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(54) AIR CONDITIONING DEVICE

(57) In an air conditioning apparatus (1, 101), a refrigerant cooling part condensation preventive control for elevating stepwise the rotation speed of a compressor (21) is configured to be performed when a refrigerant cooling part condensation occurrence condition for determining occurrence of condensation in a refrigerant jacket (29) is satisfied in a heating operation.

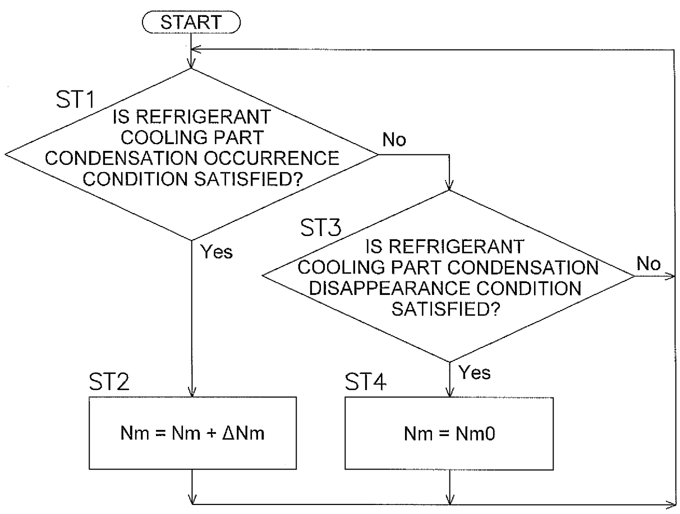

FIG. 5

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Description

TECHNICAL FIELD

[0001] The present invention relates to an air conditioning apparatus, particularly to an air conditioning apparatus that includes a refrigerant jacket configured to cool an electric component by a refrigerant, which flows at low pressure in a refrigeration cycle between an expansion valve and an outdoor heat exchanger, in performing a heating operation for circulating the refrigerant sequentially through a compressor, an indoor heat exchanger, the expansion valve and the outdoor heat exchanger in this order.

BACKGROUND ART

[0002] As described in PTL 1 (Japan Laid-open Patent Application Publication No. 2010-25374), there has conventionally been a type of air conditioning apparatus that includes a refrigerant jacket configured to cool an electric component such as a power device by a refrigerant, which flows at low pressure in a refrigeration cycle between an expansion valve and an outdoor heat exchanger, in performing a heating operation for circulating the refrigerant sequentially through a compressor, an indoor heat exchanger, the expansion valve and the outdoor heat exchanger in this order. This type of air conditioning apparatus is configured to perform a control for inhibiting occurrence of condensation by elevating the rotation speed of the compressor to a predetermined rotation speed so as to increase the amount of heat radiated from the electric component when a condensation occurrence condition for determining that condensation occurs in the refrigerant jacket is satisfied.

SUMMARY OF THE INVENTION

[0003] The aforementioned type of conventional air conditioning apparatus is configured to steeply elevate the rotation speed of the compressor to the predetermined rotation speed when the condensation occurrence condition is satisfied. Hence, it is concerned that a refrigerant circulation rate in a refrigerant circuit becomes excessive, i.e., a heating capacity becomes excessive, and accordingly, the compressor is repeatedly activated and deactivated by a thermo-off function. Additionally, when R32 is used as the refrigerant, a required heating capacity can be reliably achieved with a low refrigerant circulation rate. Hence, there is a tendency that pressure loss from the refrigerant jacket to the suction side of the compressor decreases, and the refrigerant passing through the refrigerant jacket decreases in temperature. Because of this, condensation becomes likely to occur in the refrigerant jacket, and the control for steeply elevating the rotation speed of the compressor to the predetermined rotation speed is also frequently performed. Hence, it is concerned that the compressor is more repeatedly activated and deactivated by the thermo-off function.

[0004] The present invention is intended to achieve the following object in an air conditioning apparatus that includes a refrigerant jacket configured to cool an electric component by a refrigerant, which flows at low pressure in a refrigeration cycle between an expansion valve and an outdoor heat exchanger, in performing a heating operation for circulating the refrigerant sequentially through a compressor, an indoor heat exchanger, the expansion valve and the outdoor heat exchanger in this order: inhibiting activation and deactivation of the compressor attributed to a thermo-off function and simultaneously inhibiting occurrence of condensation in the refrigerant jacket in the heating operation.

[0005] An air conditioning apparatus according to a first aspect includes a refrigerant circuit constructed by connecting a compressor, an indoor heat exchanger, an expansion valve and an outdoor heat exchanger, and further includes a refrigerant jacket configured to cool an electric component by a refrigerant flowing at low pressure in a refrigeration cycle between the expansion valve and the outdoor heat exchanger in performing a heating operation for circulating the refrigerant through the refrigerant circuit in a sequential order of the compressor, the indoor heat exchanger, the expansion valve and the outdoor heat exchanger. Additionally, a refrigerant cooling part condensation preventive control for elevating stepwise a rotation speed of the compressor is herein configured to be performed when a refrigerant cooling part condensation occurrence condition for determining that condensation occurs in the refrigerant jacket is satisfied in the heating operation.

[0006] As described above, the refrigerant cooling part condensation preventive control for elevating stepwise the rotation speed of the compressor is herein configured to be performed when the refrigerant cooling part condensation occurrence condition for determining that condensation occurs in the refrigerant jacket is satisfied in the heating operation. Therefore, unlike in a well-known control for steeply elevating the rotation speed of the compressor, it is possible to inhibit a refrigerant circulation rate in the refrigerant circuit from being excessive, i.e., to inhibit a heating capacity from being excessive, and simultaneously, to inhibit occurrence of condensation in the refrigerant jacket by least necessary increment in rotation speed.

[0007] Accordingly, it is herein possible in the heating operation to inhibit activation and deactivation of the compressor attributed to a thermo-off function, and simultaneously, to inhibit occurrence of condensation in the refrigerant jacket.

[0008] An air conditioning apparatus according to a second aspect relates to the air conditioning apparatus according to the first aspect, and wherein even under satisfaction of the refrigerant cooling part condensation occurrence condition, the rotation speed of the compressor is configured not to be elevated when a refrigerant cooling part condensation preventive control restricting condition for determining that the rotation speed of the compressor is excessively high is satisfied.

[0009] As described above, even under satisfaction of the refrigerant cooling part condensation occurrence condition, the rotation speed of the compressor is herein configured not to be elevated when the refrigerant cooling part condensation preventive control restricting condition for determining that the rotation speed of the compressor is excessively high is satisfied. Hence, it is possible to effectively inhibit activation and deactivation of the compressor attributed to the thermo-off function.

[0010] An air conditioning apparatus according to a third aspect relates to the air conditioning apparatus according to the first aspect, and wherein the refrigerant cooling part condensation preventive control is a control for repeatedly adding a predetermined rotation speed increment to a lower limit rotation speed defined as a controllable lower limit of the rotation speed of the compressor as long as the refrigerant cooling part condensation occurrence condition is satisfied.

[0011] As described above, as long as the refrigerant cooling part condensation occurrence condition is satisfied, the refrigerant cooling part condensation preventive control is herein set as a control for repeatedly adding the predetermined rotation speed increment to the lower limit rotation speed defined as the controllable lower limit of the rotation speed of the compressor. Therefore, the rotation speed of the compressor can be substantially elevated stepwise by continuously performing a compressor capacity for changing the rotation speed of the compressor in accordance with a required heating capacity, and simultaneously, by elevating stepwise the lower limit rotation speed of the compressor.

[0012] Accordingly, it is herein possible in the heating operation to continuously perform the compressor capacity control for changing the rotation speed of the compressor in accordance with the required heating capacity, and simultaneously, to inhibit activation and deactivation of the compressor attributed to the thermo-off function and inhibit occurrence of condensation in the refrigerant jacket.

[0013] An air conditioning apparatus according to a fourth aspect relates to the air conditioning apparatus according to the third aspect, and wherein even under satisfaction of the refrigerant cooling part condensation occurrence condition, the rotation speed increment is configured not to be added to the lower limit rotation speed when the lower limit rotation speed has reached a predetermined lower limit rotation speed upper limit value.

[0014] As described above, even under satisfaction of the refrigerant cooling part condensation occurrence condition, the rotation speed increment is herein configured not to be added to the lower limit rotation speed when the lower limit rotation speed has reached the lower limit rotation speed upper limit value. Hence, it is possible to effectively inhibit activation and deactivation of the compressor attributed to the thermo-off function.

[0015] An air conditioning apparatus according to a fifth aspect relates to the air conditioning apparatus according to any of the first to fourth aspects, and wherein a temperature of the refrigerant jacket at a refrigerant cooling part thermally making contact with the electric component is configured to be predicted based on a temperature of the refrigerant flowing between the refrigerant jacket and the outdoor heat exchanger and a heat radiation amount of the electric component; a dew point temperature is configured to be predicted based on an atmosphere temperature of the refrigerant jacket; and the refrigerant cooling part condensation occurrence condition is configured to be satisfied when the predicted temperature of the refrigerant cooling part is lower than a condensation determining temperature to be determined based on the dew point temperature.

[0016] As an index for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied, it is most preferable to determine whether or not the temperature of the refrigerant jacket at the refrigerant cooling part thermally making contact with the electric component is lower than the dew point temperature in the atmosphere of the refrigerant jacket.

[0017] However, the temperature of the refrigerant cooling part of the refrigerant jacket is high in a region located closely to the electric component but is low in a region located far from the electric component. Hence, it is not easy to decide in which region of the refrigerant cooling part its temperature is appropriate as the representative temperature of the entire refrigerant cooling part. Additionally, increase in cost is inevitable when a large number of temperature sensors are mounted to the refrigerant cooling part.

[0018] In view of this, as described above, the temperature of the refrigerant cooling part is herein configured to be predicted based on the temperature of the refrigerant flowing between the refrigerant jacket and the outdoor heat exchanger and the heat radiation amount of the electric component. Moreover, the dew point temperature is configured to be predicted based on the atmosphere temperature of the refrigerant jacket, and the refrigerant cooling part condensation occurrence condition is configured to be satisfied when the predicted temperature of the refrigerant cooling part is lower than the condensation determining temperature to be determined based on the dew point temperature. Here, the temperature of the refrigerant flowing between the refrigerant jacket and the outdoor heat exchanger is detectable by a temperature sensor mounted to the liquid side of the outdoor heat exchanger, whereas the heat radiation amount of the electric component is predictable from electric current flowing through the electric component.

[0019] Thus, the temperature of the refrigerant cooling part of the refrigerant jacket and the dew point temperature are herein predicted, and it is possible to appropriately determine whether or not the refrigerant cooling part condensation occurrence condition is satisfied using both of the predicted temperature of the refrigerant cooling part and the predicted dew point temperature.

[0020] An air conditioning apparatus according to a sixth aspect relates to the air conditioning apparatus according to any of the first to fifth aspects, and wherein the refrigerant to be encapsulated in the refrigerant circuit is R32.

[0021] As described above, the refrigerant to be encapsulated in the refrigerant circuit is herein R32. Hence, a required heating capacity can be reliably achieved with a low refrigerant circulation rate. Hence, there is a tendency that pressure loss from the refrigerant jacket to the suction side of the compressor decreases, and the refrigerant passing through the refrigerant jacket decreases in temperature. Because of this, condensation becomes likely to occur in the refrigerant jacket, and the control for steeply elevating the rotation speed of the compressor to the predetermined rotation speed is also frequently performed. Hence, it is concerned that the compressor is more repeatedly activated and deactivated by the thermo-off function.

[0022] However, as described above, the refrigerant cooling part condensation preventive control is herein configured to be performed. Hence, it is possible in the heating operation to inhibit activation and deactivation of the compressor attributed to the thermo-off function, and simultaneously, to inhibit occurrence of condensation in the refrigerant jacket.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

FIG. 1 is a schematic configuration diagram of an air conditioning apparatus according to a first embodiment of the present invention.

FIG. 2 is a control block diagram of the air conditioning apparatus according to the first embodiment.

FIG. 3 is a cross-sectional plan view of an outdoor unit.

FIG. 4 is a front view of the outdoor unit from which a blower compartment-side front plate and a machinery compartment-side front plate are detached.

FIG. 5 is a flowchart of a refrigerant cooling part condensation preventive control.

FIG. 6 is a flowchart of a refrigerant cooling part condensation preventive control in Modification 1.

FIG. 7 is a schematic configuration diagram of an air conditioning apparatus according to a second embodiment of the present invention.

FIG. 8 is a control block diagram of the air conditioning apparatus according to the second embodiment.

DESCRIPTION OF EMBODIMENTS

[0024] Embodiments of an air conditioning apparatus according to the present invention and modifications thereof will be hereinafter explained based on drawings. It should be noted that the specific configuration of the air conditioning apparatus according to the present invention is not limited to the following embodiments and modifications thereof, and can be changed without departing from the scope of the present invention.

- First Embodiment -

(1) Entire Configuration of Air Conditioning Apparatus

[0025] FIG. 1 is a schematic configuration diagram of an air conditioning apparatus 1 according to a first embodiment of the present invention.

[0026] The air conditioning apparatus 1 is an apparatus capable of cooling and heating an indoor space of a building or so forth by performing a refrigeration cycle of a vapor compression type. The air conditioning apparatus 1 is mainly constructed by connecting an outdoor unit 2 and an indoor unit 4. Here, the outdoor unit 2 and the indoor unit 4 are connected through a liquid refrigerant communication pipe 5 and a gaseous refrigerant communication pipe 6. In other words, a refrigerant circuit 10 of a vapor compression type in the air conditioning apparatus 1 is constructed by connecting the outdoor unit 2 and the indoor unit 4 through the refrigerant communication pipes 5 and 6. Additionally, R32, which is a type of HFC refrigerant, is encapsulated as a refrigerant in the refrigerant circuit 10.

<Indoor Unit>

[0027] The indoor unit 4 is installed in the indoor space, and composes part of the refrigerant circuit 10. The indoor unit 4 mainly includes an indoor heat exchanger 41.

[0028] The indoor heat exchanger 41 is a heat exchanger that functions as an evaporator for the refrigerant so as to cool the air in the indoor space in a cooling operation and functions as a heat radiator for the refrigerant so as to heat the air in the indoor space in a heating operation. A liquid side of the indoor heat exchanger 41 is connected to the liquid refrigerant communication pipe 5, whereas a gaseous side of the indoor heat exchanger 41 is connected to the gaseous refrigerant communication pipe 6.

[0029] The indoor unit 4 includes an indoor fan 42 for sucking the indoor air into the indoor unit 4, causing the sucked indoor air to exchange heat with the refrigerant in the indoor heat exchanger 41, and thereafter, supplying the heat-exchanged air to the indoor space as supply air. In other words, the indoor unit 4 includes the indoor fan 42 as a fan for supplying the indoor air, which serves as a heating/cooling source of the refrigerant flowing through the indoor heat exchanger 41, to the indoor heat exchanger 41. A centrifugal fan, a multi-blade fan or so forth, configured to be driven by an indoor fan motor 42a, is herein used as the indoor fan 42.

[0030] The indoor unit 4 is provided with a variety of sensors. Specifically, the indoor heat exchanger 41 is provided with an indoor heat exchanger liquid side temperature sensor 49 for detecting temperature Trrl of the refrigerant on the liquid side of the indoor heat exchanger 41 and an indoor heat exchanger intermediate temperature sensor 48 for detecting temperature Trrm of the refrigerant in the intermediate part of the indoor heat exchanger 41. The indoor unit 4 is provided with an indoor temperature sensor 50 for detecting temperature Tra of the indoor air to be sucked into the indoor unit 4.

[0031] The indoor unit 4 includes an indoor side control unit 40 configured to control actions of the respective constituent elements of the indoor unit 4. Additionally, the indoor side control unit 40 includes a microcomputer, a memory and so forth that are provided for controlling the indoor unit 4, and is configured to be capable of transmitting/receiving a control signal and so forth to/from a remote controller (not shown in the drawings) and be capable of transmitting/receiving a control signal and so forth to/from the outdoor unit 2.

<Outdoor Unit>

[0032] The outdoor unit 2 is installed in an outdoor space, and composes part of the refrigerant circuit 10. The outdoor unit 2 mainly includes a compressor 21, a four-way switch valve 22, an outdoor heat exchanger 23, a refrigerant jacket 29, an expansion valve 26, a liquid side stop valve 27 and a gaseous side stop valve 28.

[0033] The compressor 21 is a machine configured to compress the refrigerant at low pressure in the refrigeration cycle until the pressure of the refrigerant becomes high. The compressor 21 has a sealed structure and is configured to rotationally drive a displacement compression element of a rotary type, a scroll type or so forth (not shown in the drawings) by a compressor motor 21 a that the frequency (rotation speed) thereof is controllable by an inverter. In other words, the compressor 21 is configured to be capable of controlling the operating capacity by changing the frequency (rotation speed). A suction pipe 31 is connected to a suction side of the compressor 21, whereas a discharge pipe 32 is connected to a discharge side of the compressor 21. The suction pipe 31 is a refrigerant pipe for connecting the suction side of the compressor 21 and the four-way switch valve 22. The discharge pipe 32 is a refrigerant pipe for connecting the discharge side of the compressor 21 and the four-way switch valve 22.

[0034] The four-way switch valve 22 is a switch valve for switching the flow direction of the refrigerant in the refrigerant circuit 10. In the cooling operation, the four-way switch valve 22 is configured to be switched into a cooling cycle state whereby the outdoor heat exchanger 23 is caused to function as a heat radiator for the refrigerant that has been compressed in the compressor 21 while the indoor heat exchanger 41 is caused to function as an evaporator for the refrigerant that has radiated heat in the outdoor heat exchanger 23. In other words, through the four-way switch valve 22, the discharge side (herein, the discharge pipe 32) of the compressor 21 and a gaseous side (herein, a first gaseous refrigerant pipe 33) of the outdoor heat exchanger 23 are configured to be connected in the cooling operation (see solid line within the four-way switch valve 22 in FIG. 1). Additionally, the suction side (herein, the suction pipe 31) of the compressor 21 and the gaseous refrigerant communication pipe 6 side (herein, a second gaseous refrigerant pipe 34) are configured to be connected (see solid line within the four-way switch valve 22 in FIG. 1). On the other hand, in the heating operation, the four-way switch valve 22 is configured to be switched into a heating cycle state whereby the outdoor heat exchanger 23 is caused to function as an evaporator for the refrigerant that has radiated heat in the indoor heat exchanger 41 while the indoor heat exchanger 41 is caused to function as a heat radiator for the refrigerant that has been compressed in the compressor 21. In other words, through the four-way switch valve 22, the discharge side (herein, the discharge pipe 32) of the compressor 21 and the gaseous refrigerant communication pipe 6 side (herein , the second gaseous refrigerant pipe 34) are configured to be connected in the heating operation (see broken line within the four-way switch valve 22 in FIG. 1). Additionally, the suction side (herein, the suction pipe 31) of the compressor 21 and the gaseous side (herein, the first gaseous refrigerant pipe 33) of the outdoor heat exchanger 23 are configured to be connected (see broken line within the four-way switch valve 22 in FIG. 1). Here, the first gaseous refrigerant pipe 33 is a refrigerant pipe for connecting the four-way switch valve 22 and the gaseous side of the outdoor heat exchanger 23. The second gaseous refrigerant pipe 34 is a refrigerant pipe for connecting the four-way switch valve 22 and the gaseous side stop valve 28.

[0035] The outdoor heat exchanger 23 is a heat exchanger that functions as a heat radiator for the refrigerant using the outdoor air as a cooling source in the cooling operation and functions as an evaporator for the refrigerant using the outdoor air as a heating source in the heating operation. The liquid side of the outdoor heat exchanger 23 is connected to a liquid refrigerant pipe 35, whereas the gaseous side thereof is connected to the first gaseous refrigerant pipe 33. The liquid refrigerant pipe 35 is a refrigerant pipe for connecting the liquid side of the outdoor heat exchanger 23 and the liquid refrigerant communication pipe 5 side.

[0036] The expansion valve 26 is a valve configured to reduce, in the cooling operation, the pressure of the refrigerant having radiated heat in the outdoor heat exchanger 23 from high pressure to low pressure in the refrigeration cycle. The expansion valve 26 is also a valve configured to reduce, in the heating operation, the pressure of the refrigerant having radiated heat in the indoor heat exchanger 41 from high pressure to low pressure in the refrigeration cycle. The expansion valve 26 is mounted to a part of the liquid refrigerant pipe 35 in adjacent to the liquid side stop valve 27. An electric expansion valve is herein used as the expansion valve 26.

[0037] The refrigerant jacket 29 is a heat exchanger configured to cool an electric component 72 (cooled component) with high exothermic properties such as a power device composing an electric component unit 70 to be described hereinafter by the refrigerant flowing between the outdoor heat exchanger 23 and the expansion valve 26. In other words, in the cooling operation, the refrigerant jacket 29 functions as a heat exchanger configured to cool the electric component 72 by the refrigerant at high pressure in the refrigeration cycle that has radiated heat in the outdoor heat exchanger 23. In the heating operation, the refrigerant jacket 29 functions as a heat exchanger configured to cool the electric component 72 by the refrigerant at low pressure in the refrigeration cycle that has been depressurized through the expansion valve 26.

[0038] The liquid side stop valve 27 and the gaseous side stop valve 28 are valves mounted to ports to be connected to external machine and piping (specifically, the liquid refrigerant communication pipe 5 and the gaseous refrigerant communication pipe 6). The liquid side stop valve 27 is mounted to an end of the liquid refrigerant pipe 35. The gaseous side stop valve 28 is mounted to an end of the second gaseous refrigerant pipe 34.

[0039] The outdoor unit 2 includes an outdoor fan 36 for sucking the outdoor air into the outdoor unit 2, causing the sucked outdoor air to exchange heat with the refrigerant in the outdoor heat exchanger 23, and thereafter, discharging the heat-exchanged air to the outside. In other words, the outdoor unit 2 includes the outdoor fan 36 as a fan for supplying the outdoor air, which serves as a cooling/heating source of the refrigerant flowing through the outdoor heat exchanger 23, to the outdoor heat exchanger 23. A propeller fan or so forth, configured to be driven by an outdoor fan motor 36a, is herein used as the outdoor fan 36.

[0040] The outdoor unit 2 is provided with a variety of sensors. Specifically, the suction pipe 31 is provided with a suction temperature sensor 43 for detecting temperature TS of the refrigerant at low pressure in the refrigeration cycle to be sucked into the compressor 21. The discharge pipe 32 is provided with a discharge temperature sensor 44 for detecting temperature Td of the refrigerant at high pressure in the refrigeration cycle to be discharged from the compressor 21. The outdoor heat exchanger 23 is provided with an outdoor heat exchanger intermediate temperature sensor 45 for detecting temperature Torm of the refrigerant in the intermediate part of the outdoor heat exchanger 23 and an outdoor heat exchanger liquid side temperature sensor 46 for detecting temperature Torl of the refrigerant on the liquid side of the outdoor heat exchanger 23. The outdoor unit 2 is provided with an outdoor temperature sensor 47 for detecting temperature Toa of the outdoor air to be sucked into the outdoor unit 2.

[0041] The outdoor unit 2 includes an outdoor side control unit 20 configured to control actions of the respective constituent elements of the outdoor unit 2. Additionally, the outdoor side control unit 20 includes a microcomputer, a memory and so forth that are provided for controlling the outdoor unit 2, and is configured to be capable of transmitting/receiving a control signal and so forth to/from the indoor unit 4 (i.e., the indoor side control unit 40). It should be noted that the outdoor side control unit 20 is made up of the electric component unit 70 to be described hereinafter.

<Refrigerant Communication Pipes>

[0042] The refrigerant communication pipes 5 and 6 are refrigerant pipes designed to be plumbed in an installation location (e.g., a building) of the air conditioning apparatus 1 in actually installing the air conditioning apparatus 1. Pipes having a variety of lengths and pipe diameters are used as the refrigerant communication pipes 5 and 6 in accordance with installation conditions including installation places, combinations as pairs of the outdoor unit and the indoor unit, and so forth.

[0043] As described above, the refrigerant circuit 10 of the air conditioning apparatus 1 is constructed by connecting the outdoor unit 2, the indoor unit 4 and the refrigerant communication pipes 5 and 6. The refrigerant circuit 10 is mainly constructed by connecting the compressor 21, the outdoor heat exchanger 23 functioning as a heat radiator or an evaporator, the refrigerant jacket 29, the expansion valve 26, and the indoor heat exchanger 41 functioning as an evaporator or a heat radiator. Additionally, the cooling operation is configured to be performed as a refrigeration cycle operation for circulating the refrigerant sequentially through the compressor 21, the outdoor heat exchanger 23 functioning as the heat radiator, the expansion valve 26, and the indoor heat exchanger 41 functioning as the evaporator. In performing the cooling operation, the refrigerant jacket 29 is configured to cool the electric component 72 by the refrigerant flowing at high pressure in the refrigeration cycle between the outdoor heat exchanger 23 and the expansion valve 26. On the other hand, the heating operation is configured to be performed as a refrigeration cycle operation for circulating the refrigerant sequentially through the compressor 21, the indoor heat exchanger 41 functioning as the heat radiator, the expansion valve 26, and the outdoor heat exchanger 23 functioning as the evaporator. In performing the heating operation, the refrigerant jacket 29 is configured to cool the electric component 72 by the refrigerant flowing at low pressure in the refrigeration cycle between the expansion valve 26 and the outdoor heat exchanger 23.

<Controller>

[0044] In the air conditioning apparatus 1, a controller 8 composed of the indoor side control unit 40 and the outdoor side control unit 20 is configured to be capable of controlling the respective machines of the outdoor unit 2 and the indoor unit 4. In other words, the indoor side control unit 40 and the outdoor side control unit 20 compose the controller 8 configured to control the entire operation of the air conditioning apparatus 1 including the aforementioned refrigeration cycle operation such as the cooling operation and the heating operation.

[0045] As shown in FIG. 2, the controller 8 is connected to the respective sensors 43 to 50 and so forth so as to be capable of receiving detection signals of these sensors, and is also connected to the respective machines and valves 21 a, 22, 26, 36a, 42a and so forth so as to be capable of controlling these machines and valves based on the detection signals and so forth.

(2) Construction of Outdoor Unit

[0046] Next, a construction of the outdoor unit 2 will be explained with FIGS. 3 and 4. Here, FIG.3 is a cross-sectional plan view of the outdoor unit 2. FIG. 4 is a front view of the outdoor unit 2 from which a blower compartment-side front plate 54 and a machinery compartment-side front plate 55 are detached. It should be noted that in the following explanation, unless particularly mentioned, directional terms such as "up", "down", "left" and "right" and terms indicating surfaces such as "front surface", "lateral surface", "rear surface", "top surface" and "bottom surface" respectively mean directions and surfaces in a condition shown in FIG. 4 as a front view of the outdoor unit 2.

[0047] The outdoor unit 2 has a structure (so-called a trunk type structure) that a blower compartment S1 and a machinery compartment S2 are formed by dividing right and left the interior space of a unit casing 50 with a partition plate 57 extending in the vertical direction. The outdoor unit 2 is configured to suck the outdoor air into the interior thereof through part of the rear surface and the lateral surface of the unit casing 50 and then discharge the sucked air through the front surface of the unit casing 50. The outdoor unit 2 is mainly composed of: refrigerant circuit constituent components including the unit casing 50, the compressor 21, the four-way switch valve 22, the outdoor heat exchanger 23, the expansion valve 26, the refrigerant jacket 29, the stop valves 27 and 28, and the refrigerant pipes 31 to 35 connecting these machines; the outdoor fan 36; the electric component unit 70 provided with a plurality of electric components; and a variety of sensors 43 to 47. It should be noted that in the exemplary construction herein explained, the blower compartment S1 is located closely to the left lateral surface of the unit casing 50 whereas the machinery compartment S2 is located closely to the right lateral surface of the unit casing 50. The right and left positions of the blower compartment S1 and the machinery compartment S2 may be reversed.

[0048] The unit casing 50 is made in the shape of a roughly cuboid and mainly accommodates the refrigerant circuit constituent components 21 to 28, the outdoor fan 36 and the electric component unit 70. The unit casing 50 includes a bottom plate 51, a blower compartment-side lateral plate 52, a machinery compartment-side lateral plate 53, the blower compartment-side front plate 54, the machinery compartment-side front plate 55 and a top plate 56.

[0049] The bottom plate 51 is a plate-shaped member composing the bottom surface part of the unit casing 50. Foundation legs 58 and 59 are mounted to the lower side of the bottom plate 51, and are fixed to the mount surface of an installation location.

[0050] The blower compartment-side lateral plate 52 is a plate-shaped member composing a blower component S1-side lateral surface part of the unit casing 50. The blower compartment-side lateral plate 52 is fixed at the lower part thereof to the bottom plate 51. A suction port 52a is provided in the blower compartment-side lateral plate 52, and the outdoor air is sucked into the unit casing 50 through the suction port 52a by the outdoor fan 36.

[0051] The machinery compartment-side lateral plate 53 is a plate-shaped member composing part of a machinery compartment S2-side lateral surface part of the unit casing 50 and a machinery compartment S2-side rear surface part of the unit casing 50. The machinery compartment-side lateral plate 53 is fixed at the lower part thereof to the bottom plate 51. A suction port 52b is provided between a rear surface-side end of the blower compartment-side lateral plate 52 and a blower compartment S1-side end of the machinery compartment-side lateral plate 53, and the outdoor air is sucked into the unit casing 50 through the suction port 52b by the outdoor fan 36.

[0052] The blower compartment-side front plate 54 is a plate-shaped member composing a front surface part of the blower compartment S1 of the unit casing 50. The blower compartment-side front plate 54 is fixed at the lower part thereof to the bottom plate 51, and is also fixed at the left lateral surface-side end thereof to the front surface-side end of the blower compartment-side lateral plate 52. A blower port 54a is provided in the blower compartment-side front plate 54 in order to blow out the outdoor air, taken into the interior of the unit casing 50 by the outdoor fan 36, to the outside.

[0053] The machinery compartment-side front plate 55 is a plate-shaped member composing part of a front surface part of the machinery compartment S2 of the unit casing 50 and part of a lateral surface part of the machinery compartment S2 of the unit casing 50. The machinery compartment-side front plate 55 is fixed at the blower compartment S1-side end thereof to the machinery compartment S2-side end of the blower compartment-side front plate 54, and is also fixed at the rear surface-side end thereof to the front surface-side end of the machinery compartment-side lateral plate 53.

[0054] The top plate 56 is a plate-shaped member composing a top surface part of the unit casing 50. The top plate 56 is fixed to the blower compartment-side lateral plate 52, the machinery compartment-side lateral plate 53 and the blower compartment-side front plate 54.

[0055] The partition plate 57 is a plate-shaped member extending in the vertical direction and is disposed on the bottom plate 51. The partition plate 57 forms the blower compartment S1 located closely to the left lateral surface and the machinery compartment S2 located closely to the right lateral surface by dividing the internal space of the unit casing 50 right and left. The partition plate 57 is fixed at the lower part thereof to the bottom plate 51, is fixed at the front surface-side end thereof to the blower compartment-side front plate 54, and is fixed at the rear surface-side end to the machinery compartment S2-side end of the outdoor heat exchanger 23.

[0056] The outdoor fan 36 is disposed in a position on the front surface side of the outdoor heat exchanger 23 within the blower compartment S1 and is faced to the blower port 54a.

[0057] The outdoor heat exchanger 23 is a heat exchanger panel having a roughly L shape, and is disposed along the left lateral surface and the rear surface of the unit casing 50 within the blower compartment S1.

[0058] The compressor 21 is a sealed compressor made in the shape of a vertical cylinder, and is disposed within the machinery compartment S2.

[0059] The electric component unit 70 is disposed closely to the front surface of the unit casing 50 within the machinery compartment S2. The electric component unit 70 is a unit provided with a plurality of electric components configured to be used for purposes such as controlling of the machines in the outdoor unit 2, and makes up the outdoor side control unit 20. The electric component unit 70 mainly includes a board 71 and a plurality of electric components including the electric component 72 with high exothermic properties such as a power device composing the inverter of the compressor motor 21 a. The electric component 72 with high exothermic properties is mounted to the front surface of the board 71.

[0060] The refrigerant jacket 29 is herein a member vertically elongated along the lengthwise direction of a U-shaped bent part of the liquid refrigerant pipe 35, and is supported on the board 71. The refrigerant jacket 29 includes a refrigerant cooling part 29a to which the liquid refrigerant pipe 35 is mounted while being folded in the up-and-down direction and thus being bent in a U-shape. The refrigerant cooling part 29a is disposed to cover the electric component 72 mounted to the board 71 from the front surface side, and thermally makes contact with the electric component 72.

[0061] It should be noted that although not herein illustrated in the drawings, the refrigerant circuit constituent components, including the four-way switch valve 22, the expansion valve 26 and so forth, and a variety of sensors 43 to 47 are also disposed in the interior of the unit casing 50.

(3) Basic Action of Air Conditioning Apparatus

[0062] Next, a basic action of the air conditioning apparatus 1 will be explained with FIG. 1. As the basic action, the air conditioning apparatus 1 is capable of cooling the electric component 72 by the refrigerant jacket 29, and is simultaneously capable of performing the cooling operation and the heating operation. Additionally, the air conditioning apparatus 1 is herein configured to perform a compressor capacity control for regulating the frequency (rotation speed) of the compressor 21 in accordance with a required air conditioning capacity during the cooling operation and during the heating operation. It should be noted that the cooling operation, the heating operation and the compressor capacity control are configured to be performed by the controller 8.

<Cooling Operation>

[0063] In the cooling operation, the four-way switch valve 22 is configured to be switched into the cooling cycle state (the state depicted with solid line in FIG. 1).

[0064] In the refrigerant circuit 10, the refrigerant in a gaseous state at low pressure in the refrigeration cycle is sucked into the compressor 21, is compressed until the pressure thereof is increased to high pressure in the refrigeration cycle, and is then discharged from the compressor 21.

[0065] The refrigerant in a gaseous state at high pressure, which has been discharged from the compressor 21, is fed to the outdoor heat exchanger 23 through the four-way switch valve 22.

[0066] The refrigerant in a gaseous state at high pressure, which has been fed to the outdoor heat exchanger 23, radiates heat by heat exchange with the outdoor air to be supplied as a cooling source by the outdoor fan 36 in the outdoor heat exchanger 23, and is changed into a liquid state at high pressure.

[0067] The refrigerant in a liquid state at high pressure, which has radiated heat in the outdoor heat exchanger 23, is fed to the refrigerant jacket 29.

[0068] The refrigerant in a liquid state at high pressure, which has been fed to the refrigerant jacket 29, is heated by heat exchange with the electric component 72 as a cooled component. At this time, the electric component 72 is configured to be cooled in accordance with the flow rate (i.e., refrigerant circulation rate) and the temperature of the refrigerant flowing in a liquid state at high pressure through the refrigerant jacket 29.

[0069] The refrigerant in a liquid state at high pressure, which has been heated in the refrigerant jacket 29, is fed to the expansion valve 26.

[0070] The refrigerant in a liquid state at high pressure, which has been fed to the expansion valve 26, is depressurized to low pressure in the refrigeration cycle by the expansion valve 26, and is changed into a gas-liquid dual phase state at low pressure. The refrigerant in a gas-liquid dual phase state at low pressure, which has been depressurized by the expansion valve 26, is fed to the indoor heat exchanger 41 through the liquid side stop valve 27 and the liquid refrigerant communication pipe 5.

[0071] The refrigerant in a gas-liquid dual phase state at low pressure, which has been fed to the indoor heat exchanger 41, evaporates by heat exchange with the indoor air to be supplied as a heating source by the indoor fan 42 in the indoor heat exchanger 41. Accordingly, the indoor air is cooled and is then supplied to the indoor space, whereby the indoor space is cooled.

[0072] The refrigerant in a gaseous state at low pressure, which has evaporated in the indoor heat exchanger 41, is again sucked into the compressor 21 through the gaseous refrigerant communication pipe 6, the gaseous side stop valve 28 and the four-way switch valve 22.

<Heating Operation>

[0073] In the heating operation, the four-way switch valve 22 is configured to be switched into the heating cycle state (the state depicted with broken line in FIG. 1).

[0074] In the refrigerant circuit 10, the refrigerant in a gaseous state at low pressure in the refrigeration cycle is sucked into the compressor 21, is compressed until the pressure thereof is increased to high pressure in the refrigeration cycle, and is then discharged from the compressor 21.

[0075] The refrigerant in a gaseous state at high pressure, which has been discharged from the compressor 21, is fed to the indoor heat exchanger 41 through the four-way switch valve 22, the gaseous side stop valve 28 and the gaseous refrigerant communication pipe 6.

[0076] The refrigerant in a gaseous state at high pressure, which has been fed to the indoor heat exchanger 41, radiates heat by heat exchange with the indoor air to be supplied as a cooling source by the indoor fan 42 in the indoor heat exchanger 41, and is changed into a liquid state at high pressure. Accordingly, the indoor air is heated and is then supplied to the indoor space, whereby the indoor space is heated.

[0077] The refrigerant in a liquid state at high pressure, which has radiated heat in the indoor heat exchanger 41, is fed to the expansion valve 26 through the liquid refrigerant communication pipe 5 and the liquid side stop valve 27.

[0078] The refrigerant in a liquid state at high pressure, which has been fed to the expansion valve 26, is depressurized to low pressure in the refrigeration cycle by the expansion valve 26, and is changed into a gas-liquid dual phase state at low pressure. The refrigerant in a gas-liquid dual phase state at low pressure, which has been depressurized by the expansion valve 26, is fed to the refrigerant jacket 29.

[0079] The refrigerant in a gas-liquid dual phase state at low pressure, which has been fed to the refrigerant jacket 29, is heated by heat exchange with the electric component 72 as a cooled component. At this time, the electric component 72 is configured to be cooled in accordance with the flow rate (i.e., refrigerant circulation rate) and the temperature of the refrigerant flowing in a gas-liquid dual phase state at low pressure through the refrigerant jacket 29.

[0080] The refrigerant in a gas-liquid dual phase state at low pressure, which has been heated in the refrigerant jacket 29, is fed to the outdoor heat exchanger 23.

[0081] The refrigerant in a gas-liquid dual phase state at low pressure, which has been fed to the outdoor heat exchanger 23, evaporates by heat exchange with the outdoor air to be supplied as a heating source by the outdoor fan 36 in the outdoor heat exchanger 23, and is changed into a gaseous state at low pressure.

[0082] The refrigerant at low pressure, which has evaporated in the outdoor heat exchanger 23, is again sucked into the compressor 21 through the four-way switch valve 22.

<Compressor Capacity Control>

[0083] During the aforementioned refrigeration cycle operations (herein, the cooling operation and the heating operation), the compressor capacity control for regulating the frequency (rotation speed) of the compressor 21 in accordance with the required air conditioning capacity is configured to be performed.

[0084] Specifically, during the cooling operation, as the compressor capacity control, the frequency (rotation speed) of the compressor 21 is configured to be regulated in accordance with a difference in temperature between the temperature Tra of the indoor air to be detected by the indoor temperature sensor 50 and target indoor temperature Tras to be set by a remote controller (not shown in the drawings) or so forth. The difference in temperature between the temperature Tra of the indoor air and the target indoor temperature Tras herein corresponds to the required air conditioning capacity (herein, required cooling capacity). Now, when the required cooling capacity is large (i.e., "Tra-Tras" is large), the frequency (rotation speed) of the compressor 21 is configured to be changed and increased. Contrarily, when the required cooling capacity is small (i.e., "Tra-Tras" is small), the frequency (rotation speed) of the compressor 21 is configured to be changed and reduced. It should be noted that in consideration of the feature of the compressor motor 21 a and so forth, the compressor 21 is configured not to be continuously operated at a frequency (rotation speed) smaller than lower limit frequency fm0 (lower limit rotation speed Nm0). Hence, when Tra reaches Tras, the compressor 21 is configured to transition to an operation deactivated state (thermo-off) so as to prevent the cooling capacity from being excessive. When "Tra-Tras" then becomes large again, the operation of the compressor 21 is configured to be started.

[0085] On the other hand, during the heating operation, as the compressor capacity control, the frequency (rotation speed) of the compressor 21 is configured to be regulated in accordance with a difference in temperature between the temperature Tra of the indoor air to be detected by the indoor temperature sensor 50 and the target indoor temperature Tras to be set by the remote controller (not shown in the drawings) or so forth. The difference in temperature between the temperature Tra of the indoor air and the target indoor temperature Tras herein corresponds to the required air conditioning capacity (herein, the required heating capacity). Now, when the required heating capacity is large (i.e., "Tras-Tra" is large), the frequency (rotation speed) of the compressor 21 is configured to be changed and increased. Contrarily, when the required heating capacity is small (i.e., "Tras-Tra" is small), the frequency (rotation speed) of the compressor 21 is configured to be changed and reduced. It should be noted that in consideration of the feature of the compressor motor 21 a and so forth, the compressor 21 is configured not to be continuously operated at a frequency (rotation speed) smaller than the lower limit frequency fm0 (lower limit rotation speed Nm0). Hence, when Tra reaches Tras, the compressor 21 is configured to transition to the operation deactivated state (thermo-off) so as to prevent the heating capacity from being excessive. When "Tras-Tra" then becomes large again, the operation of the compressor 21 is configured to be started.

(4) Refrigerant Cooling Part Condensation Preventive Control

[0086] As described above, when the heating operation is performed in the air conditioning apparatus 1 including the refrigerant jacket 29 for cooling the electric component 72 by the refrigerant flowing at low pressure in the refrigeration cycle between the expansion valve 26 and the outdoor heat exchanger 23, it is concerned that condensation occurs in the refrigerant jacket 29.

[0087] As a countermeasure for this, when the control for steeply elevating the rotation speed of the compressor 21 is performed similarly to the conventional air conditioning apparatus described in PTL 1, it is concerned that the refrigerant circulation rate in the refrigerant circuit 10 becomes excessive, i.e., the heating capacity becomes excessive, and accordingly, the compressor 21 is repeatedly activated and deactivated by the thermo-off function. Additionally, when R32 is used as the refrigerant, a required heating capacity can be reliably achieved with a low refrigerant circulation rate. Hence, there is a tendency that pressure loss from the refrigerant jacket 29 to the suction side of the compressor 21 decreases, and the refrigerant passing through the refrigerant jacket 29 decreases in temperature. Because of this, condensation becomes likely to occur in the refrigerant jacket 29, and the control for steeply elevating the rotation speed of the compressor 21 to the predetermined rotation speed is also frequently performed. Hence, it is concerned that the compressor 21 is more repeatedly activated and deactivated by the thermo-off function.

[0088] In view of the above, the refrigerant cooling part condensation preventive control is herein configured to be performed to increase stepwise the rotation speed of the compressor 21 in the heating operation when a refrigerant cooling part condensation occurrence condition for determining that condensation occurs in the refrigerant jacket 29 is satisfied.

[0089] It should be noted that unlike in performing the heating operation, there is little chance of occurrence of condensation in the refrigerant jacket 29 in performing the cooling operation. This is because in performing the cooling operation, the refrigerant jacket 29 functions as a heat exchanger configured to cool the electric component 72 by the refrigerant flowing at high pressure in the refrigeration cycle between the outdoor heat exchanger 23 and the expansion valve 26 (in this case, the temperature of the refrigerant is greater than or equal to the temperature in the atmosphere of the refrigerant jacket 29).

[0090] Next, the refrigerant cooling part condensation preventive control will be explained with FIGS. 1 to 5. FIG. 5 is herein a flowchart of the refrigerant cooling part condensation preventive control. It should be noted that as with the aforementioned basic action, the refrigerant cooling part condensation preventive control to be hereinafter explained is configured to be performed by the controller 8.

[0091] In the heating operation, firstly in Step ST1, the controller 8 determines whether or not the refrigerant cooling part condensation occurrence condition for determining that condensation occurs in the refrigerant jacket 29 is satisfied. As an index for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied, it is herein most preferable to determine whether or not temperature Tfin of the refrigerant jacket 29 at the refrigerant cooling part 29a thermally making contact with the electric component 72 is lower than dew point temperature Tdew in the atmosphere of the refrigerant jacket 29.

[0092] However, the temperature Tfin of the refrigerant cooling part 29a of the refrigerant jacket 29 is high in a region located closely to the electric component 72 but is low in a region located far from the electric component 72. Hence, it is not easy to decide in which region of the refrigerant cooling part 29a its temperature is appropriate as the representative temperature of the entire refrigerant cooling part 29a. Additionally, increase in cost is inevitable when a large number of temperature sensors are mounted to the refrigerant cooling part 29a.

[0093] In view of this, the temperature Tfin of the refrigerant cooling part 29a is herein configured to be predicted based on the temperature of the refrigerant flowing between the refrigerant jacket 29 and the outdoor heat exchanger 23 and the heat radiation amount of the electric component 72. Here, the temperature Torl of the refrigerant to be detected by the outdoor heat exchanger liquid side temperature sensor 46 mounted to the liquid side of the outdoor heat exchanger 23 is used as the temperature of the refrigerant flowing between the refrigerant jacket 29 and the outdoor heat exchanger 23, whereas the heat radiation amount of the electric component 72 is predictable from electric current Iinv flowing through the electric component 72. Specifically, the temperature Tfin of the refrigerant cooling part 29a is configured to be predicted by the following formula expressed as a relational formula of the temperature Torl of the refrigerant flowing between the refrigerant jacket 29 and the outdoor heat exchanger 23 and the electric current Iinv flowing through the electric component 72. Here, α is a coefficient preliminarily and experimentally obtained.

$$Tfin = Torl + \alpha \times Iinv \cdots (A)$$

[0094] Additionally, the dew point temperature Tdew is herein configured to be predicted based on the temperature in the atmosphere of the refrigerant jacket 29. The temperature Toa of the outdoor air to be detected by the outdoor temperature sensor 47 is herein used as the atmosphere temperature of the refrigerant jacket 29. Specifically, the dew point temperature Tdew is configured to be predicted by the following formula expressed as a relational formula of the temperature Toa of the outdoor air. Here, β is a coefficient preliminarily and experimentally obtained, whereas γ is a dew point coefficient.

$$Tdew = \beta \times Toa + \gamma \cdots (B)$$

[0095] Moreover, it is determined that the refrigerant cooling part condensation occurrence condition is satisfied when the temperature Tfin of the refrigerant cooling part 29a predicted by the relational formula (A) is lower than condensation determining temperature ($Tdew+\Delta Tdew1$) to be determined based on the dew point temperature Tdew predicted by the relational formula (B). Here, ΔTdew1 is a condensation determining value. When it is intended to make the refrigerant cooling part condensation preventive control more likely to be activated, the condensation determining temperature is set to have a value higher than that of the condensation temperature Tdew. Contrarily, when it is intended to make the refrigerant cooling part condensation preventive control less likely to be activated, the condensation determining temperature is set to have a value close to that of the condensation temperature Tdew.

[0096] Thus, the temperature Tfin of the refrigerant cooling part 29a of the refrigerant jacket 29 and the dew point temperature Tdew are herein predicted, and it is possible to appropriately determine whether or not the refrigerant cooling part condensation occurrence condition is satisfied using both of the detected temperature Tfin of the refrigerant cooling part 29a and the detected dew point temperature Tdew.

[0097] It should be noted that unlike the above, a variety of conventional indexes such as the one described in PTL 1 can be employed as the index for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied. It should be noted that in consideration of appropriateness of determination, it is preferable, as described above, to determine whether or not the temperature Tfin of the refrigerant jacket 29 at the refrigerant cooling part 29a thermally making contact with the electric component 72 is lower than the dew point temperature Tdew in the atmosphere of the refrigerant jacket 29.

[0098] Next, when it is determined in Step ST1 that the refrigerant cooling part condensation occurrence condition is satisfied, then in Step ST2, the controller 8 is configured to add a predetermined frequency increment Δfm (rotation speed increment ΔNm) to lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21, and then, return to the processing in Step ST1 for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied. In other words, as long as the refrigerant cooling part condensation occurrence condition is satisfied in Step ST1, the controller 8 is configured to repeatedly add the predetermined frequency increment Δfm (rotation speed increment ΔNm) to the lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21. As described above, the compressor 21 is herein configured to perform the compressor capacity control as the basic control. Hence, the controllable lower limit of the frequency (rotation speed) of the compressor 21 means the controllable lower limit in the compressor capacity control. Therefore, in the processing of Step ST1, when it is determined for the first time that the refrigerant cooling part condensation occurrence condition is satisfied, the predetermined frequency increment Δfm (rotation speed increment ΔNm) is configured to be added to the lower limit frequency fm0 (lower limit rotation speed Nm0) that is the initial value of the controllable lower limit in the compressor capacity control, and then likewise, the frequency increment Δfm (rotation speed increment ΔNm) is configured to be added to the lower limit frequency fm (lower limit rotation speed Nm) to which the frequency increment Δfm (rotation speed increment ΔNm) has been added.

[0099] Thus, the frequency (rotation speed) of the compressor 21 can be herein substantially elevated stepwise by continuously performing the compressor capacity control for changing the frequency (rotation speed) of the compressor 21 in accordance with the required heating capacity, and simultaneously, by elevating stepwise the lower limit frequency fm (lower limit rotation speed Nm) in the compressor capacity control. Therefore, unlike in performing the conventional control for steeply elevating the rotation speed of the compressor 21, it is possible to inhibit the refrigerant circulation rate from being excessive in the refrigerant circuit 10, in other words, to inhibit the heating capacity from being excessive, and simultaneously, to inhibit occurrence of condensation in the refrigerant jacket 29 by least necessary increment in rotational speed.

[0100] Accordingly, it is herein possible in the heating operation to continuously perform the compressor capacity control for changing the frequency (rotation speed) of the compressor 21 in accordance with the required heating capacity, to inhibit activation and deactivation of the compressor 21 attributed to the thermo-off function, and to inhibit occurrence of condensation in the refrigerant jacket 29.

[0101] On the other hand, when it is determined in Step ST1 that the refrigerant cooling part condensation occurrence condition is not satisfied, then in Step ST3, the controller 8 is configured to determine whether or not a refrigerant cooling part condensation disappearance condition for determining that condensation does not occur in the refrigerant jacket 29 is satisfied. Similarly to the refrigerant cooling part condensation occurrence condition in Step ST1, as an index for determining whether or not the refrigerant cooling part condensation disappearance condition is satisfied, it is herein used to determine whether or not the temperature Tfin of the refrigerant jacket 29 at the refrigerant cooling part 29a thermally making contact with the electric component 72 is higher than the dew point temperature Tdew in the atmosphere of the refrigerant jacket 29. Specifically, it is determined that the refrigerant cooling part condensation disappearance condition is satisfied when the temperature Tfin of the refrigerant cooling part 29a predicted by the relational formula (A) is higher than condensation disappearance temperature (Tdew+ΔTdew2) to be determined based on the dew point temperature Tdew predicted by the relational formula (B). Here, ΔTdew2 is a condensation disappearance value, and is set such that the condensation disappearance temperature is higher than the condensation determining temperature in order to produce a condition that occurrence of condensation is reliably inhibited in the refrigerant jacket 29.

[0102] Thus, the temperature Tfin of the refrigerant cooling part 29a of the refrigerant jacket 29 and the dew point temperature Tdew are herein predicted, and it is possible to appropriately determine whether or not the refrigerant cooling part condensation disappearance condition is satisfied using both of the detected temperature Tfin of the refrigerant cooling part 29a and the detected dew point temperature Tdew.

[0103] Next, when it is determined in Step ST3 that the refrigerant cooling part condensation disappearance condition is satisfied, then in Step ST4, the controller 8 is configured to restore the lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21 to the lower limit frequency fm0 (lower limit rotation speed Nm0) that is the initial value of the controllable lower limit in the compressor capacity control, and then, return to the processing in Step ST1 for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied. Accordingly, the refrigerant cooling part condensation preventive control is deactivated. Contrarily, when it is determined in Step ST3 that the refrigerant cooling part condensation disappearance condition is not satisfied, the controller 8 is configured to return to the processing in Step ST1 for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied without changing the lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21. Accordingly, the refrigerant cooling part condensation preventive control is continuously performed.

(5) Modification 1

[0104] In the aforementioned first embodiment, as long as the refrigerant cooling part condensation occurrence condition in Step ST1 is satisfied, the controller 8 is configured to repeatedly add the predetermined frequency increment Δfm (rotation speed increment ΔNm) to the lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21 so as to elevate stepwise the frequency (rotation speed) of the compressor 21.

[0105] However, when the frequency (rotation speed) of the compressor 21 is excessively elevated, activation and deactivation of the compressor 21 are inevitably caused by the thermo-off function.

[0106] In view of this, as shown in FIG. 6, a processing of determination in Step ST5 is herein designed to be added between the processing in Step ST1 for determining whether or not the refrigerant cooling part condensation occurrence condition is satisfied and the processing in Step ST2 for elevating the frequency (rotation speed) of the compressor 21. The determination processing in Step ST5 is herein a processing for determining whether or not a refrigerant cooling part condensation preventive control restricting condition for determining that the frequency (rotation speed) of the compressor 21 is excessively high is satisfied. Specifically, in Step ST5, it is herein determined whether or not the lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21 has reached a predetermined lower limit frequency upper limit value fmx (lower limit rotation speed upper limit value Nmx), in other words, whether or not the relation "fm (Nm) $\leq$ fmx (Nmx)" is not satisfied. Then in Step ST5, when the relation "fm (Nm) $\leq$ fmx (Nmx)" is satisfied, the processing in Step ST2 for elevating stepwise the frequency (rotation speed) of the compressor 21 is configured to be performed. Contrarily, when the relation "fm (Nm)$\leq$ fmx (Nmx)" is not satisfied, the processing in Step ST2 for elevating stepwise the frequency (rotation speed) of the compressor 21 is configured not to be performed. In other words, even if the refrigerant cooling part condensation occurrence condition is satisfied in Step ST1, the controller 8 is configured not to add the frequency increment Δfm (rotation speed increment ΔNm) to the lower limit frequency fm (lower limit rotation speed Nm) when the lower limit frequency fm (lower limit rotation speed Nm) has reached the lower limit frequency upper limit value fmx (lower limit rotation speed upper limit value Nmx) in Step ST5.

[0107] With the configuration, even if the refrigerant cooling part condensation occurrence condition is satisfied, the controller 8 is capable of preventing elevation in frequency (rotation speed) of the compressor 21 when the refrigerant cooling part condensation preventive control restricting condition for determining that the frequency (rotation speed) of the compressor 21 is excessively high is satisfied. Hence, it is possible to effectively inhibit activation and deactivation of the compressor 21 attributed to the thermo-off function.

(6) Modification 2

[0108] In the aforementioned first embodiment and Modification 1 thereof, as the refrigerant cooling part condensation preventive control, the predetermined frequency increment Δfm (rotation speed increment ΔNm) is configured to be repeatedly added to the lower limit frequency fm (lower limit rotation speed Nm) that is the controllable lower limit of the frequency (rotation speed) of the compressor 21 so as to elevate stepwise the frequency (rotation speed) of the compressor 21.

[0109] However, the control for elevating stepwise the frequency (rotation speed) of the compressor 21 is not limited to this.

[0110] For example, in Step ST2, the controller 8 may be configured to temporarily stop performing the compressor capacity control and repeatedly add a predetermined frequency increment (rotation speed increment) to the present value of the frequency (rotation speed) of the compressor 21 so as to elevate stepwise the frequency (rotation speed) of the compressor 21. In this control, the controller 8 may be configured to deactivate the refrigerant cooling part condensation preventive control by activating again the compressor capacity control in Step ST4 so as to restore the frequency (rotation speed) of the compressor 21 to its initial state.

[0111] Additionally, whether or not the present value of the frequency (rotation speed) of the compressor 21 has reached upper limit frequency (upper limit rotation speed) in the refrigerant cooling part condensation preventive control may be configured to be determined in Step ST5 as the determination regarding whether or not the refrigerant cooling part condensation preventive control restricting condition for determining that the frequency (rotation speed) of the compressor 21 is excessively high is satisfied. Moreover, even if the refrigerant cooling part condensation occurrence condition is satisfied in Step ST1, a predetermined frequency increment (rotation speed increment) may be configured not to be added to the present value of the frequency (rotation speed) when the present value of the frequency (rotation speed) has reached the upper limit frequency (upper limit rotation speed) in Step ST5.

- Second Embodiment -

[0112] In the aforementioned first embodiment and Modifications 1 and 2 thereof, the refrigerant cooling part condensation preventive control is applied to the air conditioning apparatus 1 including the refrigerant circuit 10. The refrigerant circuit 10 includes the single expansion valve 26 and is provided with the refrigerant jacket 29 configured to cool the electric component 72 by the refrigerant flowing at low pressure in the refrigeration cycle between the expansion valve 26 and the outdoor heat exchanger 23. However, the application target of the refrigerant cooling part condensation preventive control is not limited to the air conditioning apparatus 1.

[0113] For example, as shown in FIGS. 7 and 8, a refrigerant cooling part condensation preventive control similar to those in the first embodiment and Modifications 1 and 2 thereof may be applied to an air conditioning apparatus 101 that includes a refrigerant circuit 110 including two expansion valves 24 and 26.

[0114] Here, the configuration of the air conditioning apparatus 101 including the refrigerant circuit 110 is similar to that of the air conditioning apparatus 1 of the first embodiment except for the configuration of an outdoor unit 102. Therefore, the following explanation will be provided by focusing on the configuration of the outdoor unit 102.

[0115] The outdoor unit 102 is installed in an outdoor space, and composes part of the refrigerant circuit 110. The outdoor unit 102 mainly includes the compressor 21, the four-way switch valve 22, the outdoor heat exchanger 23, the first expansion valve 24, a receiver 25, the second expansion valve 26, the liquid side stop valve 27, the gaseous side stop valve 28 and a receiver gas vent pipe 30. The outdoor unit 102 further includes the outdoor fan 36, a variety of sensors 43 to 47 and the outdoor side control unit 20. It should be noted that the compressor 21, the four-way switch valve 22, the outdoor heat exchanger 23, the liquid side stop valve 27, the gaseous side stop valve 28, the variety of sensors 43 to 47 and the outdoor fan 36 are similar to those in the first embodiment, and therefore, explanation thereof will not be hereinafter provided.

[0116] The first expansion valve 24 is a valve functioning as an upstream side expansion valve in the cooling operation, and is configured to depressurize the refrigerant having radiated heat in the outdoor heat exchanger 23 from high pressure to intermediate pressure in the refrigeration cycle. The first expansion valve 24 is also a valve functioning as a downstream side explanation valve in the heating operation, and is configured to depressurize the refrigerant accumulated in the receiver 25 from intermediate pressure to low pressure in the refrigeration cycle. The first expansion valve 24 is mounted to a part of the liquid refrigerant pipe 35 in adjacent to the outdoor heat exchanger 23. Here, an electric expansion valve is used as the first expansion valve 24.

[0117] The receiver 25 is mounted between the first expansion valve 24 and the second expansion valve 26. The receiver 25 is a container configured to be capable of accumulating the refrigerant at intermediate pressure in the refrigeration cycle in the cooling operation and the heating operation.

[0118] Unlike the first embodiment, the second expansion valve 26 is a valve functioning as a downstream side expansion valve in the cooling operation, and is configured to depressurize the refrigerant accumulated in the receiver 25 from intermediate pressure to low pressure in the refrigeration cycle. The second expansion valve 26 is also a valve functioning as an upstream side expansion valve in the heating operation, and is configured to depressurize the refrigerant having radiated heat in the indoor heat exchanger 41 from high pressure to intermediate pressure in the refrigeration cycle.

[0119] The refrigerant jacket 29 is herein a heat exchanger configured to cool the electric component 72 (cooled component) by the refrigerant flowing between the outdoor heat exchanger 23 and the first expansion valve 24. In other words, in the cooling operation, the refrigerant jacket 29 functions as a heat exchanger configured to cool the electric component 72 by the refrigerant at high pressure in the refrigeration cycle that has radiated heat in the outdoor heat exchanger 23. In the heating operation, the refrigerant jacket 29 functions as a heat exchanger configured to cool the electric component 72 by the refrigerant at low pressure in the refrigeration cycle that has been depressurized in the first expansion valve 24.

[0120] The receiver gas vent pipe 30 is a refrigerant pipe for directing the refrigerant, accumulated in the receiver 25 in a gaseous state at intermediate pressure in the refrigeration cycle, to the suction pipe 31 of the compressor 21. The receiver gas vent pipe 30 is provided for connecting the upper part of the receiver 25 to an intermediate part of the suction pipe 31. The receiver gas vent pipe 30 is provided with a receiver gas vent valve 30a, a capillary tube 30b and a check valve 30c. The receiver gas vent valve 30a is an open/close controllable valve configured to allow/block the flow of the refrigerant in the receiver gas vent pipe 30. An electromagnetic valve is herein used as the receiver gas vent valve 30a. The capillary tube 30b is a mechanism configured to depressurize the refrigerant accumulated in a gaseous state in the receiver 25 to low pressure in the refrigeration cycle. A capillary tube, having a smaller diameter than the receiver gas vent pipe, is herein used as the capillary tube 30b. The check valve 30c is a valve mechanism configured to allow the flow of the refrigerant only when the refrigerant flows from the receiver 25 side to the suction pipe 31 side. A check valve is herein used as the check valve 30c.

[0121] Similarly to the first embodiment, the outdoor side control unit 20 composes the controller 8 together with the indoor side control unit 40. It should be noted that unlike the first embodiment, the two expansion valves 24 and 26 and the receiver gas vent valve 30a are also herein configured to be controlled by the controller 8. Additionally, similarly to the first embodiment, the compressor capacity control is herein configured to be performed as the basic action.

[0122] Moreover, similarly to the air conditioning apparatus 1 of the first embodiment, the air conditioning apparatus 101 herein described includes the refrigerant jacket 29 configured to cool the electric component 72 by the refrigerant flowing at low pressure in the refrigeration cycle between the first expansion valve 24 and the outdoor heat exchanger 23, and it is concerned that condensation occurs in the refrigerant jacket 29 in performing the heating operation. However, the air conditioning apparatus 101 can also inhibit activation and deactivation of the compressor 21 attributed to the thermo-off function and simultaneously can inhibit occurrence of condensation in the refrigerant jacket 29 in the heating operation by performing a refrigerant cooling part condensation preventive control similar to those in the first embodiment and Modifications 1 and 2 thereof.

- Other Embodiments -

[0123] In the first embodiment, the modifications thereof and the second embodiment described above, R32 is used as the refrigerant. However, the refrigerant is not limited to this, and other refrigerants may be used instead.

INDUSTRIAL APPLICABILITY

[0124] The present invention is widely applicable to a type of air conditioning apparatus that includes a refrigerant jacket configured to cool an electric component by a refrigerant, which flows at low pressure in a refrigeration cycle between an expansion valve and an outdoor heat exchanger, in performing a heating operation to circulate the refrigerant sequentially through a compressor, an indoor heat exchanger, the expansion valve and the outdoor heat exchanger.

REFERENCE SIGNS LIST

[0125]

1, 101	Air conditioning apparatus
10, 110	Refrigerant circuit
21	Compressor
23	Outdoor heat exchanger
24, 26	Expansion valve
29	Refrigerant jacket
29a	Refrigerant cooling part
41	Indoor heat exchanger
72	Electric component

CITATION LIST

PATENT LITERATURE

[0126] PTL 1: Japan Laid-open Patent Application Publication No. 2010-25374

Claims

1. An air conditioning apparatus (1, 101) including a refrigerant circuit (10, 110) constructed by connecting a compressor (21), an indoor heat exchanger (41), an expansion valve (24, 26) and an outdoor heat exchanger (23), the air conditioning apparatus further including a refrigerant jacket (29) configured to cool an electric component (72) by a refrigerant flowing at low pressure in a refrigeration cycle between the expansion valve and the outdoor heat exchanger in performing a heating operation for circulating the refrigerant through the refrigerant circuit in a sequential order of the compressor, the indoor heat exchanger, the expansion valve and the outdoor heat exchanger, wherein
a refrigerant cooling part condensation preventive control for elevating stepwise a rotation speed of the compressor is configured to be performed when a refrigerant cooling part condensation occurrence condition for determining that condensation occurs in the refrigerant jacket is satisfied in the heating operation.

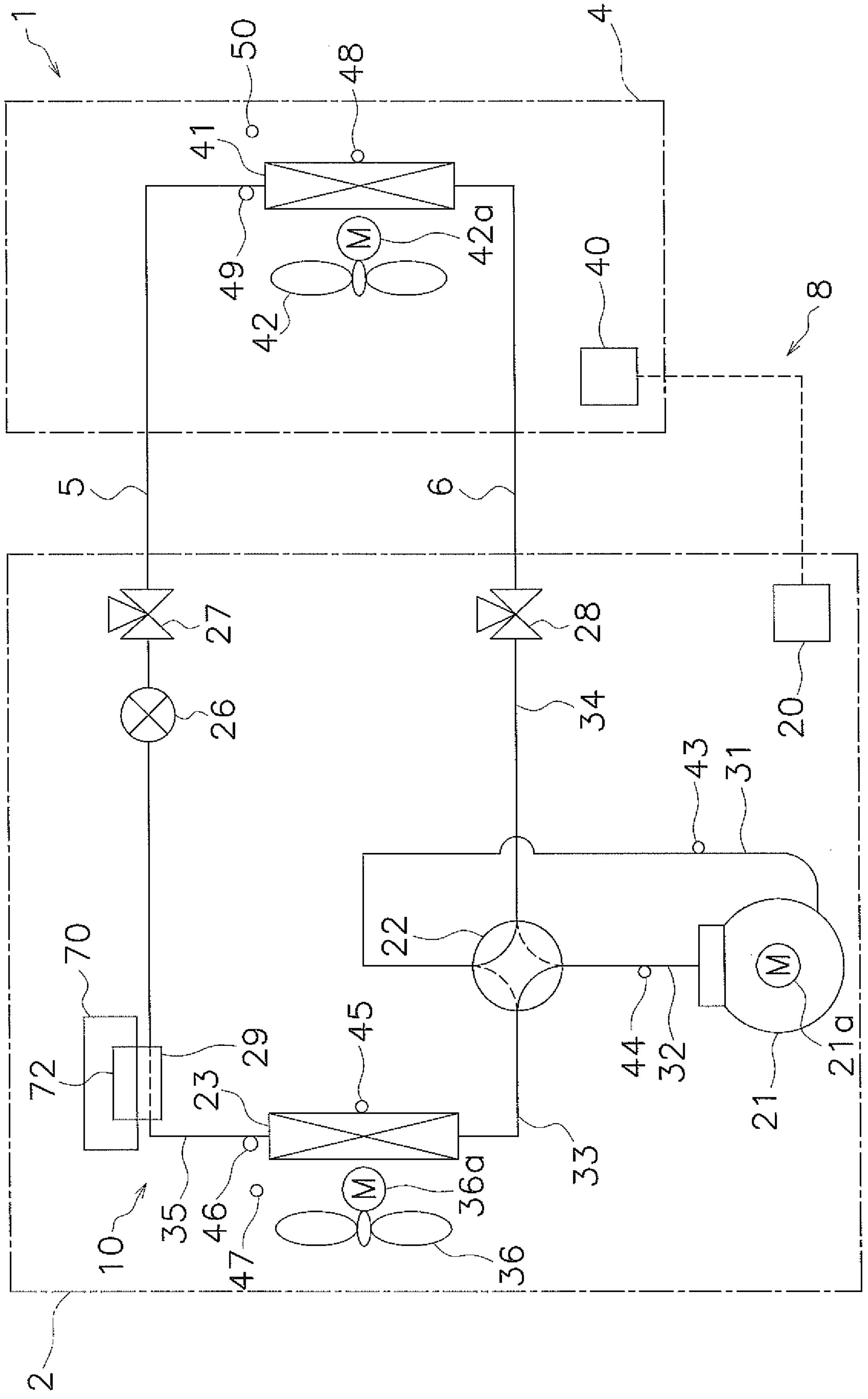
2. The air conditioning apparatus (1, 101) recited in claim 1, wherein
even under satisfaction of the refrigerant cooling part condensation occurrence condition, the rotation speed of the compressor is configured not to be elevated when a refrigerant cooling part condensation preventive control restricting condition for determining that the rotation speed of the compressor (21) is excessively high is satisfied.

3. The air conditioning apparatus (1, 101) recited in claim 1, wherein
the refrigerant cooling part condensation preventive control is a control for repeatedly adding a predetermined rotation speed increment to a lower limit rotation speed defined as a controllable lower limit of the rotation speed of the compressor (21) as long as the refrigerant cooling part condensation occurrence condition is satisfied.

4. The air conditioning apparatus (1, 101) recited in claim 3, wherein
even under satisfaction of the refrigerant cooling part condensation occurrence condition, the rotation speed increment is configured not to be added to the lower limit rotation speed when the lower limit rotation speed has reached a predetermined lower limit rotation speed upper limit value.

5. The air conditioning apparatus (1, 101) recited in any one of claims 1 to 4, wherein
a temperature of the refrigerant jacket at a refrigerant cooling part (29a) thermally making contact with the electric component is configured to be predicted based on a temperature of the refrigerant flowing between the refrigerant jacket (29) and the outdoor heat exchanger (23) and a heat radiation amount of the electric component,
a dew point temperature is configured to be predicted based on an atmosphere temperature of the refrigerant jacket, and
the refrigerant cooling part condensation occurrence condition is configured to be satisfied when the predicted temperature of the refrigerant cooling part is lower than a condensation determining temperature to be determined based on the dew point temperature.

6. The air conditioning apparatus (1, 101) recited in any one of claims 1 to 5, wherein
the refrigerant to be encapsulated in the refrigerant circuit (10, 110) is R32.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41
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42a
42
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31
22
70
72
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44
32
21a
21
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36a
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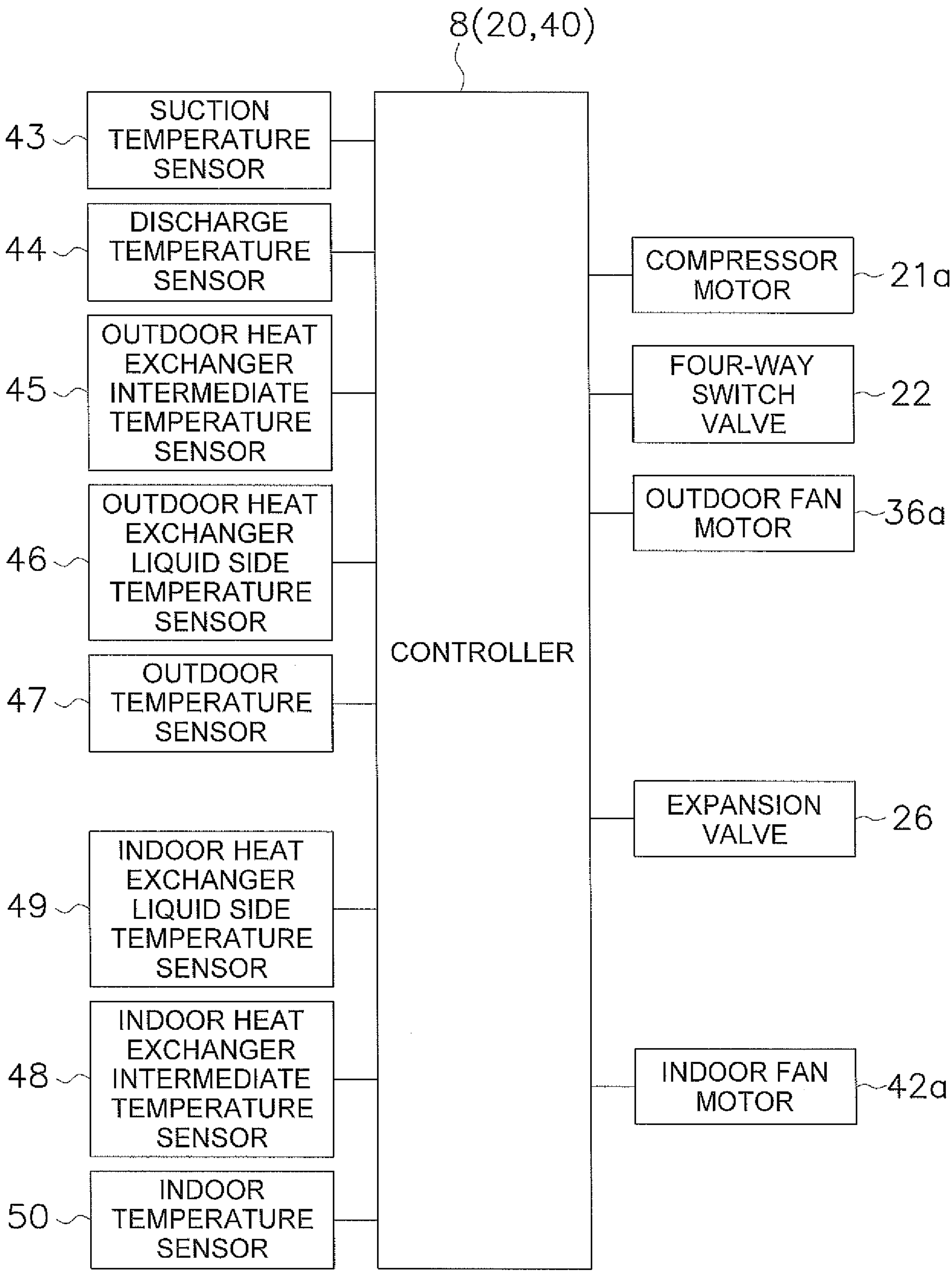
10
36
2

FIG. 1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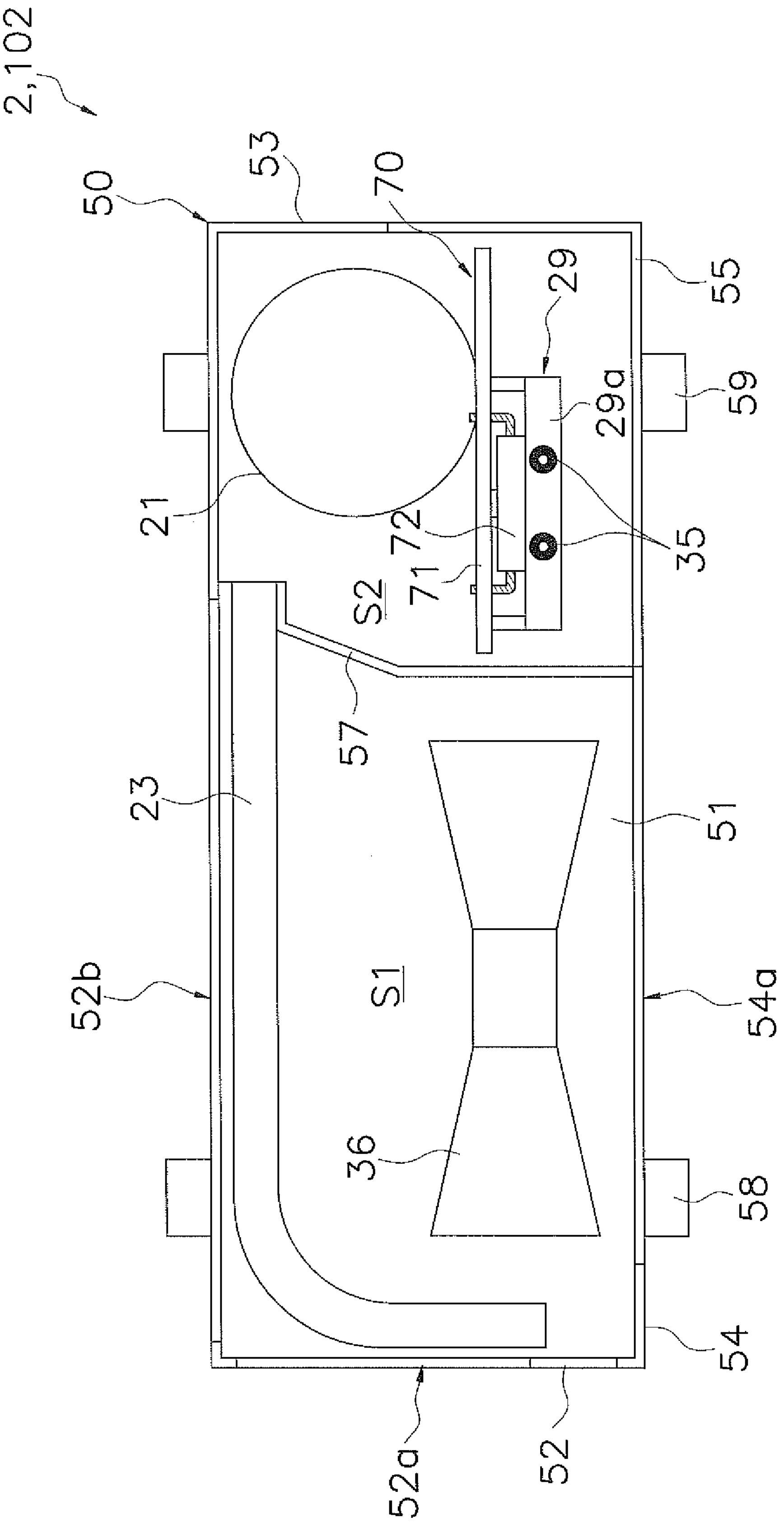
44
DISCHARGE TEMPERATURE SENSOR
45
OUTDOOR HEAT EXCHANGER INTERMEDIATE TEMPERATURE SENSOR
46
OUTDOOR HEAT EXCHANGER LIQUID SIDE TEMPERATURE SENSOR
47
OUTDOOR TEMPERATURE SENSOR
49
INDOOR HEAT EXCHANGER LIQUID SIDE TEMPERATURE SENSOR
48
INDOOR HEAT EXCHANGER INTERMEDIATE TEMPERATURE SENSOR
50
INDOOR TEMPERATURE SENSOR
CONTROLLER
COMPRESSOR MOTOR
21a
FOUR-WAY SWITCH VALVE
22
OUTDOOR FAN MOTOR
36a
EXPANSION VALVE
26
INDOOR FAN MOTOR
42a

FIG. 2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29
29a
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21
72
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S2
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23
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52b
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54a
36
58
54
52a
52

FIG. 3

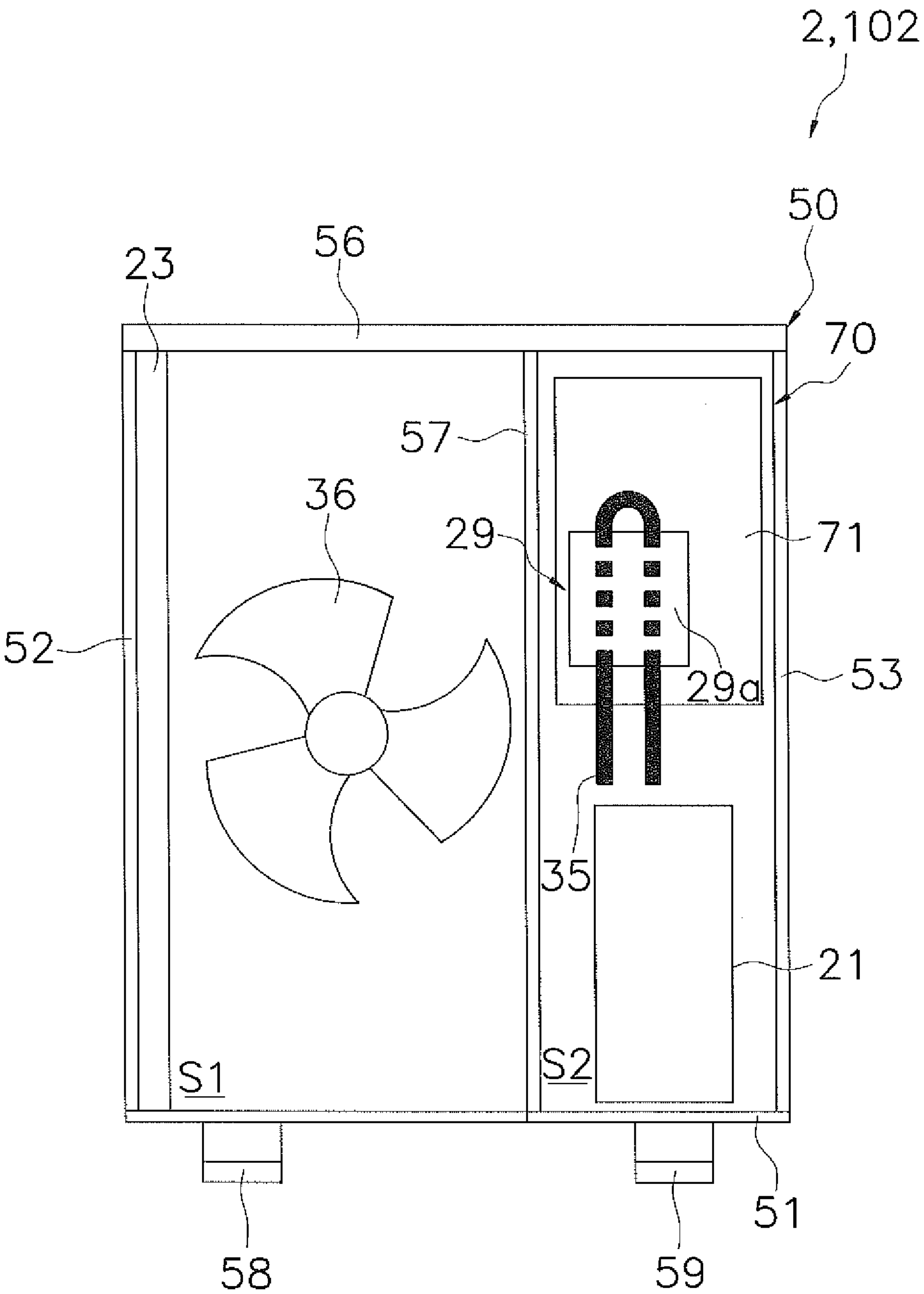
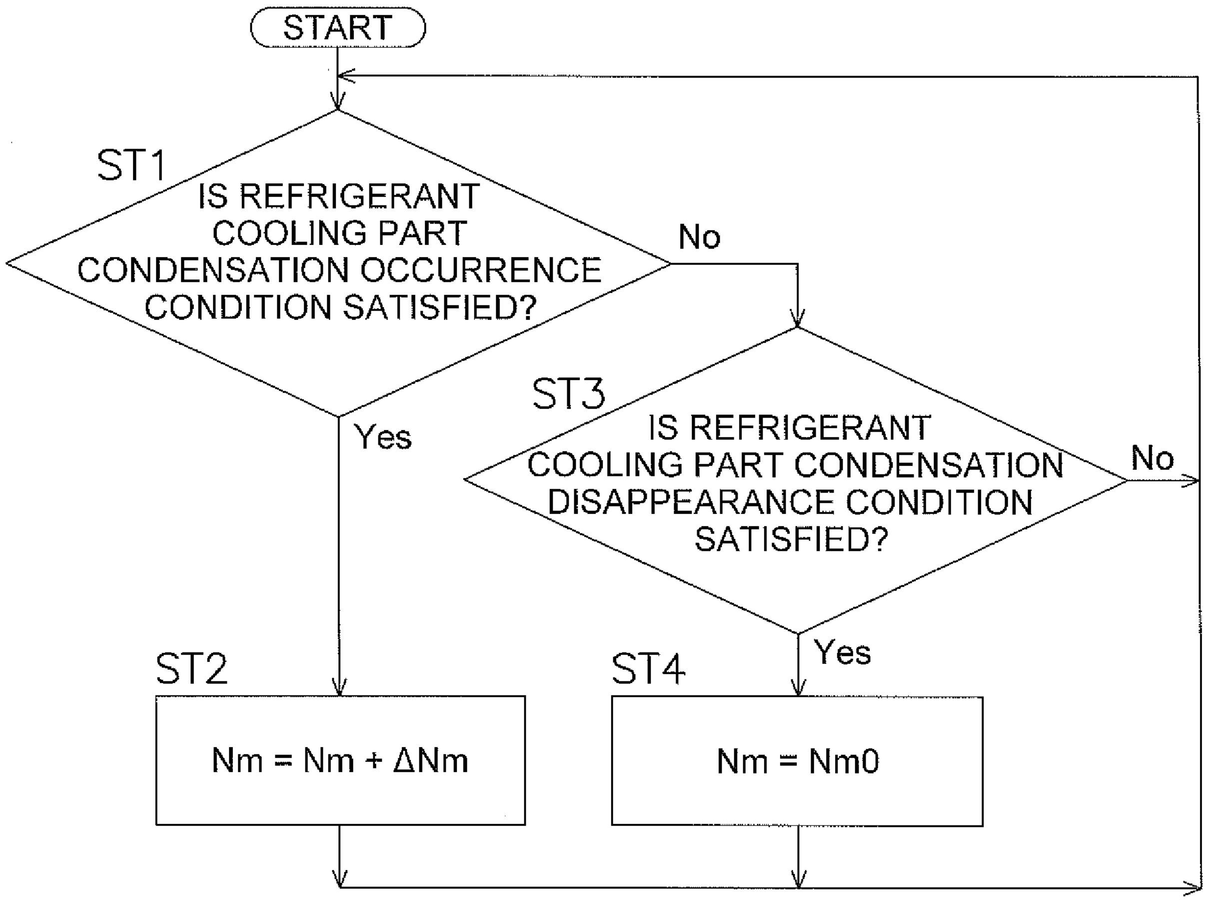


FIG. 4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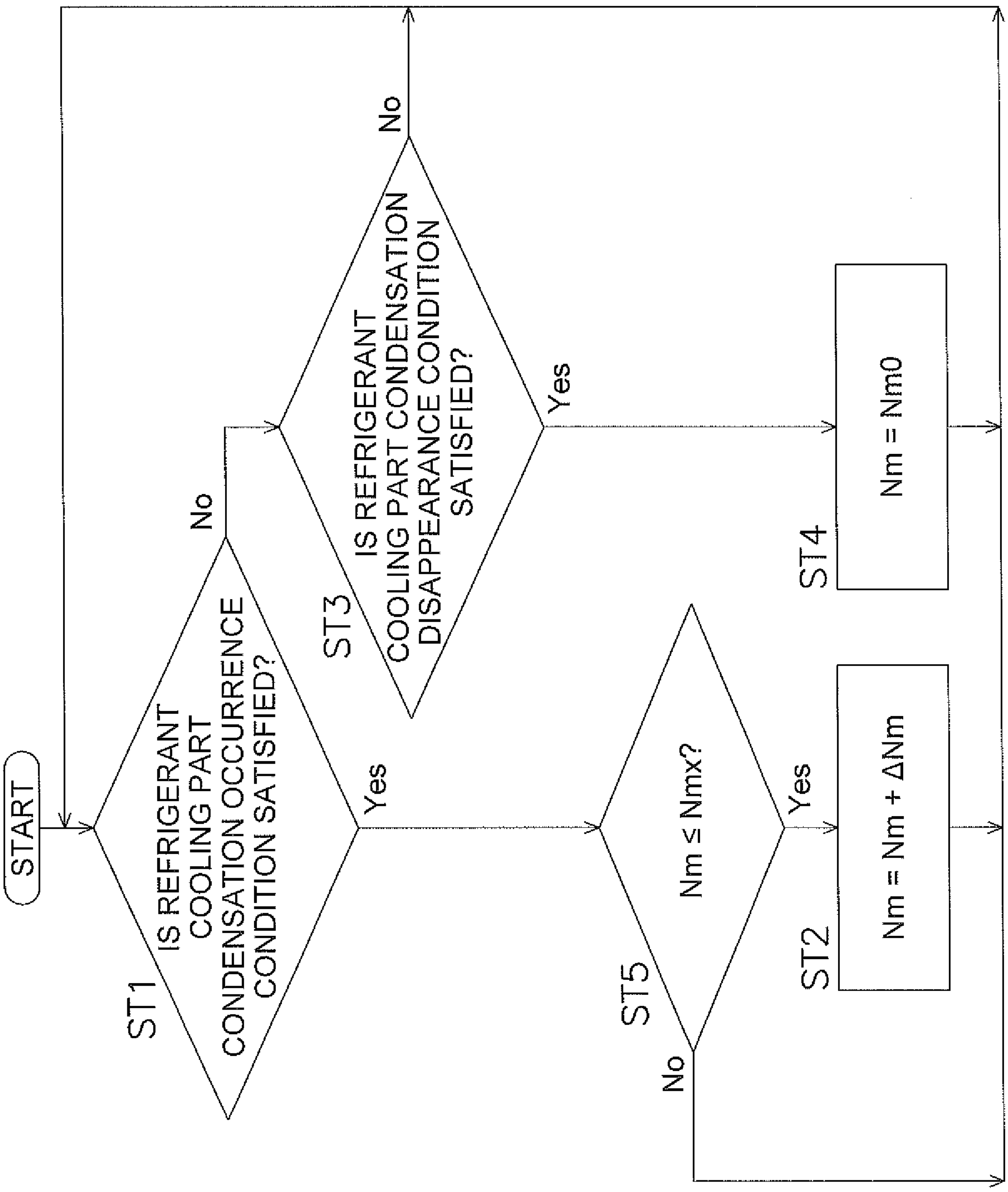
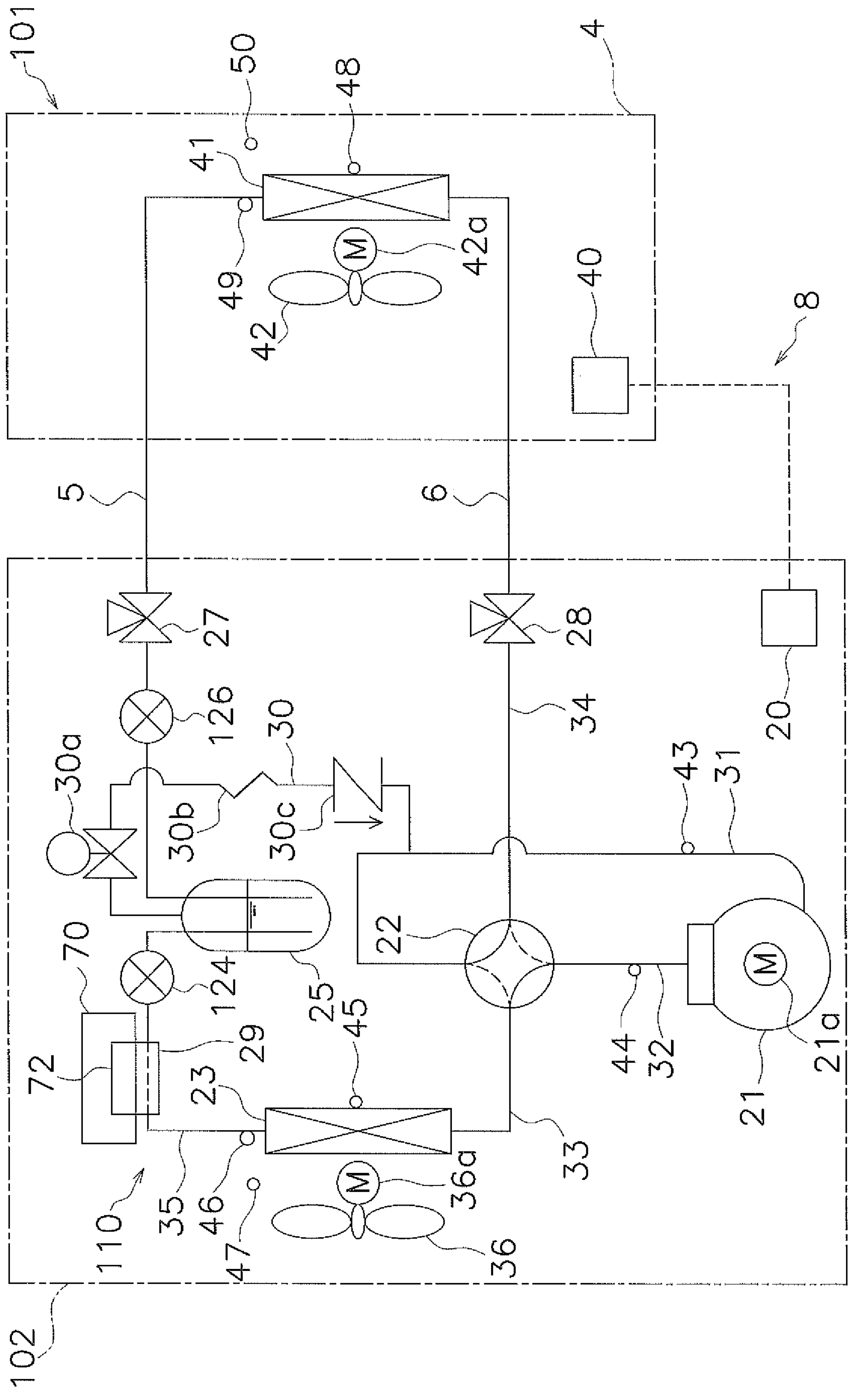
IS REFRIGERANT COOLING PART CONDENSATION OCCURRENCE CONDITION SATISFIED?
No
Yes
ST3
IS REFRIGERANT COOLING PART CONDENSATION DISAPPEARANCE CONDITION SATISFIED?
No
Yes
ST2
Nm = Nm + ΔNm
ST4
Nm = Nm0

FIG. 5

FIG. 6


START
ST1
IS REFRIGERANT COOLING PART CONDENSATION OCCURRENCE CONDITION SATISFIED?
Yes
No
ST3
IS REFRIGERANT COOLING PART CONDENSATION DISAPPEARANCE CONDITION SATISFIED?
Yes
No
ST5
Nm ≤ Nmx?
Yes
No
ST2
Nm = Nm + ΔNm
ST4
Nm = Nm0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31
30b
30c
22
70
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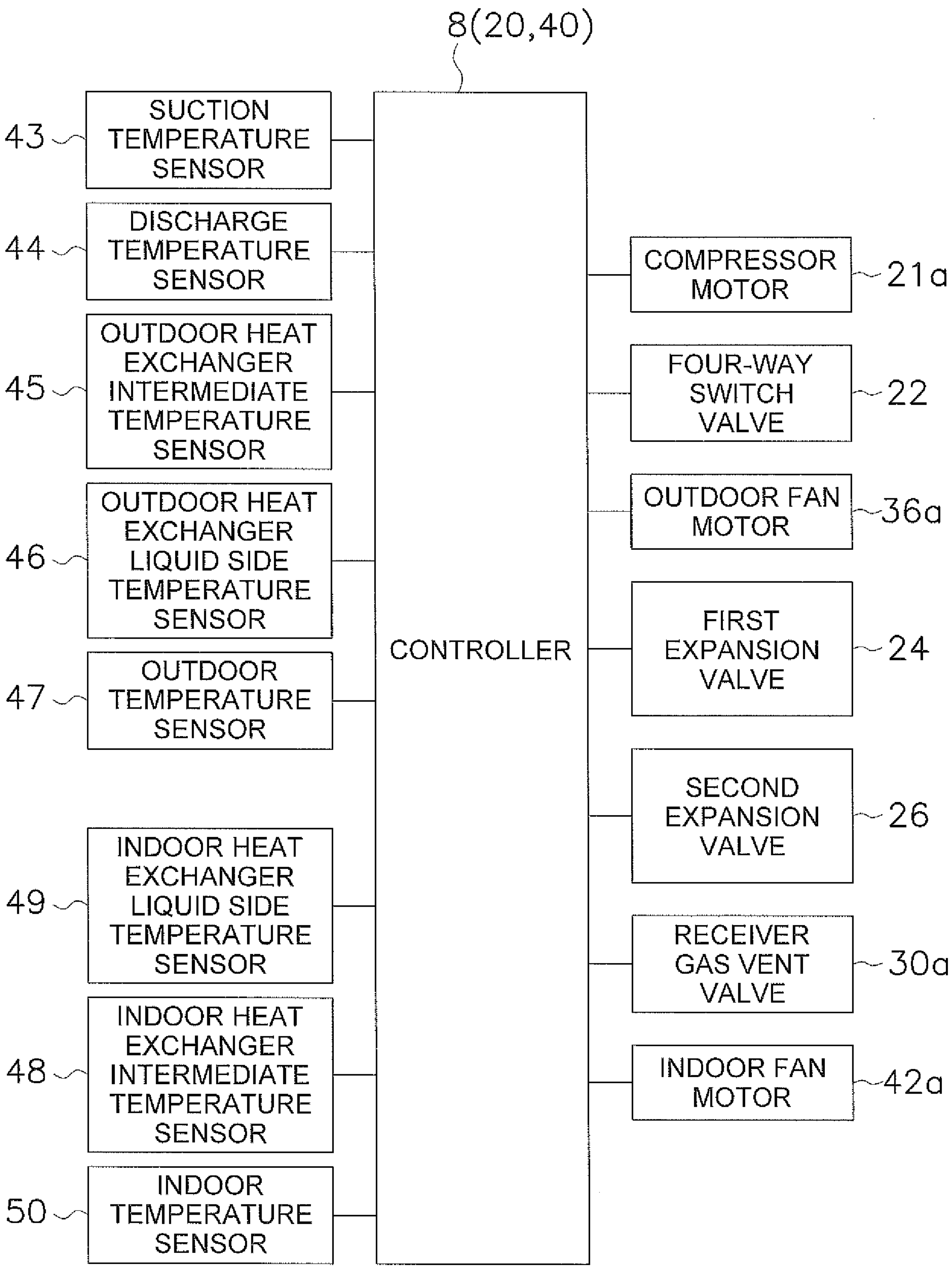
32
21a
21
33
110
35
46
36a
47
36
102

FIG. 7


8(20,40)
43
SUCTION TEMPERATURE SENSOR
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DISCHARGE TEMPERATURE SENSOR
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OUTDOOR HEAT EXCHANGER INTERMEDIATE TEMPERATURE SENSOR
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47
OUTDOOR TEMPERATURE SENSOR
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INDOOR HEAT EXCHANGER LIQUID SIDE TEMPERATURE SENSOR
48
INDOOR HEAT EXCHANGER INTERMEDIATE TEMPERATURE SENSOR
50
INDOOR TEMPERATURE SENSOR
CONTROLLER
COMPRESSOR MOTOR
21a
FOUR-WAY SWITCH VALVE
22
OUTDOOR FAN MOTOR
36a
FIRST EXPANSION VALVE
24
SECOND EXPANSION VALVE
26
RECEIVER GAS VENT VALVE
30a
INDOOR FAN MOTOR
42a

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/078065

A. CLASSIFICATION OF SUBJECT MATTER
F24F11/02(2006.01)i, *F24F1/24*(2011.01)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, F24F1/24

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.
Y A	JP 2010-25373 A (Daikin Industries, Ltd.), 04 February 2010 (04.02.2010), paragraphs [0055] to [0101]; fig. 1 to 4 (Family: none)	1-2,6 3-5
Y	JP 2009-299987 A (Daikin Industries, Ltd.), 24 December 2009 (24.12.2009), paragraphs [0060] to [0062]; fig. 4 (Family: none)	1-2,6
Y	WO 2011/077720 A1 (Daikin Industries, Ltd.), 30 June 2011 (30.06.2011), paragraphs [0153] to [0156]; fig. 4 & JP 5516602 B2 & US 2012/0255318 A1 & EP 2518422 A1 & CN 102667368 A	1-2,6

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed
"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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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
09 January 2015 (09.01.15)	27 January 2015 (27.01.15)

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

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

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Patent documents cited in the description

- JP 2010025374 A **[0002] [0126]**