigerant pipe 4 connecting the flow switching device 11 and the suction side of the compressor 10 to each other, and detects a pressure P2 of a low-temperature low-pressure gas refrigerant that is sucked into the compressor 10.

[0019] In addition, the outdoor unit 1 is provided with a first temperature detection device 22 formed of, for example, a thermistor. The first temperature detection device 22 is provided on the refrigerant pipe 4 connecting the discharge side of the compressor 10 and the flow switching device 11 to each other, and detects the temperature of a high-temperature high-pressure gas refrigerant that is compressed by and discharged from the compressor 10.

[Indoor Units 2a, 2b]

[0020] The indoor units 2a, 2b respectively include load-side heat exchangers 40a, 40b, expansion devices 41 a, 41 b, and indoor fans 42a, 42b. The indoor units 2a, 2b are connected to the outdoor unit 1 via the refrigerant main pipe 3 and allow refrigerant to flow in and out. The load-side heat exchangers 40a, 40b exchange heat between the air supplied from the indoor fans 42a, 42b and the refrigerant to generate a heating air or a cooling air to be supplied to a room space. The expansion devices 41 a, 41 b are formed of, for example, electronic expansion valves having functions of a pressure reducing valve and an expansion valve. Note that the load-side heat exchangers 40a, 40b correspond to the "second heat exchanger" of the present invention.

[0021] In the indoor units 2a, 2b, second temperature detection devices 50a, 50b are respectively provided on the refrigerant pipes connecting the load-side heat exchangers 40a, 40b and the expansion devices 41 a, 41 b to each other. Furthermore, third temperature detection devices 51 a, 51 b are respectively provided on the refrigerant pipes of the load-side heat exchangers 40a, 40b opposite to the expansion devices 41 a, 41 b. Moreover, fourth temperature detection devices 52a, 52b are respectively provided on the air suction side of the load-side heat exchangers 40a, 40b.

[0022] The second temperature detection devices 50a, 50b detect the temperature of the refrigerant flowing into the load-side heat exchangers 40a, 40b in a cooling operation. The third temperature detection devices 51 a, 51 b detect the temperature of the refrigerant flowing out from the load-side heat exchangers 40a, 40b. The fourth temperature detection devices 52a, 52b detect the temperature of indoor air. For each of the temperature detection devices, a thermistor, for example, is used.

[0023] The air-conditioning apparatus 100 has a controller 30 formed of a microcomputer or another device. When a leakage of refrigerant is detected on the basis of a detection value of a gas sensor provided in a room or detection values of various measuring sensors provided in the indoor units 2a, 2b, the controller 30 controls the flow switching device to switch the flow direction to

a cooling operation direction so that the refrigerant inside the refrigerant circuit is recovered into the heat-side heat exchanger 12 and the accumulator 14, and performs a pump-down operation by controlling the refrigerant shutoff device 13, the bypass opening/closing device 15 and the compressor 10. Then, the controller 30 controls the flow switching device 11 to switch the flow direction to a heating operation direction so that the recovered refrigerant is enclosed in the heat-side heat exchanger 12 and the accumulator 14, and performs a refrigerant leakage amount reduction operation by controlling the refrigerant shutoff device 13, the bypass opening/closing device 15 and the compressor 10.

[0024] Furthermore, to execute various operation modes, which will be described later, the controller 30 controls the operation frequency of the compressor 10, the rotation speed (including ON/OFF) of the outdoor fan 16, the switching of the flow switching device 11, and the opening degrees of the expansion devices 41 a, 41 b on the basis of the detection values of various detection devices and the instructions received from a remote controller. Note that Fig. 1 shows an example in which the controller 30 is provided in the outdoor unit 1, however, a controller 30 may be provided in each unit of the outdoor unit 1 and the indoor units 2a, 2b, or may be provided in any one of the outdoor unit 1 and the indoor units 2a, 2b.

[Cooling Operation Mode]

[0025] In the air-conditioning apparatus 100 configured as described above, a cooling operation mode in a case where cooling load is generated in the load-side heat exchangers 40a, 40b will be explained with reference to Fig. 2.

[0026] Fig. 2 is a diagram of refrigerant circuit illustrating the flow of refrigerant when the air-conditioning apparatus of Fig. 1 is in a cooling operation mode. Note that the solid line arrows illustrated in the figure indicate the directions of refrigerant flow.

[0027] In a cooling operation mode, a low-temperature low-pressure gas refrigerant that is sucked into the compressor 10 is compressed by the compressor 10 and is discharged therefrom as a high-temperature high-pressure gas refrigerant. The high-temperature high-pressure gas refrigerant discharged from the compressor 10 flows into the heat-side heat exchanger 12 via the flow switching device 11. The high-temperature high-pressure gas refrigerant that flows into the heat-side heat exchanger 12 condenses while rejecting heat to outside air, and becomes a high-pressure liquid refrigerant. Then, the high-pressure liquid refrigerant that flows out from the heat-side heat exchanger 12 passes through the refrigerant shutoff device 13, which is in an open state, flows out from the outdoor unit 1, and then passes through the refrigerant main pipe 3 and flows into the indoor units 2a, 2b. In doing so, the bypass opening/closing device 15 is set to a closed state to prevent the refrigerant from bypassing in the outdoor unit 1.

[0028] The refrigerant shutoff device 13 in a cooling operation mode is set to open if the device is a solenoid valve or another device of which the opening degree (opening area) cannot be regulated, or is set to an opening degree (e.g., fully open) that does not have a negative influence on an operation condition (e.g., cooling capacity) of the refrigeration cycle if the device is a device, such as an electronic expansion valve, of which the opening degree can be regulated.

[0029] Furthermore, the bypass opening/closing device 15 in a cooling operation mode is set to open if the device is a solenoid valve or another device of which the opening degree cannot be regulated, or is set to an opening degree (e.g., fully open) that does not have a negative influence on an operation condition (e.g., cooling capacity) of the refrigeration cycle if the device is a device, such as an electronic expansion valve, of which the opening degree can be regulated.

[0030] The high-pressure liquid refrigerant that flows into the indoor unit 2 is decompressed by the expansion device 41, thereby becoming a gas-liquid two-phase refrigerant having a low-temperature low-pressure, and then flows into the load-side heat exchanger 40 functioning as an evaporator to remove heat from the indoor air, thereby cooling the indoor air, and becomes a low-temperature low-pressure gas refrigerant. The low-temperature low-pressure gas refrigerant that flows from the load-side heat exchanger 40 passes through the refrigerant main pipe 3 and flows into the outdoor unit 1. The low-temperature low-pressure gas refrigerant that flows into the outdoor unit 1 passes through the flow switching device 11 and the accumulator 14 and is then sucked into the compressor 10.

[0031] The opening degrees of the expansion devices 41 a, 41 b are controlled by the controller 30 in such a manner that the superheat (degree of superheat) obtained as a difference between the temperatures detected by the second temperature detection devices 50a, 50b and the temperature detected by the third temperature detection device 51 becomes constant.

[Heating Operation Mode]

[0032] Next, a heating operation mode in a case where heating load is generated in the load-side heat exchanger 40 will be explained with reference to Fig. 3.

[0033] Fig. 3 is a diagram of refrigerant circuit illustrating the flow of refrigerant when the air-conditioning apparatus of Fig. 1 is in a heating operation mode. Note that the solid line arrows illustrated in the figure indicate the directions of refrigerant flow.

[0034] In the heating operation mode illustrated in Fig. 3, a low-temperature low-pressure gas refrigerant that is sucked into the compressor 10 is compressed by the compressor 10 and is discharged therefrom as a high-temperature high-pressure gas refrigerant. The high-temperature high-pressure gas refrigerant discharged from the compressor 10 passes through the refrigerant

main pipe 3 and flows into the indoor unit 2 via the flow switching device 11. The high-temperature high-pressure gas refrigerant that flows into the indoor unit 2 rejects heat to the indoor air at the load-side heat exchanger 40, becomes a high-pressure liquid refrigerant, and then flows into the expansion device 41. Then, after being decompressed by the expansion device 41 into a gas-liquid two-phase refrigerant having a low-temperature low-pressure, the refrigerant flows out from the indoor unit 2, passes through the refrigerant main pipe 3, and flows into the outdoor unit 1.

[0035] The low-temperature low-pressure two-phase refrigerant that flows into the outdoor unit 1 passes through the refrigerant shutoff device 13, which is in an open state, and receives heat from the outside air at the heat-side heat exchanger 12, thereby becoming a low-temperature low-pressure gas refrigerant. The low-temperature low-pressure gas refrigerant that flows out from the heat-side heat exchanger 12 passes through the flow switching device 11 and the accumulator 14 and is then sucked into the compressor 10.

[0036] The refrigerant shutoff device 13 in a heating operation mode is set to open if the device is a solenoid valve or another device of which the opening degree cannot be regulated, or is set to an opening degree (e.g., fully open) that does not have a negative influence on an operation condition (e.g., heating capacity) of the refrigeration cycle if the device is a device, such as an electronic expansion valve, of which the opening degree can be regulated.

[0037] In addition, the bypass opening/closing device 15 in a heating operation mode is set to open if the device is a solenoid valve or another device of which the opening degree cannot be regulated, or is set to an opening degree (e.g., fully open) that does not have a negative influence on an operation condition (e.g., heating capacity) of the refrigeration cycle if the device is a device, such as an electronic expansion valve, of which the opening degree can be regulated.

[0038] The opening degrees of the expansion devices 41 a, 41 b are controlled by the controller 30 in such a manner that the subcooling (degree of subcooling) obtained as a difference between the saturated liquid temperature of the refrigerant calculated on the basis of the pressure detected by the first pressure detection device 20 and the temperatures detected by the second temperature detection devices 50a, 50b becomes constant.

[0039] Next, refrigerant leakage prevention control will be explained.

[0040] Refrigerant leakage prevention control is one of the functions of the controller 30, as described above, and is a control function that is initiated when a leakage of refrigerant is detected by a gas sensor provided in a room or detected on the basis of detection values of various measurement sensors provided in the indoor units 2a, 2b. A specific example of detecting an occurrence of refrigerant leakage will be described, however, a detection method is not limited thereto and any method may

be used as long as the method is capable of detecting an occurrence of refrigerant leakage and capable of using the timing of the detected refrigerant leakage as a point of starting the control operation.

[0041] Fig. 4 is a flowchart illustrating operations of refrigerant leakage prevention control in the air-conditioning apparatus of Fig. 1.

[0042] When detecting an occurrence of refrigerant leakage (S1), the controller 30 starts the refrigerant leakage prevention control. That is, the controller 30 performs a pump-down operation for recovering the liquid refrigerant existing on the side of the indoor unit 2 into the outdoor unit 1 (S2). Then, the controller 30 performs a refrigerant leakage amount reduction operation that prevents the liquid refrigerant recovered in the outdoor unit 1 from returning to the indoor unit 2 (S3).

[Refrigerant Leakage Prevention Control in Cooling Operation Mode]

[0043] A pump-down operation of the refrigerant leakage prevention control in a cooling operation mode will be explained in detail with reference to Fig. 5.

[0044] Fig. 5 is a flowchart illustrating a pump-down operation when the air-conditioning apparatus of Fig. 2 is in a cooling operation mode.

[0045] First, the controller 30 makes the flow switching device 11 to keep the flow path of the cooling operation mode (S11), and then sets the operation frequency of the compressor 10 to a predetermined value (S12). Then, the controller 30 closes the refrigerant shutoff device 13 and opens the bypass opening/closing device 15 (S13, S14). The controller 30 then sets the rotation speed of the outdoor fan 16 to a predetermined value (S15), and at last, terminates the pump-down operation when a pressure P1 (or P2) detected by either one of the first pressure detection device 20 and the second pressure detection device 21 reaches a threshold (S16).

[0046] If the predetermined value to be set in S12 for the operation frequency of the compressor 10 is set at a high frequency, the pressure of the refrigeration cycle may change abruptly, thereby causing an abnormal stoppage or another problem. On the other hand, if the predetermined value is set at a low frequency, the effects of the pump-down are reduced, and thus operating the compressor 10 at the allowable minimum operation frequency is not preferable. Therefore, it is preferable that a pump-down operation be performed at an operation frequency corresponding to a middle frequency between the minimum and maximum frequencies.

[0047] It is preferable that the predetermined value to be set in S15 for the rotation speed of the outdoor fan 16 be set to the maximum rotation speed. By setting the rotation speed of the outdoor fan 16 to the maximum rotation speed, the refrigerant is readily condensed at the heat-side heat exchanger 12, and as a result, the discharge pressure of the compressor 10 can be suppressed from increasing.

[0048] For the thresholds which have been set for terminating a pump-down operation in S16, if the high-pressure side threshold is set to a value as high as possible and the low-pressure side threshold is set to a value as low as possible, much refrigerant can be transferred from the indoor unit 2 to the outdoor unit 1, and as a result, a higher degree of safety can be assured. Therefore, for the first pressure detection device 20, it is preferable that the threshold (first threshold) be a maximum pressure or a value near the maximum pressure allowed during operation of the compressor 10. For the second pressure detection device 21, it is preferable that the threshold (second threshold) be a minimum pressure or a value near the minimum pressure allowed during operation of the compressor 10. Note that, in S16 of Fig. 5, a pump-down operation is terminated when either one of the first pressure detection device 20 and the second pressure detection device 21 reaches the corresponding threshold, however, instead of this, a pump-down operation may be terminated when the detection pressure (P1) of the first pressure detection device 20 becomes equal to or greater than the first threshold and the detection pressure (P2) of the second pressure detection device 21 becomes equal to or less than the second threshold.

[0049] By performing the pump-down operation shown in Fig. 5 in a cooling operation mode, the refrigerant existing in the refrigerant pipe 4, which connects from the heat-side heat exchanger 12 to the expansion device 41 and in which much liquid refrigerant exists in a cooling operation mode, can be recovered to the heat-side heat exchanger 12 and the accumulator 14 via the bypass pipe 5. Therefore, the amount of the liquid refrigerant of the refrigerant existing in the indoor unit 2 and in the refrigerant main pipe 3 connected to the indoor unit 2 is reduced, and as a result, the amount of refrigerant leaking into a room space can be reduced.

[0050] Note that Fig. 5 shows a specific operation order of the pump-down operation, however, the operation order is not limited thereto, and for S11 to S15, a similar effect can be obtained even if the operation order is reversed.

[0051] Fig. 6 is a flowchart illustrating a refrigerant leakage amount reduction operation when the air-conditioning apparatus of Fig. 5 is in a cooling operation mode.

[0052] First, the controller 30 switches the flow switching device 11 to the flow path of the heating operation mode (S21), and then keeps the refrigerant shutoff device 13 close (S22). Then, the controller 30 closes the bypass opening/closing device 15 (S23), and terminates the operation of the compressor 10 (S24). The controller 30 then terminates the outdoor fan 16 (S25), and at last, fully closes the expansion device 41 (S26).

[0053] By performing the refrigerant leakage amount reduction operation shown in Fig. 6, the refrigerant recovered in the heat-side heat exchanger 12 and the accumulator 14 can be enclosed in the outdoor unit 1, and as a result, transferring of the refrigerant to the indoor unit 2 can be prevented. Consequently, the amount of

refrigerant that would leak into a room space can be reduced, thereby improving safety.

[0054] In addition, by fully closing the expansion device 41, the upstream side and the downstream side of the expansion device 41 are separated from each other, and consequently, the amount of refrigerant that would leak can be further reduced, thereby improving safety.

[0055] Note that Fig. 6 shows a specific operation order of the refrigerant leakage amount reduction operation, however, the operation order is not limited thereto, and a similar effect can be obtained even if the operation order is reversed.

[Refrigerant Leakage Prevention Control in Heating Operation Mode]

[0056] Refrigerant leakage prevention control in a heating operation mode will be explained in detail.

[0057] Fig. 7 is a flowchart illustrating a pump-down operation of the air-conditioning apparatus of Fig. 3 in a heating operation mode and a pump-down operation in a stop mode.

[0058] First, the controller 30 switches the flow switching device 11 to the flow path of the cooling operation mode (S31), and then sets the operation frequency of the compressor 10 to a predetermined value (S32). Then, the controller 30 closes the refrigerant shutoff device 13 (S33) and opens the bypass opening/closing device 15 (S34). Then, the controller 30 sets the rotation speed of the outdoor fan 16 to a predetermined value (S35), and at last, terminates the pump-down operation when a pressure P1 (or P2) detected by either one of the first pressure detection device 20 and the second pressure detection device 21 reaches a threshold. (S36).

[0059] The pump-down operation of the refrigerant leakage prevention control in a heating operation mode is the same operation as the pump-down operation in a cooling operation mode except that the first step, which is the switching operation of the flow switching device 11 shown as S11, is different.

[0060] By performing the pump-down operation shown in Fig. 7 in a heating operation mode, the refrigerant existing in the load-side heat exchanger 40 and in the refrigerant main pipe 3 connecting from the load-side heat exchanger 40 to the refrigerant shutoff device 13, the load-side heat exchanger 40 and the refrigerant main pipe 3 in which much liquid refrigerant exists in a heating operation mode, can be recovered to the heat-side heat exchanger 12 and the accumulator 14. Therefore, the amount of the liquid refrigerant of the refrigerant existing in the indoor unit 2 and in the refrigerant main pipe 3 is reduced, and as a result, the amount of refrigerant leaking into a room space can be reduced.

[0061] Note that Fig. 7 shows a specific operation order of the pump-down operation, however, the operation order is not limited thereto, and for S31 to S35, a similar effect can be obtained even if the operation order is reversed.

[0062] Note that the refrigerant leakage amount reduction operation in a heating operation mode is the same as the refrigerant leakage amount reduction operation in a cooling operation mode shown in Fig. 6. Therefore, the refrigerant recovered in the heat-side heat exchanger 12 and the accumulator 14 can be enclosed in the outdoor unit 1, and as a result, transferring of the refrigerant to the indoor unit 2 can be prevented. Consequently, the amount of refrigerant that would leak into a room space can be reduced, thereby improving safety.

[0063] In addition, by fully closing the expansion device 41, the upstream side and the downstream side of the expansion device 41 are separated from each other, and consequently, the amount of refrigerant that would leak can be further reduced, thereby improving safety.

[Refrigerant Leakage Prevention Control in Stop Mode]

[0064] Refrigerant leakage prevention control in a case where a leakage of refrigerant occurs while the air-conditioning apparatus 100 is being stopped (hereinafter referred to as stop mode) will be explained.

[0065] The pump-down operation of the refrigerant leakage prevention control to be executed when a leakage of refrigerant occurs in a stop mode is the same as the pump-down operation in a heating operation mode shown in Fig. 7, and can obtain the same effect. However, since the compressor 10 is not being operated in a stop mode and the pressure in the refrigerant circuit is constant, operation of a device that is driven by using a pressure difference needs to be performed after the operation frequency of the compressor 10 is set to a predetermined value to generate a pressure difference in the refrigerant circuit.

[0066] In a stop mode, where a liquid refrigerant is present in the air-conditioning apparatus 100 depends on temperature conditions of indoor and outdoor and an elapsed time after termination, and thus the location of a liquid refrigerant varies from time to time. By performing the pump-down operation shown in Fig. 7, the ratio of the liquid refrigerant existing in the indoor unit 2 and the refrigerant main pipe 3 is reduced, and as a result, the amount of refrigerant that would leak into a room space can be reduced.

[0067] The refrigerant leakage amount reduction operation of the refrigerant leakage prevention control in a stop mode is the same as the refrigerant leakage amount reduction operation in a cooling operation mode shown in Fig. 6, and can obtain the same effect.

[Refrigerant Leakage Prevention Control in Thermo-off Mode]

[0068] Refrigerant leakage prevention control in a case where a leakage of refrigerant occurs when the air-conditioning apparatus 100 is in a thermos-off state (hereinafter referred to as thermos-off mode) will be explained.

[0069] The pump-down operation of the refrigerant

leakage prevention control to be executed when a leakage of refrigerant occurs in a thermos-off mode is the same as the pump-down operation in a heating operation mode shown in Fig. 7, and can obtain the same effect. However, since the compressor 10 is not being operated in a thermos-off mode and the pressure in the refrigerant circuit is constant, operation of a device that is driven by using a pressure difference needs to be performed after the operation frequency of the compressor 10 is set to a predetermined value to generate a pressure difference in the refrigerant circuit.

[0070] The refrigerant leakage amount reduction operation of the refrigerant leakage prevention control in a thermos-off mode is the same as the refrigerant leakage amount reduction operation in a cooling operation mode shown in Fig. 6, and can obtain the same effect.

[0071] Note that, in Embodiment 1, a case in which two indoor units 2 are connected to the outdoor unit 1 via the refrigerant main pipe 3 is illustrated as an example, but the number of the indoor units 2 to be connected is not limited to two, and only one indoor unit 2 or three or more indoor units 2 may be connected to the outdoor unit 1.

Embodiment 2

[0072] For Embodiment 2 of the present invention, only the points different from Embodiment 1 will be explained.

[0073] Fig. 8 is a diagram of refrigerant circuit illustrating one example of the schematic configuration of an air-conditioning apparatus according to Embodiment 2 of the present invention.

[0074] Embodiment 2 is different from Embodiment 1 in that an internal heat exchanger 17 is provided on a refrigerant pipe 4 on which a refrigerant shutoff device 13 is installed, a diversion part of a bypass pipe 5 is formed by branching from the refrigerant pipe 4 between the internal heat exchanger 17 and an expansion device 41, and that a bypass opening/closing device 15 is provided on the bypass pipe 5 between the diversion point and the internal heat exchanger 17.

[0075] In Embodiment 2, the internal heat exchanger 17 is used, and therefore, especially in a cooling operation mode, the degree of subcooling of the refrigerant flowing in the refrigerant main pipe 3 can be increased by bypassing some of a high-pressure liquid refrigerant generated by a heat-side heat exchanger 12 by the bypass pipe 5, reducing the pressure of the bypassed refrigerant to generate a low-pressure low-temperature gas-liquid two-phase refrigerant, and exchanging heat with the refrigerant at the inside of the internal heat exchanger 17. As the bypass opening/closing device 15, a feature in which the opening degree can be freely changed, such as an electronic expansion valve, is used. By using such a feature, the degree of subcooling at an outlet of the internal heat exchanger 17 can be controlled.

[0076] Fig. 9 is a diagram of refrigerant circuit illustrating the flow of refrigerant when the air-conditioning apparatus of Fig. 8 is in a cooling operation mode. Note that

the solid line arrows illustrated in the figure indicate the directions of refrigerant flow.

[0077] The difference from Embodiment 1 is that, in a cooling operation mode, since the bypass opening/closing device 15 is in an open state, a refrigerant flow that is bypassed from the upstream of the expansion device 41 and passes through the bypass opening/closing device 15 and the internal heat exchanger 17, in this order, is added.

[0078] The flow of refrigerant in a heating operation mode is the same as Embodiment 1, and thus the explanation thereof is omitted.

[Refrigerant Leakage Prevention Control in Embodiment 2]

[0079] Refrigerant leakage prevention control according to Embodiment 2 can obtain the same effect as Embodiment 1 by using the same operation in each operation mode as described in Embodiment 1. Therefore, the explanation is omitted.

[0080] In Embodiment 1, a bypass pipe 5 and a bypass opening/closing device 15, which are not used in a normal cooling operation mode or a normal heating operation mode, are required to be installed to perform a pump-down operation of the refrigerant leakage prevention control. However, in Embodiment 2, a bypass pipe 5 and a bypass opening/closing device 15 are required to make the internal heat exchanger 17 function to increase the degree of subcooling of the refrigerant that flows into the indoor unit 2 in a cooling operation mode. Thus, it is not required to increase the number of components only for the pump-down operation of the refrigerant leakage prevention control.

Embodiment 3

[0081] For Embodiment 3 of the present invention, only the points different from Embodiment 1 will be explained. In an air-conditioning apparatus 100 according to Embodiment 3, an outdoor unit 1 and a heat medium conversion unit 60 are connected by a refrigerant main pipe 3, and the heat medium conversion unit 60 and an indoor unit 2 are connected by a heat medium pipe 64.

[Outdoor unit 1]

[0082] An outdoor unit 1 according to Embodiment 3 has the same configuration as the outdoor unit 1 of Embodiment 1, and therefore the explanation is omitted.

[Indoor unit 2]

[0083] An indoor unit 2 in Embodiment 3 has the same configuration as the indoor unit 2 of Embodiment 1 except that a pipe for connecting components is a heat medium pipe 64, instead of a refrigerant pipe 4, and therefore the explanation is omitted.

[Heat Medium Conversion unit 60]

[0084] A heat medium conversion unit 60 is formed by connecting, by a heat medium pipe 64, a heat medium heat exchanger 61, a pump 62 that feeds a heat medium such as water or brine, and a flow rate control device 63 that controls the flow rate of the heat medium flowing inside the heat medium pipe 64, and is provided in a space such as a machine room or above a ceiling.

[0085] The heat medium heat exchanger 61 exchanges heat between refrigerant supplied from the outdoor unit 1 and the heat medium, and is formed of, for example, a plate-type heat exchanger. The indoor unit 2 can perform a cooling operation or a heating operation by using the heat exchanged from the refrigerant to the heat medium at the heat medium heat exchanger 61.

[0086] The flow rate control device 63 controls the flow rate of the heat medium supplied to the indoor unit 2, and a mechanism capable of arbitrarily controlling the degree of opening is used as the flow rate control device 63. In addition, by controlling the flow rate control device 63 in such a manner that a difference in temperature between a third temperature detection device 51 and a fourth temperature detection device 52 provided in the indoor unit 2 becomes constant, the capacity is controlled according to the indoor load, and thus is convenient.

[0087] Furthermore, in Embodiment 3, a case in which there are one heat medium conversion unit 60 and one indoor unit 2 is illustrated as an example, but the numbers of the units are not limited thereto, and a plurality of heat medium conversion units 60 and indoor units 2 may be connected.

[Refrigerant Leakage Prevention Control in Embodiment 3]

[0088] Refrigerant leakage prevention control according to Embodiment 3 can obtain the same effect as Embodiment 1 by using the same operation in each operation mode as described in Embodiment 1. Therefore, the explanation is omitted.

[0089] Even in an indirect air-conditioning system in which refrigerant does not flow through an indoor unit 2, as in Embodiment 3, the amount of refrigerant that would leak into a machine room or a space above a ceiling can be reduced by performing the refrigerant leakage prevention control, and as a result, a higher degree of safety is assured in the air-conditioning apparatus 100.

[0090] Note that Embodiments 1 to 3 each show an example in which the bypass pipe 5 and the bypass opening/closing device 15 are provided inside the outdoor unit 1, but the location is not limited thereto, and the bypass pipe 5 and the bypass opening/closing device 15 may be provided outside the outdoor unit 1. In this case, too, the same effect can be obtained.

[0091] In addition, in Embodiments 1 to 3, an example where the number of the outdoor unit 1 is one is explained, but the number of the outdoor unit 1 is not limited

to one, and, when a leakage of refrigerant occurs, each of a plurality of outdoor units 1 performs the refrigeration leakage prevention control defined in each embodiment and the same effect can be obtained.

[0092] As a system where a plurality of indoor units 2 are connected, not only a system where a cooling or heating operation is performed by all the connected indoor units 2, but also a system where a cooling operation and a heating operation are performed simultaneously according to each indoor unit 2 may be used.

[0093] In this case, the same effect can be obtained by performing the refrigerant leakage prevention control for a cooling operation mode if the heat-side heat exchanger 12 of the outdoor unit 1 functions as a condenser, and performing the refrigerant leakage prevention control for heating operation mode if the heat-side heat exchanger 12 of the outdoor unit 1 functions as an evaporator.

[0094] In addition, in Embodiments 1 to 3, an example where one compressor 10 is connected to the outdoor unit 1 is explained, but two or more compressors 10 may be connected to the outdoor unit 1.

[0095] Embodiments 1 to 3 each show an example where the refrigerant shutoff device 13 is provided in the outdoor unit 1, but the configuration is not limited thereto, and the refrigerant shutoff device 13 may be provided anywhere between the heat-side heat exchanger 12 and the expansion device 41.

Reference Signs List

[0096]

1 outdoor unit 2 (2a, 2b) indoor unit 3 refrigerant main pipe 4 refrigerant pipe 5 bypass pipe 10 compressor 11 flow switching device 12 heat-side heat exchanger 13 refrigerant shutoff device 14 accumulator 15 bypass opening/closing device 16 outdoor fan 17 internal heat exchanger 20 first pressure detection device 21 second pressure detection device 22 first temperature detection device 30 controller 40 (40a, 40b) load-side heat exchanger 41 (41 a, 41 b) expansion device 42 (42a, 42b) indoor fan 50 (50a, 50b) second temperature detection device 51 (51 a, 51 b) third temperature detection device 52 (52a, 52b) fourth temperature detection device 60 heat medium conversion unit 61 heat medium heat exchanger 62 pump 63 flow rate control device 64 heat medium pipe 100 air-conditioning apparatus

Claims

1. An air-conditioning apparatus comprising:

a refrigerant circuit formed by connecting a compressor, a flow switching device, a first heat exchanger, a first expansion device, a second heat

- exchanger, and an accumulator by a pipe, the air-conditioning apparatus being configured to switch between a cooling operation in which the first heat exchanger serves as a condenser and the second heat exchanger serves as an evaporator and a heating operation in which the second heat exchanger serves as a condenser and the first heat exchanger serves as an evaporator by switching the flow switching device, the air-conditioning apparatus;
- a first opening-closing device provided on the pipe between the first heat exchanger and the expansion device;
- a bypass pipe branching from the pipe between the first opening-closing device and the expansion device and connected to the pipe between the flow switching device and the accumulator;
- a second opening-closing device provided on the bypass pipe; and
- a controller configured to perform a pump-down operation in which, when a leakage of refrigerant is detected, the flow switching device is switched to a state of the cooling operation so that refrigerant in the pipes is recovered into the first heat exchanger and the accumulator, and in which the first and the second opening-closing devices and the compressor are controlled, and then perform a refrigerant leakage amount reduction operation in which the flow switching device is switched to a state of the heating operation so that the recovered refrigerant is enclosed in the first heat exchanger and the accumulator, and in which the first and the second opening-closing devices and the compressor are controlled.
2. The air-conditioning apparatus of claim 1, wherein, when performing the pump-down operation, the controller is configured to close the first opening-closing device, open the second opening-closing device, and control an operation frequency of the compressor.
 3. The air-conditioning apparatus of claim 1 or 2, wherein, when performing the refrigerant leakage amount reduction operation, the controller is configured to close the first opening-closing device, close the second opening-closing device, and terminate operation of the compressor.
 4. The air-conditioning apparatus of any one of claims 1 to 3, further comprising a fan configured to send an outside air to the first heat exchanger, wherein the controller is configured to set a rotation speed of the fan to maximum during the pump-down operation.
 5. The air-conditioning apparatus of any one of claims 1 to 4, further comprising:
 - a first pressure detection device configured to detect a pressure of a discharge side of the compressor; and
 - a second pressure detection device configured to detect a pressure of a suction side of the compressor, wherein, the controller is configured to set a condition for terminating the pump-down operation, with either one of a situation in which a detection value of the first pressure detection device becomes equal to or greater than a first threshold and a detection value of the second pressure detection device becomes equal to or less than a second threshold, and a situation in which a detection value of the first pressure detection device becomes equal to or greater than a first threshold or a detection value of the second pressure detection device becomes equal to or less than a second threshold.
 6. The air-conditioning apparatus of any one of claims 1 to 5, wherein, when performing the refrigerant leakage amount reduction operation, the controller fully closes the expansion device.
 7. The air-conditioning apparatus of any one of claims 1 to 6, further comprising an outdoor unit having at least the compressor, the flow switching device, the first heat exchanger, the accumulator, and the first opening-closing device.
 8. The air-conditioning apparatus of any one of claims 1 to 7, wherein the first opening-closing device is an expansion device having a valve of which an opening degree thereof is changeable.
 9. The air-conditioning apparatus of any one of claims 1 to 8, further comprising an internal heat exchanger provided between the first opening-closing device and the expansion device, the internal heat exchanger being configured to increase a degree of subcooling of the refrigerant condensed by the first heat exchanger in a cooling operation, wherein a flow path on a low-pressure side of the internal heat exchanger is formed of the bypass pipe, and wherein the second opening-closing device is an expansion device having a valve of which an opening degree thereof is changeable.
 10. The air-conditioning apparatus of any one of claims 1 to 9, further comprising a heat medium heat exchanger configured to exchanging heat between refrigerant and a heat medium, wherein the second heat exchanger is configured to perform air conditioning of a room by using the heat

medium exchanged heat with the heat medium heat exchanger.

11. The air-conditioning apparatus of any one of claims 7 to 10, 5
wherein a plurality of the outdoor units are provided,
and a pump-down operation and a refrigerant leak-
age prevention operation are performed in each out-
door unit. 10
12. The air-conditioning apparatus of any one of claims 1 to 11, further comprising a plurality of indoor units each having at least the first expansion device and the second heat exchanger, 15
wherein the plurality of indoor units perform an op-
eration mode in which a cooling operation and a heat-
ing operation are performed simultaneously.
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- 50
- 55

FIG. 1

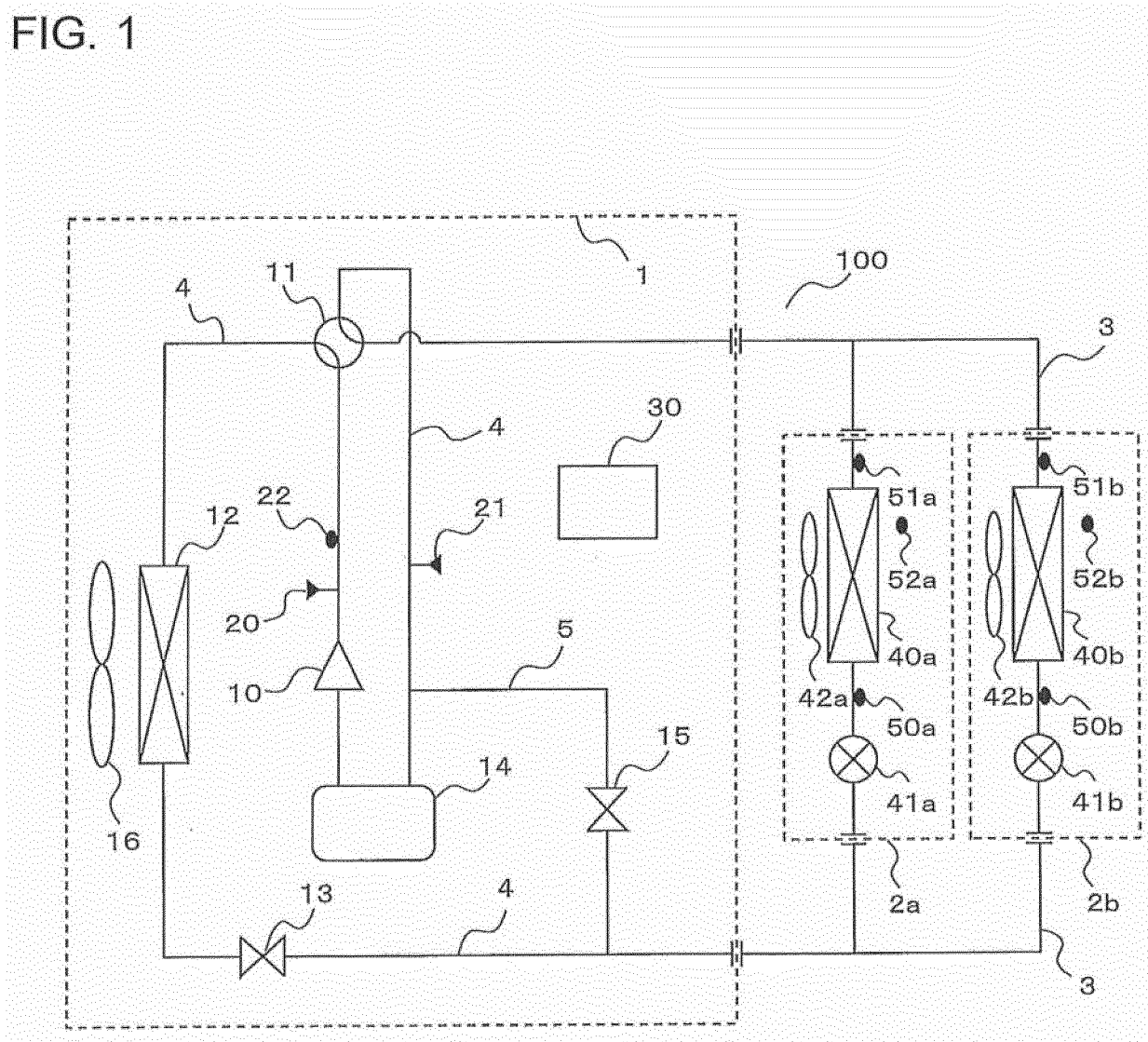


FIG. 2

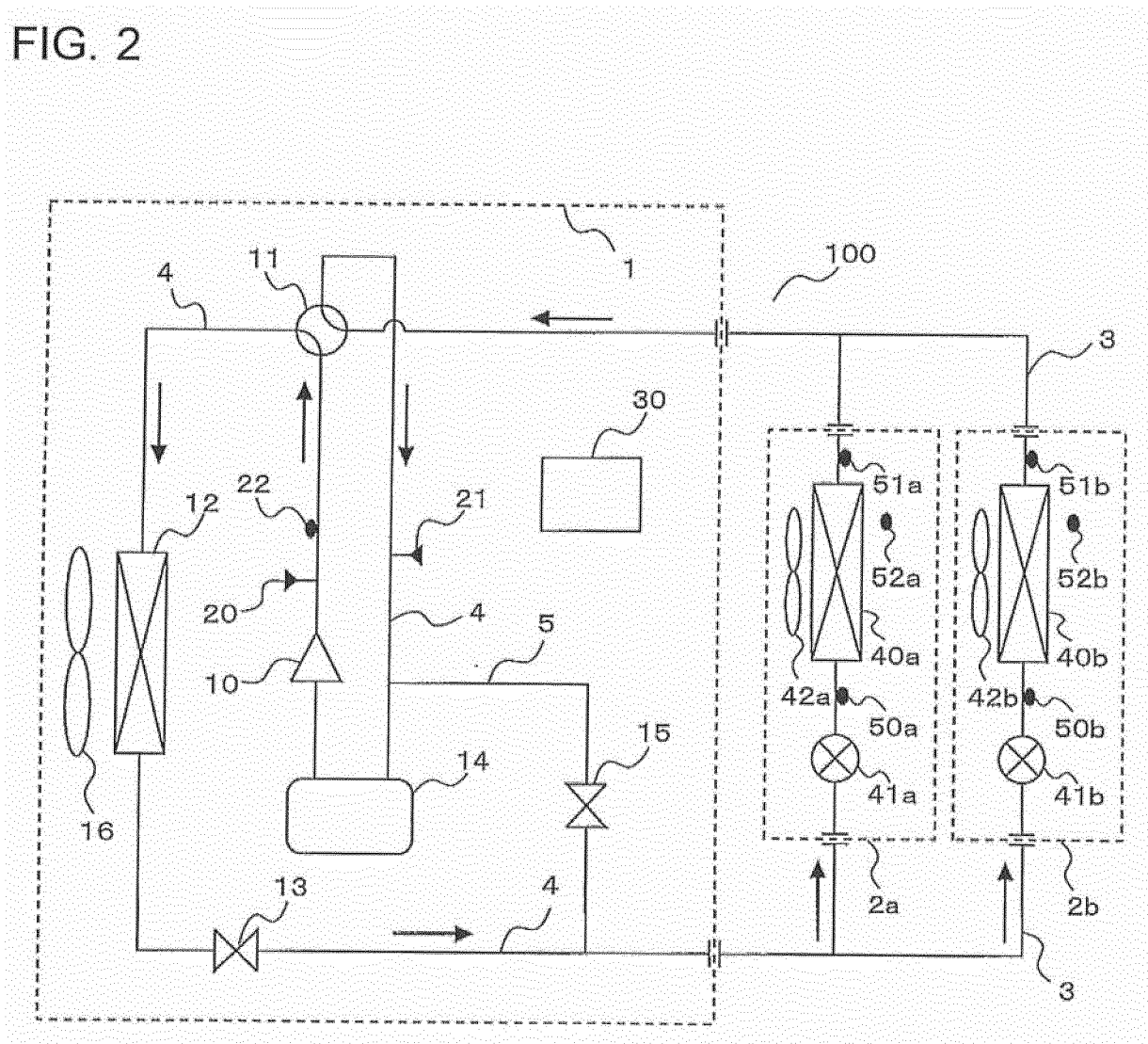


FIG. 3

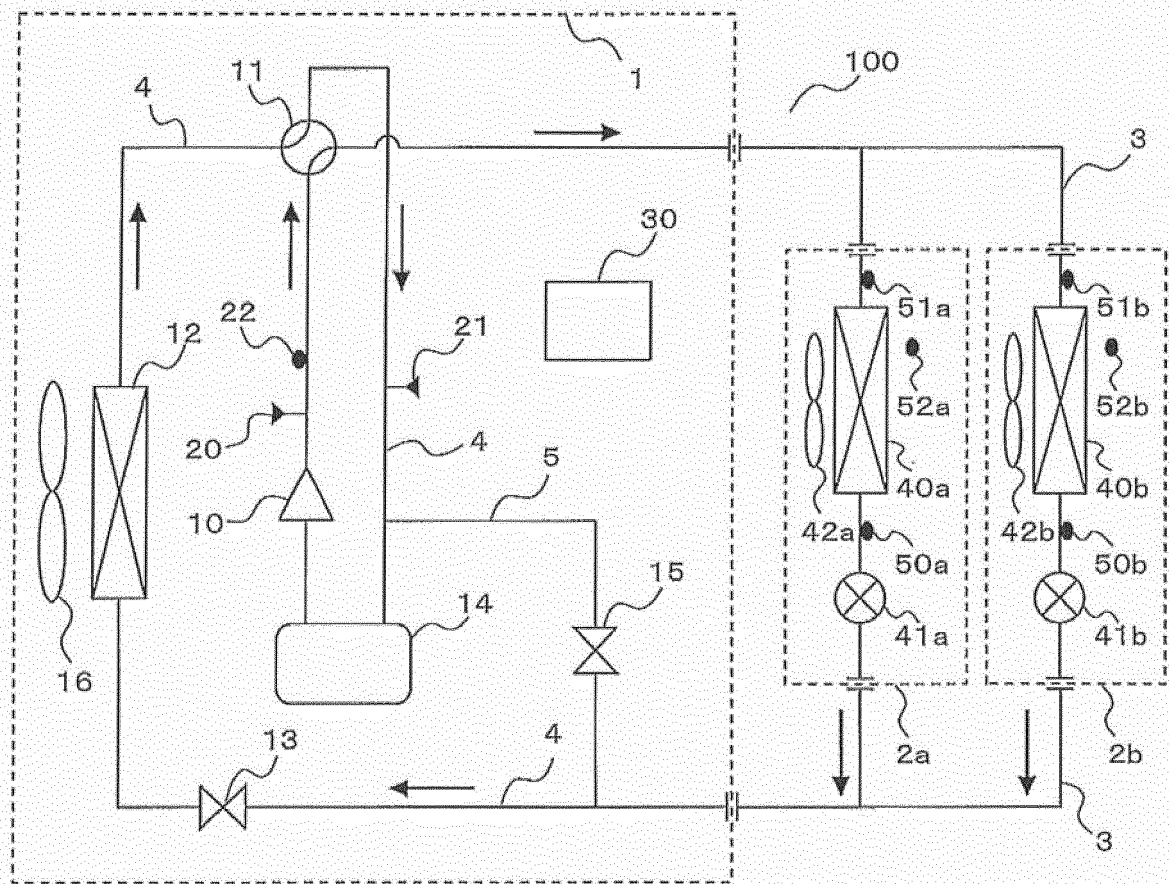


FIG. 4

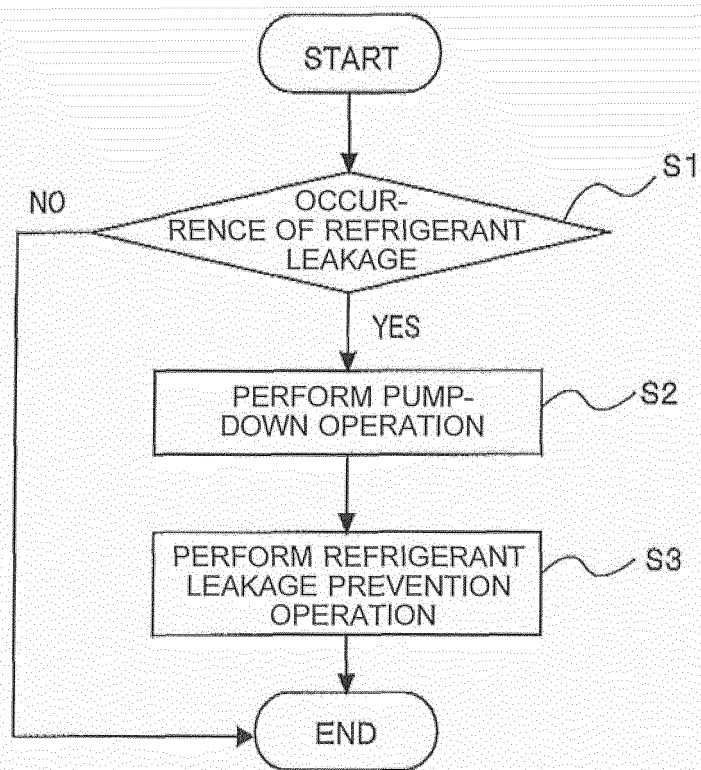


FIG. 5

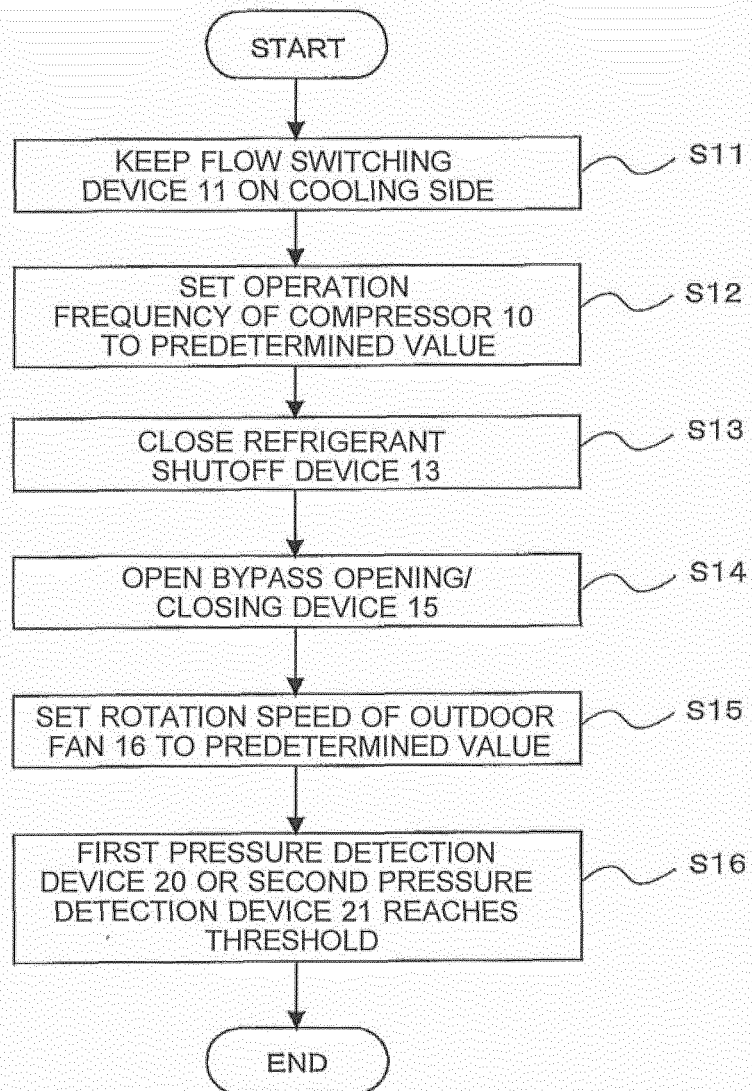


FIG. 6

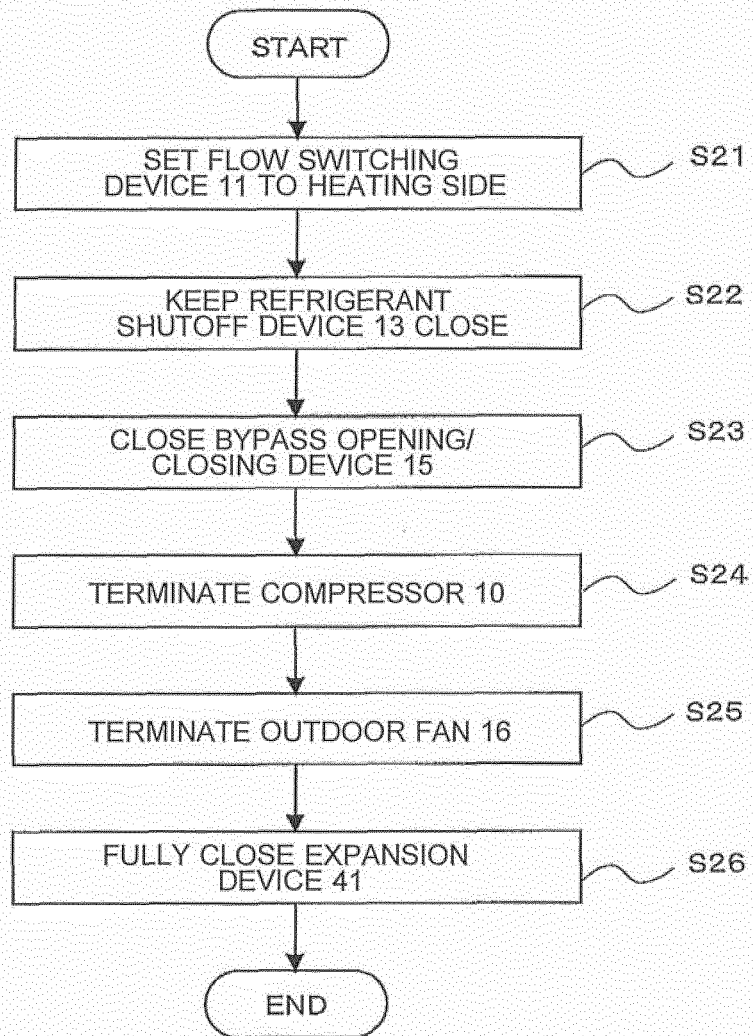


FIG. 7

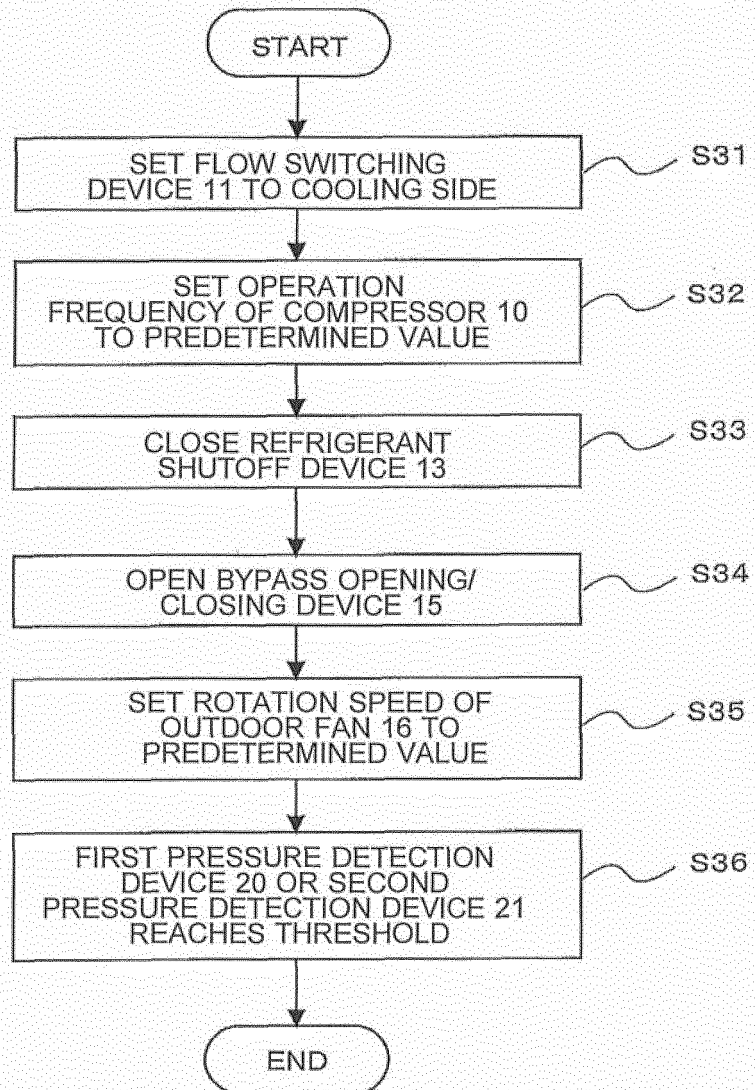


FIG. 8

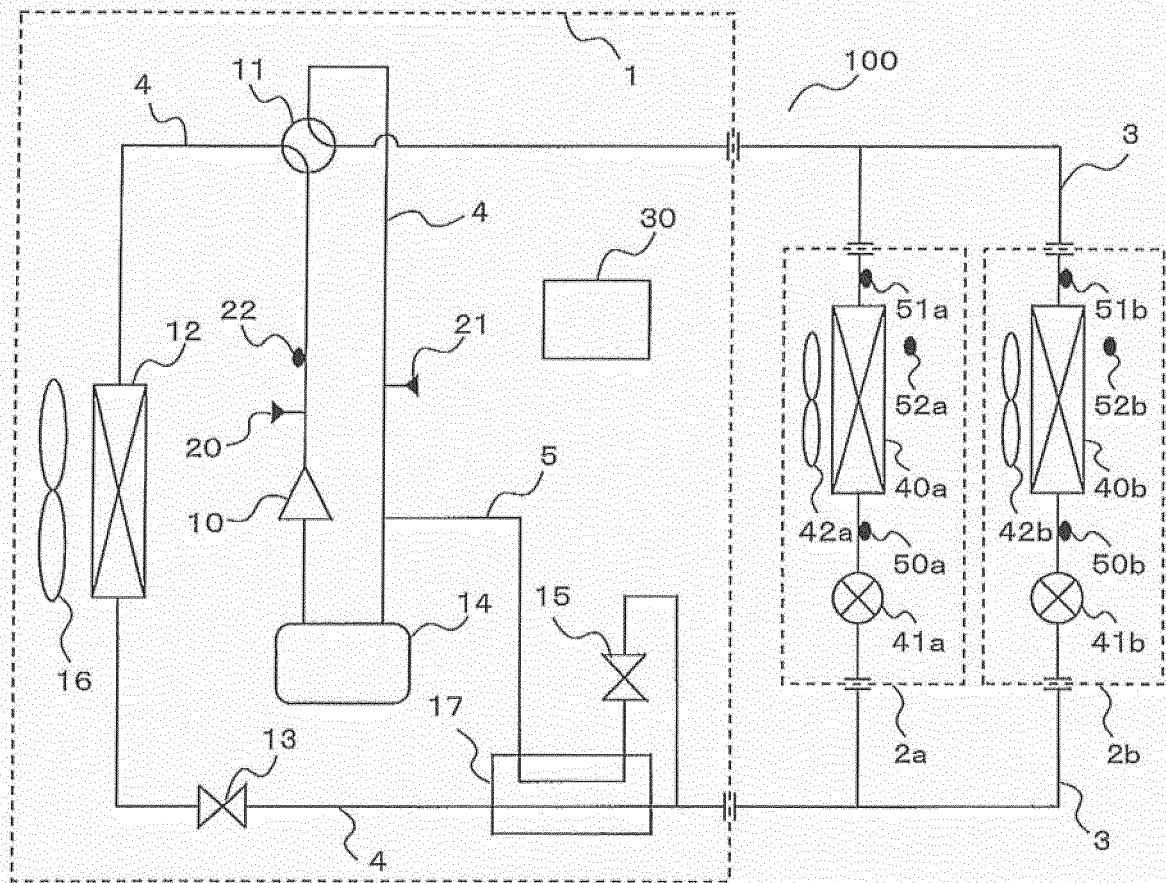


FIG. 9

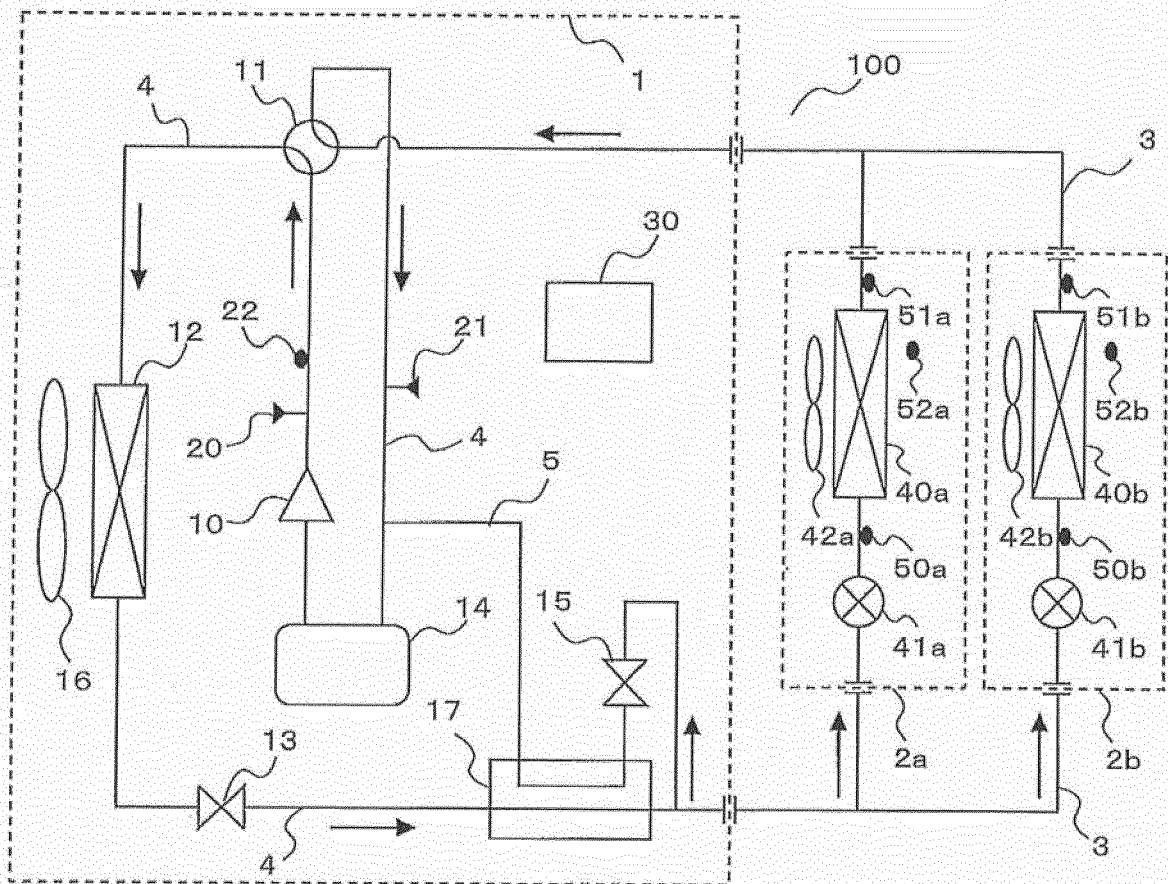
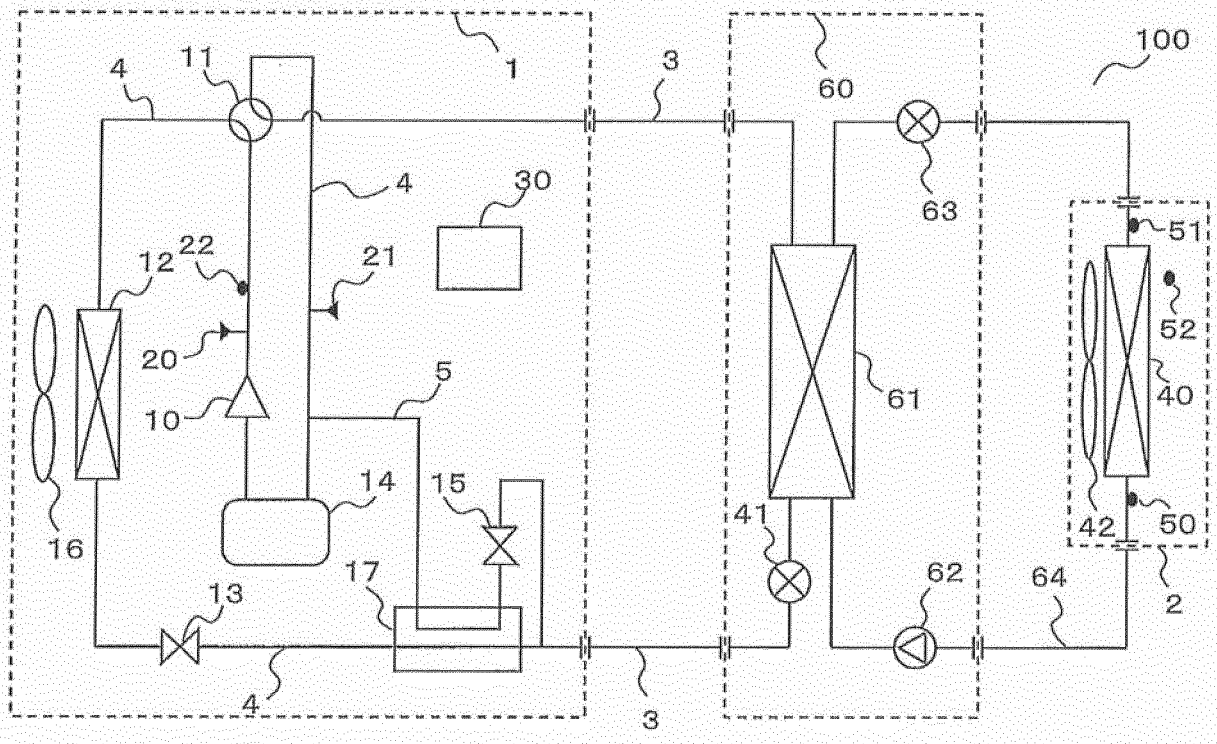


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/060601

A. CLASSIFICATION OF SUBJECT MATTER

F24F11/02(2006.01)i, F25B49/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24F11/02, F25B49/02

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015

Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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.
A	JP 2013-122364 A (Mitsubishi Electric Corp.), 20 June 2013 (20.06.2013), claims; paragraphs [0013] to [0030], [0032] to [0037]; fig. 1 to 4 (Family: none)	1-12
A	JP 2000-249385 A (Daikin Industries, Ltd.), 12 September 2000 (12.09.2000), claims; paragraphs [0009] to [0014]; fig. 1 (Family: none)	1-12
A	JP 2011-21837 A (Mitsubishi Electric Corp.), 03 February 2011 (03.02.2011), paragraphs [0024] to [0028]; fig. 2 (Family: none)	1-12

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

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Date of the actual completion of the international search

23 June 2015 (23.06.15)

Date of mailing of the international search report

07 July 2015 (07.07.15)

Name and mailing address of the ISA/

Japan Patent Office

3-4-3, Kasumigaseki, Chiyoda-ku,

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Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/060601

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 13098/1987 (Laid-open No. 120063/1988) (Daikin Industries, Ltd.), 03 August 1988 (03.08.1988), entire text; all drawings (Family: none)	1-12

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