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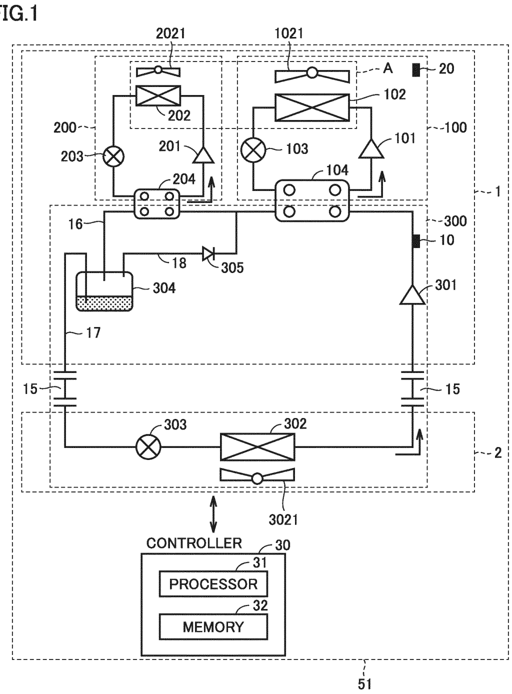
(54) **BINARY REFRIGERATION CYCLE DEVICE**

(57) A two-stage refrigeration cycle apparatus (51) comprises: a first higher-stage refrigerant circuit (100) configured to circulate a first refrigerant; a second higher-stage refrigerant circuit (200) configured to circulate a second refrigerant; a lower-stage refrigerant circuit (300) configured to circulate a third refrigerant; a first cascade condenser (104); and a second cascade condenser (204). The first higher-stage refrigerant circuit (100) comprises a first compressor (101), a first heat exchanger (102), and a first expansion valve (103). The second higher-stage refrigerant circuit (200) comprises a second compressor (201), a second heat exchanger (202), and a second expansion valve (203). The first higher-stage refrigerant circuit (100) and the second higher-stage refrigerant circuit (200) are configured to have different maximum cooling capacities.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a two-stage refrigeration cycle apparatus.

BACKGROUND ART

[0002] Conventionally, a two-stage refrigeration cycle apparatus has been known. PTL 1 describes a two-stage refrigeration cycle apparatus having a first higher-stage refrigeration cycle, a second higher-stage refrigeration cycle, and a lower-stage refrigeration cycle.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: WO 2012/066763

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] When a plurality of refrigeration cycles are formed on the higher-stage refrigeration cycle side, it is desirable that a flexible operation in response to a change in cooling capacity required for a load can be realized by the plurality of higher-stage refrigeration cycles.

[0005] It is an object of the present disclosure to provide a two-stage refrigeration cycle apparatus by which a flexible operation in response to a change in cooling capacity required for a load can be realized by a plurality of higher-stage refrigeration cycles.

SOLUTION TO PROBLEM

[0006] A two-stage refrigeration cycle apparatus of the present disclosure comprises: a first higher-stage refrigerant circuit in which a first refrigerant is circulated; a second higher-stage refrigerant circuit in which a second refrigerant is circulated; a lower-stage refrigerant circuit in which a third refrigerant is circulated; a first cascade condenser configured to perform heat exchange between the first refrigerant and the third refrigerant; and a second cascade condenser configured to perform heat exchange between the second refrigerant and the third refrigerant. The first higher-stage refrigerant circuit comprises a first compressor, a first heat exchanger, and a first expansion valve, and is configured to circulate the first refrigerant in an order of the first compressor, the first heat exchanger, the first expansion valve, the first cascade condenser, and the first compressor. The second higher-stage refrigerant circuit comprises a second compressor, a second heat exchanger, and a second expansion valve, and is configured to circulate the second refrigerant in an order of the second compressor, the second heat exchanger, and the second expansion valve, the second cascade condenser, and the second compressor. The lower-stage refrigerant circuit comprises a third compressor, a third heat exchanger, and a third expansion valve, and is configured to circulate the third refrigerant in an order of the third compressor, the first cascade condenser, the second cascade condenser, the third expansion valve, the third heat exchanger, and the third compressor. The first higher-stage refrigerant circuit and the second higher-stage refrigerant circuit are configured to have different maximum cooling capacities.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] According to the present disclosure, it is possible to provide a two-stage refrigeration cycle apparatus by which a flexible operation in response to a change in cooling capacity required for a load can be realized by a plurality of higher-stage refrigeration cycles.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is a diagram showing a configuration of a two-stage refrigeration cycle apparatus according to a first embodiment.

Fig. 2 is a diagram showing an arrangement relation between a liquid receiver and each of a first cascade condenser and a second cascade condenser.

Fig. 3 is a diagram showing comparative examples of configurations of a first higher-stage refrigerant circuit, a second higher-stage refrigerant circuit, and a lower-stage refrigerant circuit.

Fig. 4 is a diagram showing a first modification of the two-stage refrigeration cycle apparatus according to the first embodiment.

Fig. 5 is a diagram showing a fifth heat exchanger obtained by integrating a first heat exchanger and a second heat exchanger.

Fig. 6 is a diagram showing an example in which an uninterruptible power supply device is provided in the two-stage refrigeration cycle apparatus according to the first embodiment.

Fig. 7 is a diagram showing an example in which an uninterruptible power supply device is provided in the two-stage refrigeration cycle apparatus of the first modification.

Fig. 8 is a first graph showing a relation between a frequency range and a cooling capacity of a first higher-stage refrigeration cycle and a relation between a frequency range and a cooling capacity of a second higher-stage refrigeration cycle.

Fig. 9 is a second graph showing the relation between the frequency range and the cooling capacity of the first higher-stage refrigeration cycle and the relation between the frequency range and the cooling capacity of the second higher-stage refrigeration cycle.

Fig. 10 is a flowchart showing a content of control in an operation mode according to the first embodiment.

Fig. 11 is a flowchart showing a content of control in a suspension operation mode.

Fig. 12 is a flowchart showing a content of control in a cooling operation mode.

Fig. 13 is a graph showing a relation between a setting value of an evaporation temperature in a compartment and the cooling capacity (first embodiment).

Fig. 14 is a flowchart showing a content of control in a high-capacity operation mode.

Fig. 15 is a flowchart showing a content of control in a low-capacity operation mode.

Fig. 16 is a diagram showing a configuration of a two-stage refrigeration cycle apparatus according to a second embodiment.

Fig. 17 is a diagram showing a ratio of heat transfer areas of a first heat exchanger and a second heat exchanger to a heat transfer area of a fourth heat exchanger.

Fig. 18 is a diagram showing a sixth heat exchanger obtained by integrating the first heat exchanger, the second heat exchanger, and the fourth heat exchanger.

Fig. 19 is a diagram showing a seventh heat exchanger obtained by integrating the second heat exchanger and the fourth heat exchanger, and the first heat exchanger used in combination with the seventh exchanger.

Fig. 20 is a flowchart showing a content of control in an operation mode according to the second embodiment.

Fig. 21 is a flowchart showing a content of control in a second cooling operation mode according to the second embodiment.

Fig. 22 is a graph showing a relation between a setting value of an evaporation temperature in a compartment and the cooling capacity (second embodiment).

Fig. 23 is a graph showing a relation between a frequency of a third compressor (Comp 301) and the setting value of the evaporation temperature in the compartment (second embodiment).

Fig. 24 is a flowchart showing a modification of the second cooling operation mode according to the second embodiment.

DESCRIPTION OF EMBODIMENTS

[0009] Hereinafter, embodiments of the present disclosure will be described in detail with reference to figures. In the description below, the plurality of embodiments will be described, but it is initially expected at the time of filing of the application to appropriately combine configurations described in the embodiments. It should be noted that in the figures, the same or corresponding portions are denoted by the same reference symbols, and will not be described repeatedly.

First Embodiment.

[0010] Fig. 1 is a diagram showing a configuration of a two-stage refrigeration cycle apparatus 51 according to a first embodiment. Circuit configuration and operation of two-stage refrigeration cycle apparatus 51 will be described with reference to Fig. 1. Two-stage refrigeration cycle apparatus 51 comprises a lower-stage refrigerant circuit 300, a first higher-stage refrigerant circuit 100, a second higher-stage refrigerant circuit 200, and a controller 30.

[0011] Each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 is disposed in an outdoor unit 1. Lower-stage refrigerant circuit 300 is disposed to extend across outdoor unit 1 and an indoor unit 2 by an extension pipe 15. Controller 30 is disposed in outdoor unit 1 or indoor unit 2. Outdoor unit 1 is provided with a temperature sensor 20 configured to detect an outside air temperature. Controller 30 may be disposed at a position different from outdoor unit 1 and indoor unit 2. Controller 30 may communicate wirelessly with a remote controller manipulated by a user.

[0012] A first refrigerant is sealed in first higher-stage refrigerant circuit 100. A second refrigerant is sealed in second higher-stage refrigerant circuit 200. A third refrigerant is sealed in lower-stage refrigerant circuit 300. Outdoor unit 1 is provided with a first cascade condenser 104 configured to perform heat exchange between the first refrigerant of first higher-stage refrigerant circuit 100 and the third refrigerant of lower-stage refrigerant circuit 300, and a second cascade condenser 204 configured to perform heat exchange between the second refrigerant of second higher-stage refrigerant circuit 200 and the third refrigerant of lower-stage refrigerant circuit 300.

[0013] First cascade condenser 104 may be included in first higher-stage refrigerant circuit 100, or may be included in lower-stage refrigerant circuit 300. Second cascade condenser 204 may be included in second higher-stage refrigerant circuit 200, or may be included in lower-stage refrigerant circuit 300.

configuration of First Higher-Stage Refrigerant Circuit 100>

[0014] First higher-stage refrigerant circuit 100 comprises a first compressor 101, a first heat exchanger 102, and a first expansion valve 103. First compressor 101, first heat exchanger 102, and first expansion valve 103 are connected together by a refrigerant pipe through which the first refrigerant flows. First heat exchanger 102 is provided with a first fan 1021 configured to promote heat exchange between the outside air and the first refrigerant. First higher-stage refrigerant circuit 100 is configured to circulate the first refrigerant in the order of first compressor 101, first heat exchanger 102, first expansion valve 103, first cascade condenser 104, and first compressor 101. Accordingly, first heat exchanger 102 functions as a condenser. First higher-stage refrigerant circuit 100 is provided with a microcomputer configured to operate in response to a command from controller 30. When controller 30 activates first higher-stage refrigerant circuit 100, a first higher-stage refrigeration cycle is activated.

<Configuration of Second Higher-Stage Refrigerant Circuit 200>

[0015] Second higher-stage refrigerant circuit 200 comprises a second compressor 201, a second heat exchanger 202, and a second expansion valve 203. Second compressor 201, second heat exchanger 202, and second expansion valve 203 are connected together by a refrigerant pipe through which the second refrigerant flows. Second heat exchanger 202 is provided with a second fan 2021 configured to promote heat exchange between the outside air and the second refrigerant. Second higher-stage refrigerant circuit 200 is configured to circulate the second refrigerant in the order of second compressor 201, second heat exchanger 202, second expansion valve 203, second cascade condenser 204, and second compressor 201. Accordingly, second heat exchanger 202 functions as a condenser. Second higher-stage refrigerant circuit 200 is provided with a microcomputer configured to operate in response to a command from controller 30. When controller 30 activates second higher-stage refrigerant circuit 200, a second higher-stage refrigeration cycle is activated.

[0016] In the present embodiment, first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 are configured to have different maximum cooling capacities. In particular, at least one component of second compressor 201, second heat exchanger 202, second expansion valve 203, and second cascade condenser 204 is constituted of a component smaller than a corresponding component of first compressor 101, first heat exchanger 102, first expansion valve 103, and first cascade condenser 104 of first higher-stage refrigerant circuit 100 such that the maximum cooling capacity of second higher-stage refrigerant circuit 200 is lower than the maximum cooling capacity of first higher-stage refrigerant circuit 100.

<Configuration of Lower-Stage Refrigerant Circuit 300>

[0017] Lower-stage refrigerant circuit 300 comprises a third compressor 301, a third heat exchanger 302, a third expansion valve 303, and a liquid receiver 304. Each of third heat exchanger 302 and third expansion valve 303 is disposed in indoor unit 2. Liquid receiver 304 is disposed in outdoor unit 1. Third compressor 301, third heat exchanger 302, third expansion valve 303, and liquid receiver 304 are connected together by a refrigerant pipe through which the third refrigerant flows. Third heat exchanger 302 is provided with a third fan 3021 configured to promote heat exchange between air in a compartment and the third refrigerant.

[0018] Lower-stage refrigerant circuit 300 is configured to circulate the third refrigerant in the order of third compressor 301, first cascade condenser 104, second cascade condenser 204, liquid receiver 304, third expansion valve 303, third heat exchanger 302, and third compressor 301. Accordingly, third heat exchanger 302 functions as an evaporator configured to cool inside of the compartment. Lower-stage refrigerant circuit 300 is provided with a microcomputer configured to operate in response to a command from controller 30. When controller 30 activates lower-stage refrigerant circuit 300, a lower-stage refrigeration cycle is activated.

[0019] A pressure sensor 10 is provided at the refrigerant pipe on the discharge side of third compressor 301. Pressure sensor 10 may be provided at any position as long as pressure sensor 10 is located in a section from a discharge portion of third compressor 301 to an inlet of first cascade condenser 104. However, pressure sensor 10 is preferably provided at the discharge portion of third compressor 301. This is because pressure of the third refrigerant is the highest at the discharge portion of third compressor 301. Third compressor 301 increases the pressure of the third refrigerant to circulate the third refrigerant in lower-stage refrigerant circuit 300. Third compressor 301 uses an inverter to control a motor (not shown) inside third compressor 301 to change an operation capacity in accordance with a situation. Third compressor 301 controls a frequency of third compressor 301 to cause the temperature of the third refrigerant to attain a target outlet temperature set by controller 30.

[0020] Third expansion valve 303 adjusts a flow rate of the third refrigerant. Third expansion valve 303 is, for example, an electronic expansion valve or a capillary. The electronic expansion valve has a function of efficiently controlling the flow rate of the third refrigerant by adjusting a throttle opening degree.

[0021] Liquid receiver 304 stores a high-pressure liquid refrigerant. Liquid receiver 304 is disposed between second cascade condenser 204 and third expansion valve 303 in lower-stage refrigerant circuit 300. In other words, liquid receiver 304 is disposed on the downstream side with respect to first cascade condenser 104 and second cascade condenser 204 and is disposed on the upstream side with respect to third expansion valve 303.

[0022] Liquid receiver 304 and second cascade condenser 204 are connected together by a first refrigerant pipe 16. Liquid receiver 304 and third expansion valve 303 are connected together by a second refrigerant pipe 17 and extension pipe 15. First refrigerant pipe 16 is connected to an upper portion of liquid receiver 304. Second refrigerant pipe 17 is connected to a lower portion of liquid receiver 304. A return refrigerant pipe 18 is further connected to the upper portion of liquid receiver 304. Return refrigerant pipe 18 connects, to liquid receiver 304, the refrigerant pipe located between first cascade condenser 104 and second cascade condenser 204. Return refrigerant pipe 18 is provided with a check valve 305 configured to prevent the first refrigerant from flowing from first cascade condenser 104 or second cascade condenser 204 into liquid receiver 304 through return refrigerant pipe 18.

<Configuration of Controller 30>

[0023] Controller 30 comprises a processor 31 and a memory 32. Processor 31 executes an operating system and an application program stored in memory 32. Processor 31 references to various types of data stored in memory 32 when executing the application program. Processor 31 collects data indicating operation statuses from first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300 in accordance with the application program stored in memory 32.

[0024] Processor 31 acquires the pressure of the third refrigerant based on a detection value of pressure sensor 10. Processor 31 acquires the outside air temperature based on a detection value of temperature sensor 20. Processor 31 controls first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300 in accordance with the application program stored in memory 32.

[0025] Controller 30 can switch the operation mode between a cooling operation mode and a suspension operation mode. The cooling operation mode is an operation mode for cooling inside of the compartment in which third heat exchanger 302 is disposed. In the cooling operation mode, lower-stage refrigerant circuit 300 and second higher-stage refrigerant circuit 200 are operated. In the cooling operation mode, first higher-stage refrigerant circuit 100 may be further operated in accordance with an operation status of each of lower-stage refrigerant circuit 300 and second higher-stage refrigerant circuit 200.

[0026] The suspension operation mode is an operation mode used when the inside of the compartment is not cooled. In the suspension operation mode, the operation of lower-stage refrigerant circuit 300 is suspended. In the suspension operation mode, second higher-stage refrigerant circuit 200 is operated in order to prevent a pressure in lower-stage refrigerant circuit 300 from being increased abnormally. In the suspension operation mode, first higher-stage refrigerant circuit 100 may be further operated.

[0027] Controller 30 can independently control first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300 in the cooling operation mode.

[0028] Controller 30 can select one of a low-capacity operation mode and a high-capacity operation mode in the cooling operation mode. The low-capacity operation mode is a mode in which first higher-stage refrigerant circuit 100 is suspended and lower-stage refrigerant circuit 300 and second higher-stage refrigerant circuit 200 are operated. The high-capacity operation mode is a mode in which first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300 are operated.

[0029] It should be noted that controller 30 may be configured to select an operation mode for operating only lower-stage refrigerant circuit 300 among first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300.

<Operations of First Higher-Stage Refrigerant Circuit 100 and Second Higher-Stage Refrigerant Circuit 200>

[0030] The operation of first higher-stage refrigerant circuit 100 will be described. The first refrigerant discharged from first compressor 101 in a high-temperature and high-pressure gas state flows to first heat exchanger 102 functioning as a condenser. The first refrigerant is changed from the refrigerant in the gas state to a refrigerant in a liquid state in first heat exchanger 102. The first refrigerant having flowed out from first heat exchanger 102 flows into first expansion valve 103 and is decompressed. As a result, the first refrigerant in the liquid state is changed to a low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant flows from first expansion valve 103 into first cascade condenser 104. The first refrigerant having flowed into first cascade condenser 104 draws heat from the third refrigerant flowing through lower-stage refrigerant circuit 300. Thus, the third refrigerant is condensed to gasify the first refrigerant. The gasified first refrigerant is suctioned into first compressor 101.

[0031] The operation of second higher-stage refrigerant circuit 200 is the same as the operation of first higher-stage refrigerant circuit 100, and therefore will not be described repeatedly here. A difference between first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 lies in magnitude of maximum cooling capacity. In other words, first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 have a difference in capacity for condensing the third refrigerant flowing through lower-stage refrigerant circuit 300. Second higher-stage refrigerant circuit 200 is designed to have a lower capacity for condensing the third refrigerant than that of first higher-stage refrigerant circuit 100.

<Operation of Lower-Stage Refrigerant Circuit 300>

[0032] The operation of lower-stage refrigerant circuit 300 will be described. The third refrigerant discharged from third compressor 301 in the high-temperature and high-pressure gas state flows to first cascade condenser 104 and second cascade condenser 204. When first higher-stage refrigerant circuit 100 is being operated, first cascade condenser 104 functions as a condenser for the third refrigerant. When second higher-stage refrigerant circuit 200 is being operated, second cascade condenser 204 functions as a condenser for the third refrigerant. Thus, the third refrigerant is changed from the refrigerant in the gas state to the refrigerant in the liquid state. The third refrigerant having flowed out from second cascade condenser 204 flows into liquid receiver 304. The third refrigerant in the liquid state as accumulated in liquid receiver 304 is pushed out to second refrigerant pipe 17 by a gas pressure in liquid receiver 304. The third refrigerant having flowed into second refrigerant pipe 17 flows toward third expansion valve 303 via extension pipe 15.

[0033] The third refrigerant having flowed into third expansion valve 303 is decompressed by third expansion valve 303. As a result, the third refrigerant in the liquid state is changed to a low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant is moved from third expansion valve 303 to third heat exchanger 302. On this occasion, third heat exchanger 302 functions as an evaporator. The third refrigerant having flowed into third heat exchanger 302 exchanges heat with the air in the compartment. Thus, the inside of the compartment is cooled. The third refrigerant gasified in third heat exchanger 302 is suctioned into third compressor 301.

[0034] Controller 30 adjusts the frequency of third compressor 301 or the rotation speed of third fan 3021 based on various parameters. Examples of the parameters include a suction temperature, a discharge temperature, a heat exchanger temperature, an air suction temperature, a humidity, and the like. Controller 30 can acquire these parameters using values of the sensors disposed in lower-stage refrigerant circuit 300.

[0035] For example, a temperature sensor may be provided at the discharge portion of third compressor 301 to detect the discharge temperature of the third refrigerant. Controller 30 sends a control signal to lower-stage refrigerant circuit 300 based on a temperature difference between a detection result of the temperature sensor and a previously set discharge temperature of third compressor 301. Lower-stage refrigerant circuit 300 adjusts the rotation speed of third compressor 301, the rotation speed of third fan 3021, or the opening degree of third expansion valve 303 based on the control signal. By this adjustment, controller 30 can control to avoid the temperature of each device provided in lower-stage refrigerant circuit 300 from being increased to be equal to or more than a heatproof temperature.

[0036] It should be noted that in view of precision, it is desirable to directly detect the various parameters by the sensors. However, part of these parameters can also be estimated by calculation without using the sensors. For example, a condensation temperature (CT) may be estimated from the detection value of pressure sensor 10.

[0037] Fig. 2 is a diagram showing an arrangement relation between liquid receiver 304 and each of first cascade condenser 104 and second cascade condenser 204. As shown in Fig. 2, liquid receiver 304 is disposed at a position lower than those of first cascade condenser 104 and second cascade condenser 204 in the vertical direction. Therefore, even when lower-stage refrigerant circuit 300 is not activated, the third refrigerant cooled and liquefied by first cascade condenser 104 or second cascade condenser 204 falls to liquid receiver 304 by gravity. This is particularly effective in the suspension operation mode involving control when the lower-stage refrigeration cycle is not activated. Hereinafter, the operation in the suspension operation mode will be described in detail with reference to Figs. 1 and 2.

<Operation in Suspension Operation Mode>

[0038] Controller 30 activates the higher-stage refrigeration cycle when the lower-stage refrigeration cycle is suspended. Such an operation mode is referred to as the suspension operation mode. By operating two-stage refrigeration cycle apparatus 51 in the suspension operation mode, controller 30 prevents a pressure from being increased due to an increased temperature of the third refrigerant retained in lower-stage refrigerant circuit 300. In the case where the outside air temperature when the lower-stage refrigeration cycle is suspended becomes equal to or more than a reference temperature, controller 30 activates the higher-stage refrigeration cycle. The reference temperature is, for example, -5°C.

[0039] When the lower-stage refrigeration cycle is suspended, the pressure in lower-stage refrigerant circuit 300 becomes uniform, and the pressure then becomes a pressure corresponding to the outside air temperature. When an amount of the third refrigerant sealed is small with respect to the internal volume of lower-stage refrigerant circuit 300, the average density of the third refrigerant is small. For this reason, the pressure becomes low in accordance with Boyle-Charles' law ($P \propto \rho \times T$). However, when the average density of the third refrigerant is high, the pressure in lower-stage refrigerant circuit 300 is increased.

[0040] In the case where the outside air temperature is high when the lower-stage refrigeration cycle is suspended, the third refrigerant in lower-stage refrigerant circuit 300 absorbs heat from the outside air and is accordingly vaporized. Thus, the pressure in lower-stage refrigerant circuit 300 is increased. It should be noted that since not a whole of the refrigerant becomes liquid or gas with respect to the internal volume in a general refrigeration cycle, the pressure is a value dependent on a relation, based on the type of refrigerant, between the pressure and the temperature when the pressure is uniform. For example, when the refrigerant is CO_2 (carbon dioxide) and the temperature is 20°C, the pressure is 5.6 MPaG.

[0041] When the lower-stage refrigeration cycle is suspended, the third refrigerant can be forcibly cooled by activating the higher-stage refrigeration cycle. As a result, the temperature of the third refrigerant is decreased to be less than that of the outside air. Thus, the pressure of the third refrigerant in lower-stage refrigerant circuit 300 is decreased.

[0042] The higher-stage refrigeration cycle activated by controller 30 in the suspension operation mode is the second higher-stage refrigeration cycle. Controller 30 controls the frequency of second compressor 201, the rotation speed of second fan 2021, and the opening degree of second expansion valve 203 in the second higher-stage refrigeration cycle in order to effectively suppress an abnormal increase in the pressure in lower-stage refrigerant circuit 300. When the abnormal increase in the pressure in lower-stage refrigerant circuit 300 cannot be suppressed only by activating the second higher-stage refrigeration cycle, controller 30 may activate the first higher-stage refrigeration cycle involving a higher condensation capacity.

[0043] When the second higher-stage refrigeration cycle is activated in the suspension operation mode, second cascade condenser 204 existing between second higher-stage refrigerant circuit 200 and lower-stage refrigerant circuit 300 functions as a condenser for the third refrigerant. As a result, the third refrigerant in second cascade condenser 204 is condensed. The third refrigerant condensed by second cascade condenser 204 is liquefied. The liquefied third refrigerant is dropped into liquid receiver 304 through first refrigerant pipe 16. On this occasion, since there is a height difference between second cascade condenser 204 and liquid receiver 304 in the vertical direction as shown in Fig. 2, the third refrigerant falls to liquid receiver 304 by its own weight.

[0044] As the liquid third refrigerant is dropped into liquid receiver 304, the volume of the gas phase is decreased. The gas third refrigerant, which is less likely to be affected by gravity, is suctioned to the upstream side with respect to second cascade condenser 204 via return refrigerant pipe 18.

[0045] Since return refrigerant pipe 18 is connected to the upper portion of liquid receiver 304 as shown in Fig. 2, the third refrigerant existing above liquid receiver 304 can be naturally suctioned. Further, check valve 305 prevents the third refrigerant, which is to be moved from first cascade condenser 104 toward second cascade condenser 204, from flowing into liquid receiver 304 through return refrigerant pipe 18. In particular, in the cooling operation mode, the third refrigerant can be prevented from bypassing second cascade condenser 204 to flow into liquid receiver 304.

[0046] The vapor third refrigerant suctioned to the upstream side with respect to second cascade condenser 204 is cooled by second cascade condenser 204 and is accordingly liquefied. The liquefied third refrigerant is dropped into liquid receiver 304. In the suspension operation mode, the lower-stage refrigeration cycle is not activated, but the third refrigerant flows through lower-stage refrigerant circuit 300 by such natural circulation.

[0047] By repeating such natural circulation of the third refrigerant, increase in pressure of lower-stage refrigerant circuit 300 can be effectively suppressed. Further, only the gas to be condensed can flow through return refrigerant pipe 18 in order to suppress an increase in pressure. Further, since second cascade condenser 204 is provided, the liquid third refrigerant can be stored in liquid receiver 304 without directly cooling liquid receiver 304.

[0048] Each of first cascade condenser 104 and second cascade condenser 204 functions as a condenser for the third refrigerant, and cools the third refrigerant before flowing into liquid receiver 304. Therefore, it is not necessary to provide liquid receiver 304 with a cooling function. Each of first cascade condenser 104 and second cascade condenser 204 exhibits the cooling function also in the cooling operation mode. Therefore, the configuration of liquid receiver 304 can be simplified as compared with a configuration in which liquid receiver 304 is provided with a function of cooling the third refrigerant during the cooling operation. This is because when the third refrigerant is cooled in liquid receiver 304, an evaporator is required in liquid receiver 304. When the evaporator is provided in liquid receiver 304, the volume of liquid receiver 304 has to be reduced. Further, when a heat transfer tube is provided on an outer periphery of a container of liquid receiver 304, a contact portion is likely to be deteriorated due to thermal fatigue disadvantageously, and further, the container has a complicated configuration. According to the present embodiment, the configuration of liquid receiver 304 can be simplified, with the result that manufacturing cost can be reduced.

[0049] In two-stage refrigeration cycle apparatus 51 according to the first embodiment, even when the lower-stage refrigeration cycle is suspended, at least the second higher-stage refrigeration cycle is activated to cool, by second cascade condenser 204, the third refrigerant retained in lower-stage refrigerant circuit 300. On this occasion, the third refrigerant is circulated in lower-stage refrigerant circuit 300, thereby effectively suppressing the pressure from being increased by an increased temperature of the third refrigerant. Thus, it is not necessary to set a high design pressure for each of various types of devices such as third compressor 301, third heat exchanger 302, third expansion valve 303, liquid receiver 304, and the refrigerant pipe. This results in reduced cost of the devices included in the lower-stage refrigerant circuit 300.

<Comparison between Refrigerant Circuits>

[0050] Fig. 3 is a diagram showing comparative examples of the configurations of first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300. In the present embodiment, first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 are configured to have different maximum cooling capacities. More specifically, the cooling capacity of second higher-stage refrigerant circuit 200 is configured to be lower than the cooling capacity of first higher-stage refrigerant circuit 100. In Fig. 3, indication of a numerical value for the capacity of lower-stage refrigerant circuit 300 is omitted.

[0051] Fig. 3 shows an example in which the rated capacity of first higher-stage refrigerant circuit 100 is 41 kW and the rated capacity of second higher-stage refrigerant circuit 200 is 10 kW. In this case, the capacity (cooling capacity) on the higher-stage side is calculated to be 51 kW by adding 41 kW and 10 kW. A ratio of the rated capacity of second higher-stage refrigerant circuit 200 to 51 kW is about 20% as shown in Fig. 3.

[0052] As shown in Fig. 3, the maximum cooling capacity of second higher-stage refrigerant circuit 200 may be less than 50% of the maximum cooling capacities of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200. That is, the upper limit value of the cooling capacity of second higher-stage refrigerant circuit 200 may be less than 50% of the upper limit value of the cooling capacities of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200. The upper limit value of the cooling capacity of second higher-stage refrigerant circuit 200 is preferably 35% or less of the upper limit value of the cooling capacities of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200. Further, the upper limit value of the cooling capacity of second higher-stage refrigerant circuit 200 is more preferably 20% or less of the upper limit value of the cooling capacities of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200.

[0053] Thus, in order to provide a difference in cooling capacity between first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, at least one component of second compressor 201, second heat exchanger 202, second expansion valve 203, and second cascade condenser 204 of second higher-stage refrigerant circuit 200 may be constituted of a component having a smaller capacity than a capacity of a corresponding component of first compressor 101, first heat exchanger 102, first expansion valve 103, and first cascade condenser 104 of first higher-stage refrigerant circuit 100.

[0054] The size of a compressor affects cost and cooling capacity of a refrigerant circuit most greatly. Therefore, it is desirable to provide a difference in cooling capacity between first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 by second compressor 201 being constituted of a small compressor having a smaller capacity than that of first compressor 101. By reducing the size of second compressor 201, the cost of second higher-stage refrigerant circuit 200 can be also reduced. By reducing the size of second compressor 201, material cost required for second compressor 201 can be reduced. Further, since the volume of second compressor 201 is reduced, an amount of refrigerant required for second higher-stage refrigerant circuit 200 can be reduced.

[0055] An expenditure reduced by reducing the size of second compressor 201 may be assigned to first compressor 101 so as to provide higher performance to first compressor 101. For example, in the present embodiment, second compressor 201 is constituted of a small compressor having a smaller capacity than that of first compressor 101. Further, in the present embodiment, the refrigerant capacity of second higher-stage refrigerant circuit 200 is smaller than that of first higher-stage refrigerant circuit 100.

[0056] As shown in Fig. 3, when the lower limit capacity of first higher-stage refrigerant circuit 100 and the lower limit capacity of second higher-stage refrigerant circuit 200 are compared, the lower limit capacity of first higher-stage refrigerant circuit 100 is 10 kW, and the lower limit capacity of second higher-stage refrigerant circuit 200 is 2.5 kW. It should be noted that here, 25% of the rated capacity is assumed as the lower limit capacity in accordance with the range of the frequency of the compressor.

[0057] By providing the different rated capacities to first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, the higher-stage refrigeration cycle can be operated finely depending on an operation status. That is, in the present embodiment, the higher-stage refrigeration cycle is constituted of the first higher-stage refrigeration cycle and the second higher-stage refrigeration cycle, and the capacities of the cycles are made different, with the result that the operation range is increased. Providing the different rated capacities to first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 is effective in each of the cooling operation mode and the suspension operation mode.

[0058] When cooling the inside of the compartment, controller 30 selects one cooling operation mode of the low-capacity operation mode and the high-capacity operation mode in accordance with environmental conditions such as a setting temperature in the compartment in which third heat exchanger 302 is disposed as well as the outside air temperature.

[0059] In the suspension operation mode, controller 30 activates second higher-stage refrigerant circuit 200 having a cooling capacity lower than that of first higher-stage refrigerant circuit 100. In the suspension operation mode, a cooling load is normally smaller than that in the cooling operation mode. This is because the cooling operation mode is intended to cool the inside of the compartment, whereas the suspension operation mode is intended to suppress an abnormal increase in pressure in lower-stage refrigerant circuit 300. In the suspension operation mode in which the cooling load is small, if the higher-stage refrigeration cycle involving the high capacity is activated, the activation and suspension of activation of the compressor on the higher-stage refrigeration cycle side frequently occur.

[0060] Here, consider a case where the higher-stage refrigeration cycle is constituted of a single refrigeration cycle. The rated capacity of the single higher-stage refrigeration cycle is 51 kW. The value of 51 kW is a numerical value obtained by adding the rating capacity of first higher-stage refrigerant circuit 100 and the rating capacity of second higher-stage refrigerant circuit 200 shown in Fig. 3.

[0061] Assuming that about 25% of the required cooling capacity is the lower limit of the operation range of the compressor on the higher-stage refrigeration cycle side, 13 kW is the lower limit capacity when the rated capacity is 51 kW. The value of 13 kW may be too large for the cooling capacity required in the suspension operation mode. In this case, since the capacity of the higher-stage refrigeration cycle is too large for the required cooling capacity, a suctioning pressure of the compressor of the higher-stage refrigeration cycle is decreased. As a result, activation and suspension of activation of the compressor is repeated, with the result that reliability of the two-stage refrigeration cycle apparatus may be decreased. Further, an excessive cooling operation is continued in the suspension operation mode, with the result that power consumption may be increased.

[0062] In view of the above, in the present embodiment, the higher-stage refrigeration cycle is constituted of the two cycles. As shown in Fig. 3, the operation range of 2.5 kW to 51 kW is secured by dividing the capacity of the higher-stage refrigeration cycle into two. The operation capacity of 2.5 kW that is the lower limit can be realized by second higher-stage refrigerant circuit 200. The upper limit value of the operation capacity of 51 kW can be realized by first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200.

[0063] In the suspension operation mode, second higher-stage refrigerant circuit 200 is activated. Thus, in the suspension operation mode, repeated activation and suspension of activation of the compressor of the higher-stage refrigeration cycle can be suppressed. Of course, not only in the suspension operation mode but also in the cooling operation mode, an appropriate capacity can be exhibited as required on the higher-stage refrigeration cycle side, so that repeated activation and suspension of activation of the compressor of the higher-stage refrigeration cycle can be suppressed. That is, in the present embodiment, the higher-stage refrigeration cycle is constituted of the first higher-stage refrigeration cycle and the second higher-stage refrigeration cycle, and the capacities of the cycles are made different, thereby increasing the operation range. It should be noted that the cooling capacity required in the suspension operation mode is considered to be, for example, about 1 kW to 4 kW.

[0064] According to the present embodiment, repeated activation and suspension of activation of each of first compressor 101 and second compressor 201 on the higher-stage refrigeration cycle side can be prevented. Therefore, an energy saving property can be improved. In particular, it is important to avoid repeated activation and suspension of activation of the compressor because activation loss occurs at the time of activation of the compressor.

<Types of Refrigerants>

[0065] A combination of types of refrigerants sealed in lower-stage refrigerant circuit 300, first higher-stage refrigerant circuit 100, and second higher-stage refrigerant circuit 200 can be determined in various manners. The refrigerants in the respective refrigerant circuits may be the same refrigerant. Further, the same refrigerant may be sealed in each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, and a refrigerant different from the refrigerant sealed in each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 may be used in lower-stage refrigerant circuit 300.

[0066] Generally, theoretical performance, GWP (Global-warming potential), combustibility, toxicity, and the like of refrigerants vary depending on types of refrigerants. For example, each of refrigerants such as R290 and R32 has high theoretical performance, but has high combustibility, toxicity, and GWP (Global-warming potential). Thus, in consideration of combustibility, toxicity, and GWP, it should be avoided to seal a large amount of each of these refrigerants in the refrigerant circuit. On the other hand, R1234yf or the like is considered as a very environmentally friendly refrigerant that has low ozone depletion potential and global warming potential. Further, a natural refrigerant such as CO2 has such an advantage that a total GWP of the device can be significantly reduced. Further, it is desirable to use an incombustible gas such as CO2 for the indoor unit in consideration of an unlikely event of leakage of the refrigerant.

[0067] Therefore, it is preferable to select an appropriate refrigerant in consideration of a characteristic of the refrigerant and a characteristic of a refrigerant circuit that is to have the refrigerant sealed therein. Specifically, it is considered that a type of refrigerant is selected in view of whether the refrigerant circuit to have the refrigerant sealed therein is lower-stage refrigerant circuit 300 passing through indoor unit 2 or first higher-stage refrigerant circuit 100 or second higher-stage refrigerant circuit 200 used for outdoor unit 1. Further, it is considered that the type of refrigerant is selected in view of whether the refrigerant circuit to have the refrigerant sealed therein is first higher-stage refrigerant circuit 100 having high cooling performance or second higher-stage refrigerant circuit 200 having low cooling performance. In the present embodiment, the refrigerant capacity of second higher-stage refrigerant circuit 200 is smaller than that of first higher-stage refrigerant circuit 100.

[0068] Fig. 3 shows an example in which different refrigerants are sealed in first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and lower-stage refrigerant circuit 300. Here, it is illustratively shown that appropriate refrigerants are selected in consideration of characteristics of the refrigerants and characteristics of refrigerant circuits that are to have the refrigerants sealed therein.

<Refrigerants in Higher-Stage Refrigerant Circuits>

[0069] R1234yf, which is environmentally friendly, is sealed in first higher-stage refrigerant circuit 100 having a high capacity, whereas R32, which has high theoretical performance, is sealed in second higher-stage refrigerant circuit 200 having a low capacity. That is, the first refrigerant is R1234yf, and the second refrigerant is R32. CO2, which is an incombustible gas, is sealed in lower-stage refrigerant circuit 300 passing through indoor unit 2. That is, the first refrigerant is CO2. In second higher-stage refrigerant circuit 200, R290 or R714 (ammonia) may be sealed instead of R32. In lower-stage refrigerant circuit 300, hfc1132A may be sealed instead of CO2.

[0070] In consideration of such a fact that the refrigerant such as R290 or R32 has high theoretical performance but has combustibility, toxicity, and high GWP, such a refrigerant, for which it is concerned to seal a large amount of the refrigerant, is sealed in second higher-stage refrigerant circuit 200 having a smaller refrigerant capacity than that of first higher-stage refrigerant circuit 100. Since the refrigerant having higher theoretical performance or higher performance in actual use than the refrigerants sealed in first higher-stage refrigerant circuit 100 and lower-stage refrigerant circuit 300 is sealed in second higher-stage refrigerant circuit 200 having a small capacity in this way, the COP (Coefficient Of Performance) of the system can be improved.

[0071] If R1234yf, which is considered as a very environmentally friendly refrigerant, is used for each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, it is desirable to change the refrigerant in second higher-stage refrigerant circuit 200 to R290 having higher theoretical performance than that of R1234yf.

[0072] Thus, in the present embodiment, the refrigerant that has high theoretical performance but that cannot be said as having high combustibility, toxicity, and GWP such as R32 is employed for second higher-stage refrigerant circuit 200 in which an amount of use of refrigerant is small. Thus, an influence of disadvantage of refrigerant on the apparatus can be suppressed. On the other hand, the refrigerant considered to be environmentally friendly such as R1234yf is used for first higher-stage refrigerant circuit 100 in which an amount of use of refrigerant is large. Thus, the COP of the system can be improved while suppressing an increase in GWP as compared with the two-stage refrigeration cycle apparatus in which the refrigerant such as R32 is employed in each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200.

[0073] Further, according to the present embodiment, it is possible to flexibly deal with a situation of regulations in each country. For example, in a country in which a regulation on GWP is moderate, R32 is sealed in first higher-stage refrigerant circuit 100 and R290 is sealed in second higher-stage refrigerant circuit 200. Thus, the system COP can be maximized. On the other hand, in a country in which a regulation on GWP is strict, R1234yf is sealed in first higher-stage refrigerant circuit 100, and R290 or R32 is sealed in second higher-stage refrigerant circuit 200. Thus, the system COP can be improved while setting the GWP to be equal to or less than a regulation value.

<Refrigerant of Lower-Stage Refrigerant Circuit>

[0074] Fig. 3 shows an example in which CO2 is sealed in lower-stage refrigerant circuit 300. Since the third refrigerant of lower-stage refrigerant circuit 300 flows through indoor unit 2, it is preferable to apply CO2, which is a non-combustible and high-pressure refrigerant, as the third refrigerant for lower-stage refrigerant circuit 300. Since CO2 is a natural refrigerant, the total GWP of the device can be significantly reduced.

[0075] Two-stage refrigeration cycle apparatus 51 according to the present embodiment realizes the two types of refrigeration cycles, i.e., the lower-stage refrigeration cycle and the higher-stage refrigeration cycle. Therefore, in the higher-stage refrigeration cycle, condensation pressure on the lower-stage side can be reduced. Therefore, even when CO2, which is a high-pressure refrigerant, is employed in lower-stage refrigerant circuit 300, refrigerant pipe and element device each having a low pressure resistance can be applied to lower-stage refrigerant circuit 300. Hence, even an element device that could not have been conventionally used can be used in lower-stage refrigerant circuit 300.

[0076] For example, liquid receiver 304 should have a pressure resistance to a chlorofluorocarbon (R410A). Similarly, a portion of each of first cascade condenser 104 and second cascade condenser 204 through which lower-stage refrigerant circuit 300 passes should also have a pressure resistance to a chlorofluorocarbon. Since lower-stage refrigerant circuit 300 is provided with a multiplicity of element devices such as refrigerant pipes, cost can be reduced when a required pressure resistance is low.

[0077] Since a single-step refrigeration cycle apparatus or a two-step refrigeration cycle apparatus is required to have a high pressure resistance, an expensive apparatus having a high pressure resistance has to be applied. However, in the present embodiment, since the two-stage refrigeration cycle is employed, such an apparatus is not necessary.

[0078] Generally, an amount of production of CO2 is small, and a pressure resistance standard required when CO2 is used as a refrigerant is severe. Therefore, when CO2 is employed, cost is likely to be high. In two-stage refrigeration cycle apparatus 51 according to the present embodiment, a pressure required on the side on which CO2 is condensed is lower than that in the case where CO2 is applied to the single-step refrigeration cycle apparatus or the two-step refrigeration cycle apparatus. As the pressure is lower, the density of the refrigerant is lower.

[0079] Therefore, when the volume of the condenser is the same, an amount of CO2 required as a refrigerant can be reduced. As a result, according to the present embodiment, it is possible to satisfy the strict pressure resistance standard required for CO_2 and to suppress the cost associated with CO_2. Further, according to the present embodiment, it is also possible to use an element device and a pipe that each have a low pressure resistance and that cannot be used in the single-step refrigeration cycle apparatus or the two-step refrigeration cycle apparatus.

[0080] As described above, according to the present embodiment, since the operation can be performed with the condensation temperature on the lower-stage refrigerant circuit 300 side being reduced, a pressure resistance required for a refrigerant pipe of lower-stage refrigerant circuit 300 can be reduced. Further, since the different refrigeration cycles are provided for the higher-stage side and the lower-stage side, it is possible to flexibly deal with a regulation in each country with regard to the refrigerant on the higher-stage side and the refrigerant on the lower-stage side.

[0081] For example, in a country in which only a natural refrigerant is permitted, CO_2 is applied to lower-stage refrigerant circuit 300, and R290 is applied to each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200. In a country requiring low GWP, CO_2 is applied to lower-stage refrigerant circuit 300, and R1234yf is applied to each of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200. In this way, by changing the refrigerant on the higher-stage side without changing the specification of the refrigerant in lower-stage refrigerant circuit 300, it is possible to deal with a regulation on refrigerant in each country.

[0082] Fig. 4 is a diagram showing a first modification of two-stage refrigeration cycle apparatus 51 according to the first embodiment. In the first modification, a return refrigerant pipe 18 extending from liquid receiver 304 is connected between first cascade condenser 104 and third compressor 301. Therefore, the gasified third refrigerant flows from liquid receiver 304 into first cascade condenser 104. The third refrigerant having flowed into first cascade condenser 104 is cooled by first cascade condenser 104 and then flows into second cascade condenser 204. Therefore, as compared with the configuration shown in Fig. 1, in the first modification, a cooling effect for the third refrigerant can be further attained.

[0083] It should be noted that a position to which return refrigerant pipe 18 extending from liquid receiver 304 is connected may be any position from the discharge portion of third compressor 301 to the inlet portion of first cascade condenser 104. Return refrigerant pipe 18 extending from liquid receiver 304 is more preferably connected to the discharge portion of third compressor 301. This is because the pressure of the third refrigerant is the highest at the discharge portion of third compressor 301.

<Integration of Heat Exchangers>

[0084] Fig. 5 is a diagram showing a fifth heat exchanger 502 obtained by integrating first heat exchanger 102 and second heat exchanger 202. A configuration portion indicated by a symbol A in Fig. 1 corresponds to fifth heat exchanger 502.

[0085] Fifth heat exchanger 502 has such a configuration that first higher-stage refrigerant circuit 100 through which the first refrigerant flows and second higher-stage refrigerant circuit 200 through which the second refrigerant flows are divided and first heat exchanger 102 and second heat exchanger 202 are integrated. Fifth heat exchanger 502 is provided with a fifth fan 5021. It should be noted that a plurality of fans may be provided for fifth heat exchanger 502.

[0086] By integrating first heat exchanger 102 and second heat exchanger 202, it is possible to effectively utilize a space in which devices are disposed. Further, by integrating first heat exchanger 102 and second heat exchanger 202, cost can be reduced. It should be noted that such an integrated fifth heat exchanger 502 may be applied to the first modification shown in Fig. 4.

[0087] Fig. 6 is a diagram showing an example in which an uninterruptible power supply device 205 is provided in two-stage refrigeration cycle apparatus 51 according to the first embodiment. As shown in Fig. 6, second higher-stage refrigerant circuit 200 is connected to uninterruptible power supply device 205.

[0088] It should be noted that controller 30 may be connected to uninterruptible power supply device 205. Alternatively, an uninterruptible power supply device different from uninterruptible power supply device 205 may be connected to controller 30. Thus, even when lower-stage refrigerant circuit 300 is suspended due to power failure, controller 30 can perform the operation in accordance with the suspension operation mode using second higher-stage refrigerant circuit 200. As a result, it is possible to prevent the pressure in lower-stage refrigerant circuit 300 from being increased abnormally at the time of power failure. Therefore, it is not necessary to perform an operation of suppressing increased pressure by taking out the third refrigerant from lower-stage refrigerant circuit 300 to outside at the time of power failure. According to this configuration, pressure due to an increased temperature in the lower-stage refrigeration cycle can be suppressed without decreasing the reliability.

[0089] First higher-stage refrigerant circuit 100 may also be provided with uninterruptible power supply device 205. However, it is preferable to provide uninterruptible power supply device 205 preferentially to second higher-stage refrigerant circuit 200 of first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200. This is because second higher-stage refrigerant circuit 200 is activated in the suspension operation mode.

[0090] Further, since the capacity of second higher-stage refrigerant circuit 200 is smaller than that of first higher-stage refrigerant circuit 100, a power supply capacity required for uninterruptible power supply device 205 is small. Therefore, it is economical to provide uninterruptible power supply device 205 to second higher-stage refrigerant circuit 200, rather than first higher-stage refrigerant circuit 100. In addition, a small uninterruptible power supply device 205 having a small capacity can be employed in second higher-stage refrigerant circuit 200.

[0091] Fig. 7 is a diagram showing an example in which uninterruptible power supply device 205 is provided in two-stage refrigeration cycle apparatus 51 of the first modification. As shown in Fig. 7, uninterruptible power supply device 205 can be applied to the first modification as in the configuration shown in Fig. 6. In two-stage refrigeration cycle apparatus 51 employing integrated fifth heat exchanger 502, uninterruptible power supply device 205 may be applied as in the configuration shown in Fig. 6.

[0092] Fig. 8 is a first graph showing a relation between a frequency range and a cooling capacity of the first higher-stage refrigeration cycle and a relation between a frequency range and a cooling capacity of the second higher-stage refrigeration cycle. In Fig. 8, a reference symbol L1a denotes a frequency range of first compressor 101 included in the first higher-stage refrigeration cycle. A reference symbol L2a denotes a frequency range of second compressor 201 included in the second higher-stage refrigeration cycle.

[0093] As shown in Fig. 8, the maximum cooling capacity of the first higher-stage refrigeration cycle is higher than that of the second higher-stage refrigeration cycle. On the other hand, the minimum cooling capacity of the second higher-stage refrigeration cycle is lower than that of the first higher-stage refrigeration cycle. The lower limit frequency of the first higher-stage refrigeration cycle is flmin, and the upper limit frequency of the first higher-stage refrigeration cycle is f1max. The lower limit frequency of the second higher-stage refrigeration cycle is f2min, and the upper limit frequency of the second higher-stage refrigeration cycle is f2max.

[0094] As shown in Fig. 8, the cooling capacity that can be output at upper limit frequency f2max of the second higher-stage refrigeration cycle is designed to be larger than the cooling capacity that can be output at lower limit frequency flmin of the first higher-stage refrigeration cycle. This results in a range Ca that overlaps with the cooling capacity of the first higher-stage refrigeration cycle and the cooling capacity of the second higher-stage refrigeration cycle.

[0095] Consider an imaginary example in which the range of the cooling capacity of the first higher-stage refrigeration cycle is designed to be 10 kW to 40 kW and the range of the cooling capacity of the second higher-stage refrigeration cycle is designed to be 2 kW to 10 kW. In the case of the imaginary example, the cooling capacities of both the higher-stage refrigeration cycles divided into a lower capacity and an upper capacity based on 10 kW as a boundary.

[0096] Therefore, there is no overlapping range between the cooling capacities of both the higher-stage refrigeration cycles unlike the case shown in Fig. 8. The minimum cooling capacity when each of the both higher-stage refrigeration cycles is activated is 12 kW. In the case where the first higher-stage refrigeration cycle is suspended and only the second higher-stage refrigeration cycle is operated as the higher-stage refrigeration cycle to reduce the cooling capacity when the required capacity of the lower-stage refrigeration cycle is smaller than the cooling capacity of the higher-stage refrigeration cycle, there arises such a problem that the cooling capacity of 10 to 12 kW cannot be provided in the higher-stage refrigeration cycle.

[0097] However, as shown in Fig. 8, occurrence of such a problem can be prevented by providing range Ca overlapping with the cooling capacity of the first higher-stage refrigeration cycle and the cooling capacity of the second higher-stage refrigeration cycle. For example, in the case of the above imaginary example, by increasing the maximum cooling capacity of the second higher-stage refrigeration cycle to 12 kW, range Ca overlapping with the cooling capacity of the first higher-stage refrigeration cycle and the cooling capacity of the second higher-stage refrigeration cycle can be provided as shown in Fig. 8.

[0098] Fig. 9 is a second graph showing a relation between the frequency range and the cooling capacity of the first higher-stage refrigeration cycle and a relation between the frequency range and the cooling capacity of the second higher-stage refrigeration cycle. In the example shown in Fig. 9, lower limit frequency flmin of the first higher-stage refrigeration cycle coincides with lower limit frequency f2min of the second higher-stage refrigeration cycle, and upper limit frequency f1max of the first higher-stage refrigeration cycle coincides with upper limit frequency f2max of the second higher-stage refrigeration cycle. However, also in the case of the example shown in Fig. 9, it is designed to form a range Cb overlapping with the cooling capacity of the first higher-stage refrigeration cycle and the cooling capacity of the second higher-stage refrigeration cycle as with the case of the example shown in Fig. 8. Therefore, as with the example shown in Fig. 8, the above-described problem caused by the imaginary example can be solved.

[0099] Thus, in the present embodiment, the upper limit value of the cooling capacity of first higher-stage refrigerant circuit 100 is larger than the upper limit value of the cooling capacity of second higher-stage refrigerant circuit 200. In the present embodiment, the upper limit value of the cooling capacity of second higher-stage refrigerant circuit 200 is included in the range of the cooling capacity of first higher-stage refrigerant circuit 100. In accordance with one of the patterns shown in Figs. 8 and 9, the frequency and cooling capacity of the higher-stage refrigeration cycle of two-stage refrigeration cycle apparatus 51 according to the first embodiment may be designed.

<Control in Operation Mode>

[0100] Fig. 10 is a flowchart showing a content of control in the operation mode according to the first embodiment. Controller 30 switches the operation mode between the cooling operation mode and the suspension operation mode by performing a process that is based on this flowchart.

[0101] First, controller 30 determines whether or not the cooling operation is suspended (step S1). When the operation of lower-stage refrigerant circuit 300 is suspended due to power failure or other circumstances, controller 30 determines YES in step S1 and transitions to the suspension operation mode (step S2). When the operation of lower-stage refrigerant circuit 300 is not suspended, controller 30 determines NO in step S1, and transitions to the cooling operation mode (step S3). The process in the suspension operation mode is disclosed in Fig. 11. The process in the cooling operation mode is disclosed in Fig. 12.

<Control in Suspension Operation Mode>

[0102] Fig. 11 is a flowchart showing a content of control in the suspension operation mode. First, controller 30 determines whether or not P10 is more than threshold value B (step S10). P10 denotes the pressure of lower-stage refrigerant circuit 300. Controller 30 specifies pressure P10 based on the output value of pressure sensor 10 provided in lower-stage refrigerant circuit 300.

[0103] In the suspension operation mode, controller 30 controls pressure P10 of lower-stage refrigerant circuit 300 to fall within a certain range. A frame W10 in Fig. 11 shows a relation between pressure P10 and a threshold value. Controller 30 controls the pressure not to exceed a threshold value B. Each of (1), (2), and (3) shown in frame W10 of Fig. 11 represents a range of pressure P10 detected by pressure sensor 10. Among (1) to (3), a reference pressure range targeted by controller 30 is (2).

[0104] For example, when CO_2 is employed as the third refrigerant in lower-stage refrigerant circuit 300, threshold value A is preferably 3.38 MPaG. It is assumed that when the saturation temperature of CO_2 is 0°C, the pressure of CO_2 is 3.38 MPaG. Threshold value B is preferably 3.67 MPaG. It is assumed that when the saturation temperature of CO_2 is 3°C, the pressure of CO_2 is 3.67 MPaG.

[0105] However, the threshold value pressure range may be 3.38 MPaG to 4.15 MPaG. This corresponds to a saturation temperature of 0°C to 7.7°C of CO_2. Threshold value A may be a value corresponding to a temperature when the saturation temperature of CO_2 is less than 0°C. However, in order to suppress adhesion of frost to each of first cascade condenser 104 and second cascade condenser 204, threshold value A is desirably a value corresponding to the temperature when the saturation temperature of CO_2 is 0°C.

[0106] When it is determined in step S10 that P10 is not more than threshold value B, controller 30 repeats the determination of step S10 until P10 becomes more than threshold value B. When it is determined in step S10 that pressure P10 is more than threshold value B, controller 30 operates the second higher-stage refrigeration cycle in order to decrease pressure P10 to fall within the range of (2) of frame W10 (step S11). Thus, second higher-stage refrigerant circuit 200 is activated. When second higher-stage refrigerant circuit 200 is activated, the third refrigerant is cooled by second cascade condenser 204.

[0107] After step S11, controller 30 performs a process of step S101 indicated by a broken line. Step S101 is a process of adjusting the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203, and is constituted of steps S12 and S13. In step S12, controller 30 determines whether or not the current rotation speed of second fan 2021 has achieved a target condensation temperature (CT) and whether or not the current opening degree of second expansion valve (LEV) 203 has achieved a target superheat (SH). When the respective targets have been achieved, controller 30 transitions to S14. When the respective targets have not been achieved, controller 30 resets the rotation speed of second fan 2021 and the opening degree of second expansion valve 203, and then transitions to step S12 again.

[0108] After step S101, controller 30 determines whether or not pressure P10 satisfies "pressure P10 < threshold value B" and "pressure P10 > threshold value A" (step S14). That is, controller 30 determines whether or not pressure P10 is in the range of (2) shown in frame W10.

[0109] When pressure P10 is in the range of (2) shown in frame W10, controller 30 repeats the process of step S14. When pressure P10 falls out from the range of (2) shown in frame W10, controller 30 determines whether or not pressure P10 satisfies "pressure P10 < threshold value A". Here, it is determined whether or not pressure P10 is in the range of (1) shown in frame W10.

[0110] When pressure P10 does not satisfy "pressure P10 < threshold value A" in step S15, pressure P10 is in the range of (3) shown in frame W10. Therefore, when it is determined NO in step S15, controller 30 increases the frequency of second compressor 201 (Comp 201) by a certain value (step S16). Then, controller 30 performs the same process as that in step S101 described above (step S17). Then, controller 30 transitions to the process of step S14.

[0111] When pressure P10 satisfies "pressure P10 < threshold value A" in step S15, pressure P10 is in the range of (1) shown in frame W10. In this case, it can be determined that the pressure of lower-stage refrigerant circuit 300 is sufficiently low. In other words, it can be determined that the cooling capacity of the higher-stage refrigeration cycle is too high. In this case, it is necessary to decrease the frequency of second compressor 201. However, there is a possibility that the frequency of second compressor 201 has already reached the lower limit frequency. Moreover, even though the frequency of second compressor 201 has already reached the lower limit frequency, the pressure of the lower-stage refrigeration cycle may be abruptly increased if the operation of the second higher-stage refrigeration cycle is immediately suspended when the outside air temperature is high.

[0112] Therefore, when it is determined YES in step S15, controller 30 determines whether or not the frequency of second compressor 201 (Comp 201) is the lower limit frequency and the outside air temperature is equal to or less than a setting temperature (step S20). Controller 30 specifies the outside air temperature based on the output value of temperature sensor 20.

[0113] When it is determined NO in step S20, controller 30 decreases the frequency of second compressor 201 (Comp 201) by a certain value (step S18). Then, controller 30 performs the same process as that in step S101 described above (step S19). Then, controller 30 transitions to the process of step S14.

[0114] When it is determined YES in step S20, controller 30 suspends the second higher-stage refrigeration cycle (step S21). When the outside air temperature is equal to or less than the setting temperature and the frequency of second compressor 201 (Comp 201) is the lower limit frequency, it can be determined that there is no risk that the pressure of lower-stage refrigerant circuit 300 is increased abruptly. Therefore, in step S21, the second higher-stage refrigeration cycle is suspended. Thereafter, the process of the suspension operation mode is ended.

[0115] As described with reference to Fig. 11, in the suspension operation mode, controller 30 controls first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 to cause the pressure detected by pressure sensor 10 to fall within the range of threshold value A to threshold value B.

[0116] In the process in the suspension operation mode shown in Fig. 11, an abnormal increase in pressure of lower-stage refrigerant circuit 300 is prevented by the second higher-stage refrigeration cycle. However, the first higher-stage refrigeration cycle may be further utilized in the suspension operation mode. For example, it is conceivable to activate the first higher-stage refrigeration cycle in step S16 of Fig. 11 when the frequency of second compressor 201 (Comp 201) has reached the upper limit frequency.

<Control in Cooling Operation Mode>

[0117] Fig. 12 is a flowchart showing a content of control in a cooling operation mode. First, controller 30 sets a target frequency of third compressor 301 (Comp 301) in accordance with the outside air temperature and the evaporation temperature set in indoor unit 2 (step S30). Controller 30 specifies the outside air temperature based on the output value of temperature sensor 20.

[0118] After step S30, controller 30 determines whether or not the frequency of third compressor 301 (Comp 301) is more than a threshold value X (step S31). Threshold value X is a value for determining a required operation capacity of the higher-stage refrigeration cycle. When it is determined that the frequency of third compressor 301 (Comp 301) is more than threshold value X, controller 30 operates the first and second higher-stage refrigeration cycles (step S32). When it is determined that the frequency of third compressor 301 (Comp 301) is not more than threshold value X, controller 30 operates the second higher-stage refrigeration cycle (step S34).

[0119] Thus, controller 30 controls timings of activating first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, based on the frequency set when activating third compressor 301 (Comp 301).

[0120] Fig. 13 is a graph showing a relation between a setting value of the evaporation temperature in the compartment and the cooling capacity. Here, threshold value X will be described with reference to Fig. 13. In the graph, the horizontal axis represents the condensation temperature (ET: evaporation temperature) set in indoor unit 2 disposed in the compartment. The vertical axis represents the frequency (Hz) of the compressor corresponding to the cooling capacity. As shown in Fig. 13, the required cooling capacity varies depending on outside air temperature AT (Outside air Temperature).

[0121] Generally, as the outside air temperature is higher, the required cooling capacity is higher. For example, Fig. 13 shows an example of a comparison between a case where the outside air temperature is 20°C and a case where the outside air temperature is -15°C. In the present embodiment, threshold value X is determined to be 60 Hz based on this graph. However, this value is merely an example.

[0122] Returning to the flowchart of Fig. 12, the explanation will be continued. When the first and second higher-stage refrigeration cycles are operated in step S32, controller 30 performs the same process as that in step S101 in each of the first and second higher-stage refrigeration cycles (step S33).

[0123] Thus, in first higher-stage refrigerant circuit 100, the rotation speed of first fan 1021 of first heat exchanger 102 and the opening degree of first expansion valve 103 are adjusted as required. In second higher-stage refrigerant circuit 200, the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203 are adjusted as required. After step S33, controller 30 performs the high-capacity operation mode. The process in the high-capacity operation mode is disclosed in Fig. 14.

[0124] When performing the operation of the second higher-stage refrigeration cycle in step S34, controller 30 performs the same process as that in step S101 in the second higher-stage refrigeration cycle (step S35). Thus, in second higher-stage refrigerant circuit 200, the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203 are adjusted as required. After step S35, controller 30 performs the low-capacity operation mode. The process in the low-capacity operation mode is disclosed in Fig. 15.

<High-Capacity Operation Mode>

[0125] Fig. 14 is a flowchart showing a content of control in the high-capacity operation mode. First, controller 30 determines whether or not pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A" (step S40). As already described with reference to Fig. 11, P10 denotes the pressure of lower-stage refrigerant circuit 300. Controller 30 specifies pressure P10 based on the output value of pressure sensor 10 provided in lower-stage refrigerant circuit 300. A relation between pressure P10 and each of threshold values A and B is shown in frame W10 in Fig. 11.

[0126] When pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A", pressure P10 is in the range of (2) shown in frame W10 in Fig. 11. In this case, pressure P10 can be determined as being appropriate. Therefore, controller 30 returns the process to step S40. When pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A", controller 30 determines whether or not pressure P10 satisfies "P10 < threshold value A" (step S41).

[0127] When pressure P10 satisfies "P10 < threshold value A" in step S41, pressure P10 is in the range of (1) shown in frame W10 in Fig. 11. On this occasion, pressure P10 is less than lower limit threshold value A. In this case, it can be determined that the pressure of lower-stage refrigerant circuit 300 is sufficiently low. In other words, it can be determined that the cooling capacity of higher-stage refrigeration cycle is too high. In this case, it is necessary to decrease the frequency of the compressor on the higher-stage refrigeration cycle side. However, there is a possibility that each of both the frequencies of first compressor 101 and second compressor 201 on the higher-stage refrigeration cycle side has already reached the lower limit frequency.

[0128] Therefore, when it is determined YES in step S41, controller 30 determines whether or not each of both the frequencies of first compressor 101 (Comp 101) and second compressor 201 (Comp 201) has reached the lower limit frequency (step S43).

[0129] When it is determined NO in step S43, controller 30 decreases the frequency of the compressor in the higher-stage refrigeration cycle (step S52). In step S52, controller 30 preferentially decreases the frequency of first compressor 101 (Comp 101) of first compressor 101 (Comp 101) and second compressor 201 (Comp 201).

[0130] More specifically, when the frequency of first compressor 101 (Comp 101) has not reached the lower limit, controller 30 decreases the frequency of first compressor 101 (Comp 101) by a certain value and then proceeds to the next step S53. On this occasion, the frequency of second compressor 201 (Comp 201) is not decreased. When the frequency of first compressor 101 (Comp 101) has reached the lower limit and the frequency of second compressor 201 (Comp 201) has not reached the lower limit in step S43, controller 30 decreases the frequency of second compressor 201 (Comp 201) by a certain value in step S52, and then proceeds to step S53.

[0131] In step S53, controller 30 performs the same process as that in step S101 in each of the first and second higher-stage refrigeration cycles.

[0132] Thus, in first higher-stage refrigerant circuit 100, the rotation speed of first fan 1021 of first heat exchanger 102 and the opening degree of first expansion valve 103 are adjusted as required. In second higher-stage refrigerant circuit 200, the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203 are adjusted as required. After step S53, controller 30 returns the process to step S40.

[0133] When the process of step S43 is repeatedly performed, each of the frequencies of first compressor 101 (Comp 101) and second compressor 201 (Comp 201) may reach the lower limit value. When each of the frequencies of first compressor 101 (Comp 101) and second compressor 201 (Comp 201) reaches the lower limit value, controller 30 determines YES in step S43. On this occasion, the cooling capacity of the higher-stage refrigeration cycle when both the first and second higher-stage refrigeration cycles are activated has reached the lower limit.

[0134] When it is determined YES in step S43, controller 30 suspends the first higher-stage refrigeration cycle (step S54), and then switches the operation mode from the high-capacity operation mode to the low-capacity operation mode.

[0135] When pressure P10 does not satisfy "P10 < threshold value A" in step S41, pressure P10 is in the range of (3) shown in frame W10 in Fig. 11. On this occasion, pressure P10 is more than upper limit threshold value B.

[0136] When pressure P10 is more than upper limit threshold value B, it is necessary to increase the capacity of the higher-stage refrigeration cycle. When it is determined in step S41 that pressure P10 does not satisfy "P10 < threshold value A", controller 30 determines whether or not each of both the frequencies of first compressor 101 (Comp 101) and second compressor 201 (Comp 201) has reached the upper limit value (step S42).

[0137] When it is determined NO in step S42, controller 30 increases the frequency of the compressor in the higher-stage refrigeration cycle (step S44). In step S44, controller 30 preferentially increases the frequency of second compressor 201 (Comp 201) of first compressor 101 (Comp 101) and second compressor 201 (Comp 201).

[0138] More specifically, when the frequency of second compressor 201 (Comp 201) has not reached the upper limit value, the frequency of second compressor 201 (Comp 201) is increased by a certain value, and then the process proceeds to the next step S45. On this occasion, the frequency of first compressor 101 (Comp 101) is not increased. When the frequency of second compressor 201 (Comp 201) has reached the upper limit value and the frequency of first compressor 101 (Comp 101) has not reached the upper limit value in step S42, controller 30 increases the frequency of first compressor 101 (Comp 101) by a certain value in step S44, and then proceeds to step S45.

[0139] In step S45, controller 30 performs the same process as that in step S101 in each of the first and second higher-stage refrigeration cycles.

[0140] Thus, in first higher-stage refrigerant circuit 100, the rotation speed of first fan 1021 of first heat exchanger 102 and the opening degree of first expansion valve 103 are adjusted as required. In second higher-stage refrigerant circuit 200, the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203 are adjusted as required. After step S45, controller 30 returns the process to step S40.

[0141] When the process of step S44 is repeatedly performed, each of the frequencies of first compressor 101 (Comp 101) and second compressor 201 (Comp 201) may reach the upper limit value. When each of the frequencies of first compressor 101 (Comp 101) and second compressor 201 (Comp 201) has reached the upper limit value, controller 30 determines YES in step S42. On this occasion, the cooling capacity of the higher-stage refrigeration cycle has reached the upper limit value.

[0142] When it is determined YES in step S42, controller 30 notifies the user that the capacity is insufficient (step S46). For example, controller 30 displays, on a remote controller for manipulating indoor unit 2, a message indicating that the capacity is insufficient.

[0143] After the process of step S46, controller 30 decreases the frequency of third compressor 301 (Comp 301) included in lower-stage refrigerant circuit 300 by a certain value (step S47). Controller 30 performs the same process as in step S101 in each refrigeration cycle (step S48). Then, controller 30 determines whether or not pressure P10 satisfies "P10 ≤ threshold value B" (step S49).

[0144] When pressure P10 does not satisfy "P10 ≤ threshold value B" in step S49, controller 30 returns the process to step S46. When pressure P10 satisfies "P10 ≤ threshold value B" in step S49, controller 30 determines whether or not a user manipulation for suspending the lower-stage refrigeration cycle is detected (step S50). Controller 30 continues the process of step S50 until the user manipulation for suspending the lower-stage refrigeration cycle is detected. The user manipulation is input to controller 30 from the remote controller corresponding to indoor unit 2, for example. It should be noted that when it is determined NO in step S50, controller 30 may return the process to step S46 and notify the user again that the capacity is insufficient.

[0145] When the user manipulation is detected in step S50, controller 30 suspends the lower-stage refrigeration cycle and the first higher-stage refrigeration cycle (step S51). Next, controller 30 switches the operation mode to the suspension operation mode. By switching the operation mode to the suspension operation mode, the pressure of lower-stage refrigerant circuit 300 is prevented from being abnormally increased.

[0146] As described with reference to Fig. 14, in the high-capacity operation mode, controller 30 controls first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 to cause the pressure detected by pressure sensor 10 to fall within the range of threshold value A to threshold value B.

<Low-Capacity Operation Mode>

[0147] Fig. 15 is a flowchart showing a content of control in the low-capacity operation mode. First, controller 30 determines whether or not pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A" (step S70). As described with reference to Fig. 11, P10 denotes the pressure of lower-stage refrigerant circuit 300. Controller 30 specifies pressure P10 based on the output value of pressure sensor 10 provided in lower-stage refrigerant circuit 300. The relation between pressure P10 and each of threshold values A and B is shown in frame W10 in Fig. 11.

[0148] When pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A", pressure P10 is in the range of (2) shown in frame W10 in Fig. 11. In this case, pressure P10 can be determined as being appropriate. In this case, controller 30 returns the process to step S70. When pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A", controller 30 determines whether or not pressure P10 satisfies "P10 < threshold value A" (step S71).

[0149] When pressure P10 satisfies "P10 < threshold value A" in step S71, pressure P10 is in the range of (1) shown in frame W10 in Fig. 11. On this occasion, pressure P10 is less than lower limit threshold value A. In this case, it can be determined that the pressure of lower-stage refrigerant circuit 300 is sufficiently low. In other words, it can be determined that the cooling capacity of the higher-stage refrigeration cycle is too high. In this case, it is necessary to decrease the frequency of second compressor 201 activated on the higher-stage refrigeration cycle side. However, there is a possibility that the frequency of second compressor 201 has already reached the lower limit frequency.

[0150] Therefore, when it is determined YES in step S71, controller 30 determines whether or not the frequency of second compressor 201 (Comp 201) has reached the lower limit frequency (step S73).

[0151] When it is determined NO in step S73, controller 30 decreases the frequency of second compressor 201 (Comp 201) by a certain value (step S76). Then, in step S77, controller 30 performs the same process as that in step S101 in the second higher-stage refrigeration cycle. After step S77, controller 30 returns the process to step S70.

[0152] When the process of step S76 is repeatedly performed, the frequency of second compressor 201 (Comp

201) may reach the lower limit value. When the frequency of second compressor 201 (Comp 201) reaches the lower limit value, controller 30 determines YES in step S73. On this occasion, the cooling capacity of the second higher-stage refrigeration cycle has reached the lower limit.

[0153] When it is determined YES in step S73, controller 30 increases the target superheat (SH) by adjusting the opening degree of third expansion valve 303 included in lower-stage refrigerant circuit 300 (step S78). Then, in step S79, controller 30 performs the same process as that in step S101 in the lower-stage refrigeration cycle. Specifically, controller 30 adjusts the rotation speed of third fan 3021 of third heat exchanger 302.

[0154] After step S79, controller 30 determines whether or not pressure P10 satisfies "P10 ≤ threshold value B" and "P10 ≥ threshold value A" (step S80). When pressure P10 does not satisfy "P10 ≤ threshold value B" and "P10 ≥ threshold value A", controller 30 adjusts the target superheat (SH) of third expansion valve 303 again (step S81). Then, controller 30 performs the same process as in step S79 (step S82), and returns the process to step S70.

[0155] When it is determined YES in step S80, controller 30 determines whether or not a suspension manipulation by the user is detected (step S83). For example, the user manipulates the remote controller to suspend the lower-stage refrigeration cycle. When it is determined NO in step S83, controller 30 returns the process to step S70. When it is determined YES in step S83, controller 30 suspends the lower-stage refrigeration cycle (step S84). Then, controller 30 switches the operation mode to the suspension operation mode.

[0156] When pressure P10 does not satisfy "P10 < threshold value A" in step S71, pressure P10 is in the range of (3) shown in frame W10 in Fig. 11. On this occasion, pressure P10 is more than upper limit threshold value B.

[0157] When pressure P10 is more than upper limit threshold value B, it is necessary to increase the capacity of the higher-stage refrigeration cycle. When it is determined in step S71 that pressure P10 does not satisfy "P10 < threshold value A", controller 30 determines whether or not the frequency of second compressor 201 (Comp 201) has reached the upper limit value (step S72).

[0158] When it is determined NO in step S72, controller 30 increases the frequency of second compressor 201 (Comp 201) by a certain value (step S74). Then, controller 30 performs the same process as that in step S101 in the second higher-stage refrigeration cycle (step S75). After step S75, controller 30 returns the process to step S70.

[0159] When the process of step S74 is repeatedly performed, the frequency of second compressor 201 (Comp 201) may reach the upper limit value. When the frequency of second compressor 201 (Comp 201) has reached the upper limit value, controller 30 determines YES in step S72 and switches the operation mode to the high-capacity operation mode. When the operation mode is switched to the high-capacity operation mode, the second higher-stage refrigeration cycle is activated, and the refrigeration capacity of the higher-stage refrigeration cycle is increased.

[0160] As described with reference to Fig. 15, in the low-capacity operation mode, controller 30 controls first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 to cause the pressure detected by pressure sensor 10 to fall within the range of threshold value A to threshold value B.

[0161] As understood from the above description, controller 30 switches the operation mode between the suspension operation mode and the cooling operation mode in accordance with a situation. More specifically, in each of the suspension operation mode and the cooling operation mode, controller 30 controls first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 to cause the pressure detected by pressure sensor 10 to fall within the range of threshold value A to threshold value B. It should be noted that each of the threshold values may differ depending on each mode.

[0162] Further, as shown in Fig. 12, controller 30 determines whether to operate in the low-capacity operation mode or the high-capacity operation mode based on the frequency set when activating third compressor 301 (Comp 301). In particular, in the high-capacity operation mode, both the first and second higher-stage refrigeration cycles are activated on the higher-stage side. On the other hand, in the low-capacity operation mode, only the second higher-stage refrigeration cycle is activated on the higher-stage side. Therefore, controller 30 controls the timings of activating first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, based on the frequency set when activating third compressor 301.

[0163] Further, as described with reference to Figs. 11, 14, and 15, controller 30 switches the cooling operation mode between the low-capacity operation mode and the high-capacity operation mode in accordance with a degree of required cooling capacity.

[0164] As described above, controller 30 changes the cooling capacity of the higher-stage refrigeration cycle provided by first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, based on the state of the refrigeration cycle of lower-stage refrigerant circuit 300.

[0165] Further, as described with reference to Figs. 8 and 9, when the higher-stage refrigeration cycle to be activated is changed in this manner, it is effective to design the higher-stage refrigeration cycle to form the range overlapping with the cooling capacity of the first higher-stage refrigeration cycle and the cooling capacity of the second higher-stage refrigeration cycle.

[0166] That is, when the cooling capacity that can be output at the upper limit frequency of the second higher-stage refrigeration cycle is set to be larger than the cooling capacity that can be output at the lower limit frequency of the first higher-stage refrigeration cycle as shown in

Figs. 8 and 9, activation and suspension of activation of the compressor can be suppressed from occurring when the cooling capacity on the boundary is required.

[0167] Further, the operation can be smoothly switched from the second higher-stage refrigeration cycle to the first higher-stage refrigeration cycle. Therefore, the required cooling capacity can be attained without excessively decreasing the frequency of second compressor 201.

[0168] Further, in the case of a refrigeration cycle system in which the frequency of the compressor has to be excessively decreased unlike the present embodiment, an amount of refrigeration oil to be returned to the compressor when the compressor suctions the refrigerant may be decreased with respect to an amount of refrigeration oil to be discharged when the compressor discharges the refrigerant. In this case, the motor of the compressor may be burned out. However, in the present embodiment, since there is no need to excessively decrease the frequency of second compressor 201, the motor of second compressor 201 can be prevented from being burned out due to insufficiency of the refrigerator oil, thereby improving the reliability of second compressor 201.

Second Embodiment.

[0169] Next, a second embodiment will be described. Fig. 16 is a diagram showing a configuration of a two-stage refrigeration cycle apparatus 52 according to the second embodiment. As shown in Fig. 16, in two-stage refrigeration cycle apparatus 52 according to the second embodiment, a fourth heat exchanger 402 is added to the configuration of two-stage refrigeration cycle apparatus 51 according to the first embodiment. Fourth heat exchanger 402 is provided with a fourth fan 4021 configured to promote heat exchange between the outside air and the third refrigerant.

[0170] Fourth heat exchanger 402 is provided in lower-stage refrigerant circuit 300. Fourth heat exchanger 402 is connected between first cascade condenser 104 and first compressor 101. The high-temperature and high-pressure third refrigerant discharged from first compressor 101 in a gas state is input to fourth heat exchanger 402. When fourth fan 4021 is rotated, fourth heat exchanger 402 dissipates, to the air, the heat of the third refrigerant discharged from first compressor 101. Therefore, fourth heat exchanger 402 functions as a condenser.

[0171] Two-stage refrigeration cycle apparatus 51 according to the first embodiment described above comprises the following two modes as the cooling operation modes: the low-capacity operation mode and the high-capacity operation mode. In each of these two modes, the higher-stage refrigeration cycle is activated and the third refrigerant of the lower-stage refrigeration cycle is cooled.

[0172] In addition to the low-capacity operation mode and the high-capacity operation mode, two-stage refrigeration cycle apparatus 52 according to the second embodiment has a mode in which the third refrigerant is cooled by fourth heat exchanger 402 without activating the higher-stage refrigeration cycle. Hereinafter, this mode is referred to as a "lower-stage cooling mode". Thus, the number of modes that can be switched in the cooling operation mode of the second embodiment is larger than that in the cooling operation mode of the first embodiment. Hereinafter, in order to distinguish between the cooling operation mode of the first embodiment and the cooling operation mode of the second embodiment, the latter cooling operation mode may be particularly referred to as a "second cooling operation mode".

[0173] In the lower-stage cooling mode, fourth fan 4021 corresponding to fourth heat exchanger 402 is rotated to cool the third refrigerant flowing through lower-stage refrigerant circuit 300. It should be noted that two-stage refrigeration cycle apparatus 52 may control the rotation speed of fourth fan 4021 based on the output value of pressure sensor 10 in order to maintain the pressure of the third refrigerant appropriately.

[0174] When the pressure of the third refrigerant is increased to exceed the appropriate range, two-stage refrigeration cycle apparatus 52 switches the operation mode from the lower-stage cooling mode to the low-capacity operation mode. The content of the low-capacity operation mode is the same as that of the first embodiment. However, in the low-capacity operation mode according to the second embodiment, fourth heat exchanger 402 continues to function as a condenser. Therefore, in the low-capacity operation mode according to the second embodiment, fourth fan 4021 corresponding to fourth heat exchanger 402 is rotated. Therefore, the maximum cooling capacity in the low-capacity operation mode according to the second embodiment is higher than that in the low-capacity operation mode according to the first embodiment.

[0175] It should be noted that in the low-capacity operation mode according to the second embodiment, the rotation of fourth fan 4021 corresponding to fourth heat exchanger 402 may be suspended. Further, in the low-capacity operation mode according to the second embodiment, controller 30 may control the rotation speed of fourth fan 4021 based on the output value of pressure sensor 10 in order to maintain the pressure of the third refrigerant appropriately.

[0176] When the pressure of the third refrigerant is increased to exceed the appropriate range in the low-capacity operation mode, two-stage refrigeration cycle apparatus 52 switches the operation mode from the low-capacity operation mode to the high-capacity operation mode. The content of the high-capacity operation mode is the same as that of the first embodiment. However, in the low-capacity operation mode according to the second embodiment, fourth heat exchanger 402 continues to function as a condenser. Therefore, in the low-capacity operation mode according to the second embodiment, fourth fan 4021 corresponding to fourth heat exchanger 402 is rotated. Therefore, the maximum cooling capacity in the high-capacity operation mode according to the second embodiment is higher than that in the low-capacity operation mode according to the first embodiment.

[0177] It should be noted that in the high-capacity operation mode according to the second embodiment, the rotation of fourth fan 4021 corresponding to fourth heat exchanger 402 may be suspended. In the high-capacity operation mode according to the second embodiment, controller 30 may control the rotation speed of fourth fan 4021 based on the output value of pressure sensor 10 in order to maintain the pressure of the third refrigerant appropriately.

<Heat Transfer Area Ratio>

[0178] Fig. 17 is a diagram showing a ratio of heat transfer areas of first heat exchanger 102 and second heat exchanger 202 and a heat transfer area of fourth heat exchanger 402. In the second embodiment, first heat exchanger 102 and second heat exchanger 202 constitute the condenser of the higher-stage refrigeration cycle, and fourth heat exchanger 402 constitutes the condenser of the lower-stage refrigeration cycle. Therefore, Fig. 17 corresponds to a diagram of a comparison between the heat transfer area of the condenser of the higher-stage refrigeration cycle and the heat transfer area of the condenser of the lower-stage refrigeration cycle.

[0179] A pattern 1 and a pattern 2 are shown in Fig. 17 with regard to the ratio of the heat transfer area of fourth heat exchanger 402 to the total heat transfer area of first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402.

[0180] In pattern 1, the ratio of the heat transfer area of fourth heat exchanger 402 to the total heat transfer area of first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402 is in the range of 3% to 50%. That is, pattern 1 is an example in which the ratio of the heat transfer area of the lower-stage refrigeration cycle to the total heat transfer area of the condensers of the lower-stage refrigeration cycle and the higher-stage refrigeration cycle is in the range of 3% to 50%.

[0181] In pattern 2, the ratio of the heat transfer area of fourth heat exchanger 402 to the total heat transfer area of first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402 is in the range of 8% to 30%. That is, pattern 2 is an example in which the ratio of the heat transfer area of the lower-stage refrigeration cycle to the total heat transfer area of the condensers of the lower-stage refrigeration cycle and the higher-stage refrigeration cycle is in the range of 8% to 30%.

[0182] It is more desirable to employ pattern 2 as the heat transfer area ratio, rather than pattern 1. For example, since the heat transfer area ratio of the condenser of the lower-stage refrigeration cycle in pattern 2 is higher than that in pattern 1, it can be expected that the cooling function in the lower-stage cooling mode using fourth heat exchanger 402 is increased in pattern 2 as compared with pattern 1.

[0183] It should be noted that in pattern 1, any heat transfer ratio of fourth heat exchanger 402 in the range of 3 to 50% may be employed. Also, in pattern 2, any heat transfer ratio of fourth heat exchanger 402 in the range of 8 to 30% may be employed.

<Integration of Heat Exchangers>

[0184] Fig. 18 is a diagram showing a sixth heat exchanger 602 obtained by integrating first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402. Sixth heat exchanger 602 corresponds to a heat exchanger obtained by integrating configuration portions denoted by reference symbols B, C, and D in Fig. 16.

[0185] Sixth heat exchanger 602 has such a configuration that first higher-stage refrigerant circuit 100 through which the first refrigerant flows, second higher-stage refrigerant circuit 200 through which the second refrigerant flows, and lower-stage refrigerant circuit 300 through which the third refrigerant flows are divided and first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402 are integrated. Sixth heat exchanger 602 is provided with a sixth fan 6021. It should be noted that a plurality of fans may be provided for sixth heat exchanger 602.

[0186] By integrating first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402, it is possible to effectively utilize a space in which devices are disposed. Further, by integrating first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402, cost can be reduced.

[0187] Fig. 19 is a diagram showing a seventh heat exchanger 702 obtained by integrating second heat exchanger 202 and fourth heat exchanger 402, and first heat exchanger 102 used in combination with seventh heat exchanger 702. Seventh heat exchanger 702 corresponds to a heat exchanger obtained by integrating the configuration portions denoted by reference symbols B and C in Fig. 16.

[0188] Seventh heat exchanger 702 has such a configuration that second higher-stage refrigerant circuit 200 through which the second refrigerant flows and lower-stage refrigerant circuit 300 through which the third refrigerant flows are divided and second heat exchanger 202 and fourth heat exchanger 402 are integrated. Seventh heat exchanger 702 is provided with a seventh fan 7021. It should be noted that a plurality of fans may be provided for seventh heat exchanger 702.

[0189] By integrating second heat exchanger 202 and fourth heat exchanger 402, it is possible to effectively utilize a space in which devices are disposed. Further, by integrating second heat exchanger 202 and fourth heat exchanger 402, cost can be reduced. It should be noted that first heat exchanger 102 and fourth heat exchanger 402 may be integrated.

<Control in Operation Mode>

[0190] Fig. 20 is a flowchart showing a content of control in the operation mode according to the second embodiment. Controller 30 switches the operation mode between the second cooling operation mode and the suspension operation mode by performing the process based on this flowchart.

[0191] First, controller 30 determines whether or not the cooling operation is suspended (step S1000). When the operation of lower-stage refrigerant circuit 300 is suspended due to power failure or other circumstances, controller 30 determines YES in step S1000 and transitions to the suspension operation mode (step S2000).

[0192] The content of the suspension operation mode is the same as that in the first embodiment, and therefore will not be described repeatedly here. When the operation of lower-stage refrigerant circuit 300 is not suspended, controller 30 determines NO in step S1000 and transitions to the second cooling operation mode (step S3000).

<Control in Second Cooling Operation Mode>

[0193] Fig. 21 is a flowchart showing a content of control in the second cooling operation mode. First, controller 30 sets a target frequency of third compressor 301 (Comp 301) in accordance with the outside air temperature and the evaporation temperature set in indoor unit 2 (step S90). Controller 30 specifies the outside air temperature based on the output value of temperature sensor 20.

[0194] After step S90, controller 30 determines whether or not the frequency of third compressor 301 (Comp 301) is equal to or less than threshold value Y and whether or not the outside air (outside air temperature) is equal to or less than the setting value (step S91). The setting value of the outside air temperature is a value set in advance. The setting value of the outside air temperature will be described later with reference to Fig. 22. Controller 30 stores the setting value.

[0195] Controller 30 stores threshold value X and threshold value Y as threshold values for determining whether to switch the operation of the refrigeration cycle. A frame W20 in Fig. 21 shows a relation between the frequency of third compressor 301 (Comp 301) and each of threshold values X and Y. First, the relation between the frequency of third compressor 301 (Comp 301) and each of threshold values X and Y will be described with reference to frame W20.

[0196] In frame W20, each of (1) to (3) represents a range of values taken by the frequency of third compressor 301 (Comp 301). (1) represents a range in which the frequency of third compressor 301 (Comp 301) is equal to or less than threshold value Y. (2) represents a range in which the frequency of third compressor 301 (Comp 301) is more than threshold value Y and is less than threshold value X. (3) represents a range in which the frequency of third compressor 301 (Comp 301) is equal to or more than threshold value X. The frequency range (2) represents an appropriate range. The frequency range (1) represents a range lower than the appropriate range. The frequency range (3) represents a range higher than the appropriate range.

[0197] Here, the setting values of threshold value X, threshold value Y, and the outside air temperature will be described in detail with reference to Figs. 22 and 23. Fig. 22 is a graph showing a relation between the setting value of the evaporation temperature in the compartment and the cooling capacity (second embodiment). Fig. 23 is a graph showing a relation between the frequency of the third compressor (Comp 301) and the setting value of the evaporation temperature in the compartment (second embodiment). Threshold value X and the setting value of the outside air temperature will be described with reference to Fig. 22, and threshold value Y will be described with reference to Fig. 23.

[0198] In the graph shown in Fig. 22, the horizontal axis represents the condensation temperature (ET: evaporation temperature) set in indoor unit 2 disposed in the compartment. The vertical axis represents the frequency (Hz) of the compressor corresponding to the cooling capacity. As shown in Fig. 22, the required cooling capacity is changed depending on the outside air temperature AT (Outside air Temperature).

[0199] Generally, as the outside air temperature is higher, the required cooling capacity is higher. For example, Fig. 22 shows an example of a comparison between a case where the outside air temperature is 20°C and a case where the outside air temperature is -15°C. In the second embodiment, threshold value X is determined to be 60 Hz based on this graph. It should be noted that this value is merely an example.

[0200] Fig. 22 further shows a region R10 in which the higher-stage operation is not required. In region R10, both the first and second higher-stage refrigeration cycles do not need to be operated when the lower-stage refrigeration cycle is operated. In region R10, controller 30 selects the lower-stage cooling mode as the operation mode. In the lower-stage cooling mode, fourth heat exchanger 402 provided in lower-stage refrigerant circuit 300 functions as a condenser, thereby cooling the third refrigerant. In the lower-stage cooling mode, the higher-stage refrigeration cycle is not activated.

[0201] As shown in Fig. 22, region R10 is set based on outside air temperature AT10 as a boundary. That is, controller 30 selects the lower-stage cooling mode under condition that the outside air temperature is equal to or less than AT10. Outside air temperature AT10 is set as any value in the range of -15°C to 20°C.

[0202] In the graph shown in Fig. 23, the horizontal axis represents the frequency of third compressor 301 (Comp 301). The vertical axis represents the condensation temperature (ET) set in indoor unit 2 disposed in the compartment. The graph of Fig. 23 shows region R10 in which the higher-stage operation is not required and region R20 in which the higher-stage operation is required in the relation between the frequency of third compressor 301 (Comp 301) and the condensation temperature (ET). Region R20 is partitioned by a capacity equivalent line. As the frequency of third compressor 301 (Comp 301) and the condensation temperature (ET) are higher, the required cooling capacity is higher.

[0203] Fig. 23 shows Y1 and Y2 as examples of values that can be each employed as threshold value Y. Threshold value Y1 is the maximum frequency of third compressor 301 (Comp 301) in region R10 in which the higher-stage operation is not required. Therefore, Y1 is a fixed value. Threshold value Y2 is the frequency of third compressor 301 (Comp 301) along the capacity equivalent line. Therefore, Y2 is a value that varies according to the condensation temperature (ET) set in indoor unit 2.

[0204] In the second embodiment, any one of Y1 and Y2 may be employed as threshold value Y. Further, two threshold values Y1 and Y2 may be stored in advance in memory 32 of controller 30. Controller 30 may be configured to select one of threshold values Y1 and Y2.

[0205] Returning to the flowchart of Fig. 21, the explanation will be continued. When it is determined NO in step S91, controller 30 performs an operation of rotating fourth fan 4021 of fourth heat exchanger 402 (step S95). That is, controller 30 starts the operation of the lower-stage cooling mode. Thus, fourth heat exchanger 402 functions as a condenser. As a result, the third refrigerant in lower-stage refrigerant circuit 300 is cooled by fourth heat exchanger 402.

[0206] Next, controller 30 determines whether or not the frequency of third compressor 301 (Comp 301) is more than threshold value Y and the frequency of third compressor 301 (Comp 301) is less than threshold value X (step S96). That is, controller 30 determines whether or not the frequency of third compressor 301 falls within the appropriate range (2) shown in frame W20.

[0207] When it is determined YES in step S96, controller 30 operates the second higher-stage refrigeration cycle (step S99). When the second higher-stage refrigeration cycle is operated, controller 30 performs the same process as that in step S101 in the second higher-stage refrigeration cycle (step S100). Thus, in second higher-stage refrigerant circuit 200, the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203 are adjusted as required.

[0208] After step S100, controller 30 performs the low-capacity operation mode. The process in the low-capacity operation mode is disclosed in Fig. 15. The process of the low-capacity operation of the second embodiment is the same as that of the low-capacity operation mode of the first embodiment shown in Fig. 15, and therefore will not be described repeatedly here. It should be noted that in the second embodiment, even when the operation mode is transitioned to the low-capacity operation mode, the operation of fourth fan 4021 of fourth heat exchanger 402 shown in step S95 is continued.

[0209] When it is determined NO in step S96, controller 30 operates the first and second higher-stage refrigeration cycles (step S97).

[0210] When the first and second higher-stage refrigeration cycles are operated in step S97, controller 30 performs the same process as that in step S101 in each of the first and second higher-stage refrigeration cycles (step S98).

[0211] Thus, in first higher-stage refrigerant circuit 100, the rotation speed of first fan 1021 of first heat exchanger 102 and the opening degree of first expansion valve 103 are adjusted as required. In second higher-stage refrigerant circuit 200, the rotation speed of second fan 2021 of second heat exchanger 202 and the opening degree of second expansion valve 203 are adjusted as required.

[0212] After step S98, controller 30 performs the high-capacity operation mode. The process in the high-capacity operation mode is disclosed in Fig. 14. The process in the high-capacity operation of the second embodiment is the same as that in the high-capacity operation mode of the first embodiment shown in Fig. 14, and therefore will not be described repeatedly here. It should be noted that in the second embodiment, even when the operation mode is transitioned to the high-capacity operation mode, the operation of fourth fan 4021 of fourth heat exchanger 402 as shown in step S95 is continued.

[0213] When it is determined YES in step S91, controller 30 performs an operation of rotating fourth fan 4021 of fourth heat exchanger 402 (step S92). This process is the same as step S95 described above.

[0214] Next, controller 30 determines whether or not pressure P10 of lower-stage refrigerant circuit 300 is more than threshold value B (step S93).

[0215] As described with reference to Fig. 11, P10 denotes the pressure of lower-stage refrigerant circuit 300. Controller 30 specifies pressure P10 based on the output value of pressure sensor 10 provided in lower-stage refrigerant circuit 300. The relation between pressure P10 and each of threshold values A and B is shown in frame W10 in Fig. 11.

[0216] When pressure P10 is not more than threshold value B in step S93, pressure P10 is not more than the upper limit value of the set pressure range. Therefore, when it is determined NO in step S93, controller 30 repeats the determination in step S93 until pressure P10 becomes more than threshold value B.

[0217] When pressure P10 is more than threshold value B in step S93, it can be determined that heat dissipation is insufficient only with fourth heat exchanger 402. Therefore, when it is determined YES in step S93, controller 30 operates the second higher-stage refrigeration cycle in order to decrease pressure P10 to fall within the range of (2) of frame W10 in Fig. 11 (step S94). Thus, second higher-stage refrigerant circuit 200 is activated. When second higher-stage refrigerant circuit 200 is activated, the third refrigerant is cooled by second cascade condenser 204.

[0218] In this way, when pressure P10 becomes higher than the range of threshold value A to threshold value B even though fourth heat exchanger 402 is activated, controller 30 activates second higher-stage refrigerant circuit 200.

[0219] After step S94, controller 30 performs the low-capacity operation mode. The content of the control in the low-capacity operation mode is disclosed in Fig. 15. The process of the low-capacity operation of the second embodiment is the same as the content of the control in the low-capacity operation mode of the first embodiment shown in Fig. 15, and therefore will not be described repeatedly here. It should be noted that in the second embodiment, even when the operation mode is transitioned to the low-capacity operation mode, the operation of fourth fan 4021 of fourth heat exchanger 402 shown in step S92 is continued.

[0220] According to the second embodiment described above, when a load on the refrigeration cycle is low, the heat dissipation function of fourth heat exchanger 402 included in lower-stage refrigerant circuit 300 is utilized to prevent the pressure of the third refrigerant from being increased abnormally. On this occasion, it is not necessary to operate the higher-stage refrigeration cycle. Therefore, the refrigeration cycle can be operated with high efficiency.

[0221] In the second embodiment, controller 30 controls the timings of activating first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200, based on the frequency set when activating third compressor 301. Also in the second embodiment, the low-capacity operation mode and the high-capacity operation mode are performed. The contents of the low-capacity operation mode and the high-capacity operation mode are as described in the first embodiment. However, in the second embodiment, fourth heat exchanger 402 is also activated. Accordingly, controller 30 according to the second embodiment controls first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and fourth heat exchanger 402 to cause pressure P10 to fall within the range of first threshold value A to second threshold value B.

[0222] When the outside air temperature is low (for example, -5°C), controller 30 controls the rotation speed of fourth fan 4021 without activating the higher-stage refrigeration cycle, thereby preventing an abnormal increase in pressure in lower-stage refrigerant circuit 300. In particular, in winter, since the refrigeration cycle can be operated without activating the higher-stage refrigeration cycle, an energy saving property of two-stage refrigeration cycle apparatus 52 can be improved. In addition, the service life of the higher-stage refrigeration cycle can be increased. As a result, the performance of two-stage refrigeration cycle apparatus 52 can be improved.

[0223] The third refrigerant flowing from third compressor 301 into fourth heat exchanger 402 is superheated vapor. By activating fourth heat exchanger 402 when operating the higher-stage refrigeration cycle, part of an amount of heat of the third refrigerant before flowing into first cascade condenser 104 can be dissipated by fourth heat exchanger 402. Therefore, in first cascade condenser 104, heat can be exchanged between the third refrigerant and the first refrigerant in the two-phase region having a high heat transfer coefficient. The same applies to second cascade condenser 204.

[0224] In a low-load state, fourth fan 4021 of fourth heat exchanger 402 is rotated without activating the higher-stage refrigeration cycle. This makes it possible to improve the performance of two-stage refrigeration cycle apparatus 52 while suppressing an abnormal increase in pressure of lower-stage refrigerant circuit 300 when activating the refrigeration cycle. For example, when the frequency of third compressor 301 is lower than the threshold value and the outside air temperature is lower than the setting value, two-stage refrigeration cycle apparatus 52 is in the low-load state.

[0225] On the other hand, when the frequency of third compressor 301 is lower than the threshold value and the outside air temperature is higher than the setting value, fourth fan 4021 is rotated and the second higher-stage refrigeration cycle is activated. Thus, in a situation in which heat cannot be handled only with fourth heat exchanger 402, it is possible to securely suppress an abnormal increase in the pressure of lower-stage refrigerant circuit 300 from the time of activation of the refrigeration cycle.

[0226] On this occasion, since the first higher-stage refrigeration cycle is not activated, it is possible to suppress an increase in the pressure of lower-stage refrigerant circuit 300 by activating minimally necessary devices. Therefore, the energy saving property of two-stage refrigeration cycle apparatus 52 can be increased. Further, the service life of the higher-stage refrigeration cycle can be increased. As a result, the performance of two-stage refrigeration cycle apparatus 52 can be improved.

[0227] Further, when the frequency of third compressor 301 is higher than the threshold value and the outside air temperature is higher than the setting value, fourth fan 4021 may be rotated and the first and second higher-stage refrigeration cycles may be activated. Thus, in a situation in which heat cannot be handled only with fourth heat exchanger 402 and the second higher-stage refrigeration cycle, it is possible to securely suppress an abnormal increase in the pressure of lower-stage refrigerant circuit 300 from the time of activation of the refrigeration cycle.

<Modification of Control in Second Cooling Operation Mode>

[0228] Fig. 24 is a flowchart showing a modification of the second cooling operation mode according to the second embodiment. The modification of the second cooling operation mode according to the second embodiment will be described with reference to Fig. 24.

[0229] First, controller 30 sets the target frequency of third compressor 301 (Comp 301) in accordance with the outside air temperature and the evaporation temperature set in indoor unit 2 (step S120). The process in step S 120 is the same as the process in step S90 in Fig. 21.

[0230] Next, controller 30 determines whether or not the frequency of third compressor 301 (Comp 301) is equal to or less than threshold value Y (step S121). When it is determined that the frequency of third compressor 301 set in step S120 is equal to or lower than threshold value Y, controller 30 determines whether or not the outside air temperature is equal to or lower than the setting value (step S122). Here, the outside air temperature is a temperature detected by temperature sensor 20.

[0231] When it is determined that the outside air temperature is equal to or less than the setting value, controller 30 performs an operation of rotating fourth fan 4021 of fourth heat exchanger 402 (step S123). Thus, fourth heat exchanger 402 is activated. This process is the same as step S92 of Fig. 21. Then, controller 30 performs the processes of steps S124 to S125. These processes are the same as the processes in steps S93 to S94 in Fig. 21.

[0232] When it is determined in step S 122 that the outside air temperature is not equal to or less than the setting value, controller 30 rotates fourth fan 4021 of fourth heat exchanger 402 and activates second higher-stage refrigerant circuit 200 (step S126). Next, controller 30 performs the same process as that in step S101 in the second higher-stage refrigeration cycle (step S127), and transitions to the low-capacity operation mode.

[0233] When it is determined in step S121 that the frequency of third compressor 301 is not equal to or less than threshold value Y, controller 30 determines whether or not the outside air temperature is equal to or less than the setting value (step S128). When it is determined that the outside air temperature is equal to or less than the setting value, controller 30 performs the process of step S126 described above.

[0234] When it is determined in step S128 that the outside air temperature is not equal to or less than the setting value, controller 30 rotates fourth fan 4021 of fourth heat exchanger 402 and activates first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 (step S129). Next, controller 30 performs the same process as in step 5101 in the second higher-stage refrigeration cycle (step S130), and transitions to the high-capacity operation mode.

[0235] As described above, in the modification, controller 30 controls the timings of activating first higher-stage refrigerant circuit 100, second higher-stage refrigerant circuit 200, and fourth heat exchanger 402, based on the frequency set when activating third compressor 301 and the detection result of temperature sensor 20.

[0236] The various modifications described as the first embodiment can be applied to the second embodiment. For example, any of the modifications of the first embodiment shown in Figs. 4 to 7 may be applied to the second embodiment. Further, all the modifications may be applied thereto, or one or two or more of those modifications may be applied thereto.

<Other Modifications>

[0237] Each of two-stage refrigeration cycle apparatus 51 and two-stage refrigeration cycle apparatus 52 comprises such a configuration that the higher-stage refrigeration cycle is divided into two systems as compared with one system of the lower-stage refrigeration cycle. However, each of two-stage refrigeration cycle apparatus 51 and two-stage refrigeration cycle apparatus 52 may comprise such a configuration that the higher-stage refrigeration cycle is divided into three systems as compared with one system of the lower-stage refrigeration cycle. For example, each of two-stage refrigeration cycle apparatus 51 and two-stage refrigeration cycle apparatus 52 may further comprise a third higher-stage refrigeration cycle.

[0238] The third higher-stage refrigeration cycle may have a higher cooling capacity than that of the first higher-stage refrigeration cycle. The third higher-stage refrigeration cycle may have a lower cooling capacity than that of the second higher-stage refrigeration cycle. A different type of refrigerant from the first to third refrigerants may be used in the third higher-stage refrigeration cycle. Any one of the first to third refrigerants may be used in the third higher-stage refrigeration cycle. The same type of refrigerant may be used in each of the first to third higher-stage refrigeration cycles.

[0239] A discharge temperature sensor configured to detect the temperature of the high-temperature refrigerant discharged from third compressor 301 may be provided on the discharge side of third compressor 301. A low-pressure sensor may be provided on the suction portion side of third compressor 301 to calculate low-pressure saturation temperature ET.

[0240] In the second cooling operation mode shown in Fig. 21, controller 30 performs the operation of rotating fourth fan 4021 of fourth heat exchanger 402 in each of the case where it is determined YES in step S91 and the case where it is determined NO in step S91. Alternatively, when it is determined NO in step S91, controller 30 may transition to the process of step S96 without rotating fourth fan 4021 of fourth heat exchanger 402.

[0241] In the high-capacity operation mode according to the second embodiment, controller 30 may control the rotation speed of fourth fan 4021 based on the output value of pressure sensor 10 in order to maintain the pressure of the third refrigerant appropriately. For example, when it is determined NO in step S42 of the flowchart shown in Fig. 14, controller 30 may increase the rotation speed of fourth fan 4021 of fourth heat exchanger 402 to the maximum value. Then, controller 30 may make the same determination as that of step S41 before performing the process of step S44. In the case where pressure increase cannot be suppressed even when the rotation speed of fourth fan 4021 of fourth heat exchanger 402 is increased to the maximum value, controller 30 may perform the process of step S44.

[0242] That is, based on the detection result of pressure sensor 10, controller 30 may control the refrigeration cycle of fourth heat exchanger 402 or first higher-stage refrigerant circuit 100 or second higher-stage refrigerant circuit 200 to cause the pressure to fall within the range of the first threshold value to the second threshold value.

[0243] In the low-capacity operation mode according to the second embodiment, controller 30 may control the rotation speed of fourth fan 4021 based on the output value of pressure sensor 10 in order to maintain the pressure of the third refrigerant appropriately. For example, when controller 30 determines in step S73 of the flowchart shown in Fig. 15 that the frequency of second compressor 201 (Comp 201) has reached the lower limit frequency, controller 30 may decrease the rotation speed of fourth fan 4021 of fourth heat exchanger 402 by a certain value. Then, controller 30 may perform the processes of steps S78 to S80 after decreasing the rotation speed of fourth fan 4021. Further, when it is determined NO in step S80, controller 30 may decrease the rotation speed of fourth fan 4021 by a certain value again. Alternatively, controller 30 may suspend fourth fan 4021 of fourth heat exchanger 402 when it is determined NO in step S73.

[0244] That is, based on the detection result of pressure sensor 10, controller 30 may control the rotation speed of fourth fan 4021 of fourth heat exchanger 402, first higher-stage refrigerant circuit 100, and the refrigeration cycle of second higher-stage refrigerant circuit 200 to cause the pressure to fall within the range of the first threshold value to the second threshold value.

[0245] As described above, according to each of two-stage refrigeration cycle apparatuses 51 and 52 according to the first and second embodiments, since first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 are configured to have different maximum cooling capacities, the higher-stage refrigeration cycle corresponding to the required cooling capacity for the load can be activated in each of the cooling operation mode and the suspension operation mode. As a result, according to the two-stage refrigeration cycle apparatus of the first embodiment, a flexible operation in response to a change in the cooling capacity required for the load can be realized by the plurality of higher-stage refrigeration cycles.

[0246] Further, according to each of two-stage refrigeration cycle apparatuses 51 and 52 of the first and second embodiments, the cooling capacity of the higher-stage refrigeration cycle provided by first higher-stage refrigerant circuit 100 and second higher-stage refrigerant circuit 200 is varied based on the state of the refrigeration cycle of lower-stage refrigerant circuit 300. For example, one of the low-capacity operation mode and the high-capacity operation mode is selected in accordance with the magnitude of the target frequency set for third compressor 301. As a result, according to the two-stage refrigeration cycle apparatus of the first embodiment, a flexible operation in response to a change in the cooling capacity required for the load can be realized by the plurality of higher-stage refrigeration cycles.

<Points of the Disclosure>

[0247] Some points of the present disclosure are summarized below.

(Point 1)

[0248] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, at least one component of second compressor 201, second heat exchanger 202, second expansion valve 203, and second cascade condenser 204 of the second higher-stage refrigeration cycle is constituted of a component having a smaller capacity than that of a corresponding component of first compressor 101, first heat exchanger 102, first expansion valve 103, and first cascade condenser 104 of the first higher-stage refrigeration cycle.

[0249] Generally, when the capacity of the higher-stage refrigeration cycle is too large with respect to the cooling capacity required for the suspension operation mode, activation and suspension of activation of the compressor frequently occur, thereby decreasing reliability of the refrigeration cycle. However, in the present disclosure, the second higher-stage refrigeration cycle is constituted of a small element as compared with the first higher-stage refrigeration cycle, with the result that it is possible to suppress frequent occurrence of activation and suspension of activation of the compressor of the higher-stage refrigeration cycle in the suspension operation mode.

[0250] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, the higher-stage refrigeration cycle is divided into the plurality of stages. Thus, even when a trouble such as a failure occurs in part of the refrigeration cycles of the higher-stage refrigeration cycle, the other higher-stage refrigeration cycle can be operated. As a result, in the suspension operation mode, it is possible to suppress an abnormal increase in pressure in the lower-stage refrigeration cycle.

[0251] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, since the two-stage refrigeration cycle is used, even when a high-pressure refrigerant is used for the lower-stage refrigeration cycle, an operation can be performed with the condensation temperature of the lower-stage refrigeration cycle being reduced.

[0252] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, since the operation is performed with the condensation temperature of the lower-stage refrigeration cycle being reduced, the pressure resistance required for the refrigerant pipe can be reduced.

[0253] Since each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure has the different refrigeration cycle circuits for the higher stage and the lower stage, it is possible to flexibly deal with a regulation on refrigerant in each country.

(Point 2)

[0254] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, the capacity of the second higher-stage refrigeration cycle is preferably less than 50% when the required capacity (cooling capacity) of the higher-stage refrigeration cycle is assumed as 100%. Further, the capacity of the second higher-stage refrigeration cycle is more preferably 35% or less, and the capacity of the second higher-stage refrigeration cycle is more preferably 20% or less. It should be noted that when reducing the capacity, it is preferable to reduce the size of the compressor. This is because the size reduction of the compressor is most effective for cost reduction and cooling capacity reduction.

[0255] It is preferable to design such that the cooling capacity that can be output at the upper limit frequency of the second higher-stage refrigeration cycle is larger than the cooling capacity that can be output at the lower limit frequency of the first higher-stage refrigeration cycle. The operation range can be increased by providing a difference between the capacities of the higher-stage refrigeration cycles.

[0256] By designing such that the cooling capacity that can be output at the upper limit frequency of the second higher-stage refrigeration cycle is larger than the cooling capacity that can be output at the lower limit frequency of the first higher-stage refrigeration cycle, it is possible to suppress frequent occurrence of activation and suspension of activation of the compressor when a cooling capacity on the boundary is required.

(Point 3)

[0257] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, first heat exchanger 102 and second heat exchanger 202 used in the higher-stage refrigeration cycle are constituted of fifth heat exchanger 502 obtained by integrating the both heat exchangers. According to the present disclosure, it is possible to reduce the number of fans in the higher-stage refrigeration cycle. As a result, space saving and cost reduction can be achieved.

(Point 4)

[0258] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, the refrigerant used in the lower-stage refrigeration cycle is CO2. When CO2, which is a high-pressure refrigerant, is used in the lower-stage refrigeration cycle, the condensation pressure of the lower-stage refrigeration cycle can be reduced in the higher-stage refrigeration cycle. As a result, a pipe and each element device each having a low pressure resistance can be applied to the lower-stage refrigeration cycle.

[0259] CO2 can significantly reduce the total GWP of the device because it is a natural refrigerant. By using the incombustible gas for the lower-stage refrigeration cycle connected to the indoor unit in a warehouse or the like, the refrigerant is not combusted when the refrigerant is leaked.

[0260] Since the pressure used on the condensation side is lower than that in the case where CO2 is applied to the single-step refrigeration cycle or the two-step refrigeration cycle, the amount of use of the refrigerant can be reduced as compared with the case where CO2 is used in the single-step refrigeration cycle or the two-step refrigeration cycle.

(Point 5)

[0261] By providing uninterruptible power supply device 205 in the second higher-stage refrigeration cycle, the second higher-stage refrigeration cycle can be operated even when the lower-stage refrigeration cycle and the first higher-stage refrigeration cycle are suspended due to power failure. Thus, it is possible to suppress a pressure increase in the lower-stage refrigeration cycle.

[0262] Since uninterruptible power supply device 205 is applied to the second higher-stage refrigeration cycle that is smaller than the first higher-stage refrigeration cycle, a required power supply capacity can be made small. Cost can be suppressed by making the required power supply capacity small. Further, a power supply size can be made small.

(Point 6)

[0263] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, the refrigerant sealed in the circuit of the second higher-stage refrigeration cycle is different from the refrigerant sealed in each of the circuit of the lower-stage refrigeration cycle and the circuit of the first higher-stage refrigeration cycle. In particular, a refrigerant having higher theoretical performance or higher performance in actual use than that of the refrigerant sealed in each of the circuits of the lower-stage refrigeration cycle and the first higher-stage refrigeration cycle is sealed in the second higher-stage refrigeration cycle having a small capacity. Thus, the system COP can be improved. Further, reliability can be secured.

(Point 7)

[0264] In two-stage refrigeration cycle apparatus 52 according to the present disclosure, the lower-stage refrigeration cycle comprises fourth heat exchanger 402 that is located between third compressor 301 and first cascade condenser 104 and that dissipates, to air, heat of the high-temperature refrigerant discharged from third compressor 301. Thus, when the outside air temperature is low, only by the heat dissipation of fourth heat exchanger 402, the pressure of the third refrigerant in the lower-stage refrigeration cycle can be prevented from being abnormally increased. That is, the operation of the higher-stage refrigeration cycle is unnecessary. As a result, high-efficiency operation can be performed.

[0265] Further, in the lower-stage refrigeration cycle, part of the amount of heat of the third refrigerant can be dissipated to the air. As a result, the third refrigerant, which is a superheated vapor, is cooled by fourth heat exchanger 402 and is then guided to first cascade condenser 104. Therefore, in first cascade condenser 104, heat can be exchanged between the third refrigerant in the two-phase region having a high heat transfer coefficient and the first refrigerant. The same applies to second cascade condenser 204.

(Point 8)

[0266] In two-stage refrigeration cycle apparatus 52 according to the present disclosure, fourth heat exchanger 402 is constituted of sixth heat exchanger 602 obtained by integrating first heat exchanger 102 and second heat exchanger 202. Further, fourth heat exchanger 402 is constituted of seventh heat exchanger 702 obtained by integrating second heat exchanger 202. According to the present disclosure, the number of fans in the higher-stage refrigeration cycle can be reduced. As a result, space saving and cost reduction can be achieved.

(Point 9)

[0267] The ratio of the heat transfer area of fourth heat exchanger 402 to the total heat transfer area of first heat exchanger 102, second heat exchanger 202, and fourth heat exchanger 402 is in the range of 3% or more and less than 50%, or is in the range of 8% or more and less than 30%. By attaining an appropriate ratio of the heat transfer area of fourth heat exchanger 402, depending on an operation status of the refrigeration cycle, an increase in pressure of lower-stage refrigerant circuit 300 can be suppressed only by the heat dissipation of fourth heat exchanger 402 without activating the higher-stage refrigeration cycle.

(Point 10)

[0268] In each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure, return refrigerant pipe 18 is provided to communicate the gas refrigerant from liquid receiver 304 through check valve 305 to the inlet of first cascade condenser 104 or second cascade condenser 204. Return refrigerant pipe 18 is provided above liquid receiver 304. Therefore, only the gas refrigerant to be condensed in order to suppress pressure increase of the refrigerant can be returned to first cascade condenser 104 or second cascade condenser 204.

[0269] Liquid receiver 304 is provided at a position lower than second cascade condenser 204 in the vertical direction. Therefore, the liquid third refrigerant can be collected in liquid receiver 304 by its own weight.

(Point 11)

[0270] Based on the detection result of pressure sensor 10 provided in the condensation portion of the lower-stage refrigeration cycle, each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure controls the rotation speeds of the fans (first fan 1021 and second fan 2021), the frequencies of the compressors (first compressor 101 and second compressor 201), and the opening degrees of the expansion valves (first expansion valve 103 and second expansion valve 203) of the higher-stage refrigeration cycle so as to attain the pressure threshold value range set in advance.

[0271] Each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure activates the higher-stage refrigeration cycle in accordance with the detection result of pressure sensor 10. When the load is large, not only the second higher-stage refrigeration cycle but also the first higher-stage refrigeration cycle are activated. Further, by controlling the rotation speed of the fan, the opening degree of the expansion valve, and the frequency of the compressor in the higher-stage refrigeration cycle so as to attain a desired refrigeration cycle state, a pressure increase in the lower-stage refrigeration cycle can be suppressed.

[0272] In particular, by controlling the rotation speed of each of the fans (first fan 1021 and second fan 2021) (by controlling the condensation temperature), the rotation speed can be reduced under an operation condition that the compression ratio is low, while suppressing an abnormal increase in the pressure of the higher-stage refrigeration cycle, thereby maintaining the compression ratio.

[0273] Further, by controlling the opening degrees of the expansion valves (first expansion valve 103 and second expansion valve 203) (by controlling SH), the gas refrigerant can be suctioned into first compressor 101 and second compressor 201 on the higher-stage side in accordance with the operation state. By suctioning the gas refrigerant into each of first compressor 101 and second compressor 201, reliability of each of first compressor 101 and second compressor 201 can be improved.

[0274] By controlling the frequency of each of the compressors (first compressor 101 and second compressor 201) to attain the set pressure, the cooling capacity of the higher-stage refrigeration cycle can be controlled in accordance with the load of the lower-stage refrigeration cycle. Further, by providing the pressure threshold value range, frequent occurrence of activation and suspension of activation of the compressor can be suppressed, and a frequent change of the frequency of the compressor can be prevented.

[0275] For example, third compressor 301 of the lower-stage refrigeration cycle and second compressor 201 of the second higher-stage refrigeration cycle are activated. It is assumed that when the condensation capacity of the lower-stage refrigeration cycle is more than the evaporation capacity of the higher-stage refrigeration cycle, the pressure of the third refrigerant is increased to be equal to or higher than a pressure corresponding to, for example, 3°C. In this case, the frequency of second compressor 201 in the second higher-stage refrigeration cycle is increased until the pressure of the third refrigerant becomes a reference value (for example, a pressure corresponding to 0°C). When the pressure of second compressor 201 corresponds to a frequency as a target value, the operation is maintained. When the load is large, first compressor 101 of the first higher-stage refrigeration cycle is activated. However, when the frequency of third compressor 301 at the time of activation is very high, the first and second higher-stage refrigeration cycles may be simultaneously activated.

[0276] Pressure sensor 10 may be provided at any position in a section from the discharge portion of third compressor 301 to the inlet of first cascade condenser 104, but is preferably provided at the discharge portion of third compressor 301 at which the pressure of the third refrigerant is the highest. Basically, it is preferable that the second higher-stage refrigeration cycle having a small capacity in the higher-stage refrigeration cycles is activated preferentially so as to suppress an abnormal increase in the pressure in lower-stage refrigerant circuit 300. This is due to the following reason: since the capacity of the second higher-stage refrigeration cycle is smaller than that of the first higher-stage refrigeration cycle, frequent occurrence of activation and suspension of activation of the compressor can be prevented. Further, when the refrigerant having high theoretical performance is sealed in the second higher-stage refrigeration cycle, a high-efficiency operation can be performed.

(Point 12)

[0277] Each of two-stage refrigeration cycle apparatuses 51 and 52 according to the present disclosure controls the timings of activating the first higher-stage refrigeration cycle and the second higher-stage refrigeration cycle, based on the setting frequency at the time of activation of third compressor 301. For example, when the frequency of third compressor 301 is lower than the threshold value, only the second higher-stage refrigeration cycle having a small capacity is activated, whereas when the frequency of third compressor 301 is higher than the threshold value, the first higher-stage refrigeration cycle and the second higher-stage refrigeration cycle are activated from the time of activation.

[0278] Thus, the pressure can be securely suppressed from being increased abruptly when the refrigeration cycle is activated. Further, since the first higher-stage refrigeration cycle is not activated when the frequency of third compressor 301 is low, it is possible to suppress frequent repetition of activation and suspension of activation of the compressor on the higher-stage refrigeration cycle side. As a result, reliability can be improved. Further, since the cooling operation can be performed without unnecessary device operations, the performance can be improved.

(Point 13)

[0279] Based on the detection result of pressure sensor 10, two-stage refrigeration cycle apparatus 52 according to the present disclosure controls the rotation speed of fourth fan 4021 of fourth heat exchanger 402, the rotation speed of each of the fans (first fan 1021 and second fan 2021) of the higher-stage refrigeration cycle, the frequency of each of the compressors (first compressor 101 and second compressor 201), and the opening degree of each of the expansion valves (first expansion valve 103 and second expansion valve 203) so as to maintain the pressure within the set range.

[0280] According to the present disclosure, by providing fourth heat exchanger 402, when the outside air temperature is low (for example, -5°C), it is possible to prevent an abnormal increase in the pressure in lower-stage refrigerant circuit 300 by controlling the rotation speed of fourth fan 4021 without activating the higher-stage refrigeration cycle.

(Point 14)

[0281] Based on the setting frequency at the time of activation of third compressor 301 and the outside air temperature, two-stage refrigeration cycle apparatus 52 according to the present disclosure controls the timing of activating the fan of fourth heat exchanger 402, the timing of activating the first higher-stage refrigeration cycle, and the timing of activating the second higher-stage refrigeration cycle.

<Features of the Disclosure>

[0282] Some of the features of the present disclosure will be listed below.

(1) A two-stage refrigeration cycle apparatus (51) according to the present disclosure comprises: a first higher-stage refrigerant circuit (100) in which a first refrigerant is circulated; a second higher-stage refrigerant circuit (200) in which a second refrigerant is circulated; a lower-stage refrigerant circuit (300) in which a third refrigerant is circulated; a first cascade condenser (104) configured to perform heat exchange between the first refrigerant and the third refrigerant; and a second cascade condenser (204) configured to perform heat exchange between the second refrigerant and the third refrigerant, wherein

the first higher-stage refrigerant circuit (100) comprises a first compressor (101), and a first heat exchanger (102), and a first expansion valve (103), and is configured to circulate the first refrigerant in an order of the first compressor (101), the first heat exchanger (102), the first expansion valve (103), the first cascade condenser (104), and the first compressor (101), the second higher-stage refrigerant circuit (200) comprises a second compressor (201), a second heat exchanger (202), and a second expansion valve (203), and is configured to circulate the second refrigerant in an order of the second compressor (201), the second heat exchanger (202), the second expansion valve (203), the second cascade condenser (204), and the second compressor (201), the lower-stage refrigerant circuit (300) comprises a third compressor (301), a third heat exchanger (302), and a third expansion valve (303), and is configured to circulate the third refrigerant in an order of the third expansion valve (303), the third heat exchanger (302), and the third compressor (301), the first higher-stage refrigerant circuit (100) and the second higher-stage refrigerant circuit (200) are configured to have different maximum cooling capacities (Fig. 3).

[0283] According to the present disclosure, there can be provided a two-stage refrigeration cycle apparatus by which a flexible operation in response to a change in cooling capacity required for a load can be realized by a plurality of higher-stage refrigeration cycles.

(2) The maximum cooling capacity of the second higher-stage refrigerant circuit (200) is less than 50% of the maximum cooling capacities of the first higher-stage refrigerant circuit (100) and the second higher-stage refrigerant circuit (200) (Fig. 3).
(3) At least one component of the second compressor (201), the second heat exchanger (202), the second expansion valve (203), and the second cascade condenser (204) is constituted of a component having a capacity smaller than a capacity of a corresponding component of the first compressor (101), the first heat exchanger (102), the first expansion valve (103), and the first cascade condenser (104).
(4) The maximum cooling capacity of the first higher-stage refrigerant circuit (100) is larger than the maximum cooling capacity of the second higher-stage refrigerant circuit (200), and an upper limit value of the cooling capacity of the second higher-stage refrigerant circuit (200) is included in a range of a cooling capacity of the first higher-stage refrigerant circuit (100) (Figs. 8 and 9).
(5) The first heat exchanger (102) and the second heat exchanger (202) are constituted of an integrated heat exchanger (502).
(6) The third refrigerant is carbon dioxide (Fig. 3).
(7) The second higher-stage refrigerant circuit (200) is connected to an uninterruptible power supply device (205) (Figs. 6 and 7).
(8) The first refrigerant (R1234yf, etc.) is a different type of refrigerant from the second refrigerant (R32, or the like).
(9) The lower-stage refrigerant circuit (300) further comprises a liquid receiver (304) disposed between the second cascade condenser (204) and the third expansion valve (303), and a return path (path of return refrigerant pipe 18) via which the third refrigerant having flowed from the second cascade condenser (204) into the liquid receiver (304) is returned to the first cascade condenser (104) or the second cascade condenser (204), and the return path is provided with a check valve (305) configured to prevent the third refrigerant from flowing in a direction of the liquid receiver (304).
(10) The return path is connected to an upper portion of the liquid receiver (304) (Fig. 2).
(11) The liquid receiver (304) is disposed at a position lower than a position of the second cascade condenser (204) in a vertical direction (Fig. 2).

[0284] The embodiments disclosed herein are illustrative and non-restrictive in any respect. The scope of the present disclosure is defined by the terms of the claims, rather than the description of the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0285] 1: outdoor unit; 2: indoor unit; 10: pressure sensor; 15: extension pipe; 16: first refrigerant pipe; 17: second refrigerant pipe; 18: return refrigerant pipe; 20: temperature sensor; 30: controller; 31: processor; 32: memory: 51, 52: two-stage refrigeration cycle apparatus; 100: first higher-stage refrigerant circuit; 101: first compressor; 102: first heat exchanger; 103: first expansion valve; 104: first cascade condenser; 200: second higher-stage refrigerant circuit; 201: second compressor; 202: second heat exchanger; 203: second expansion valve; 204: second cascade condenser; 205: uninterruptible power supply device; 300: lower-stage refrigerant circuit; 301: third compressor; 302: third heat exchanger; 303: third expansion valve; 304: liquid receiver; 305: check valve; 402: fourth heat exchanger; 502: fifth heat exchanger; 602: sixth heat exchanger; 702: seventh heat exchanger; 1021: first fan; 2021: second fan; 3021: third fan; 4021: fourth fan; 5021: fifth fan; 6021: sixth fan; 7021: seventh fan; AT10: outside air temperature; R10: region in which higher-stage operation is not required; R20: region in which higher-stage operation is required; W10, W20: frame.

Claims

1. A two-stage refrigeration cycle apparatus comprising:

    a first higher-stage refrigerant circuit in which a first refrigerant is circulated;
    a second higher-stage refrigerant circuit in which a second refrigerant is circulated;
    a lower-stage refrigerant circuit in which a third refrigerant is circulated;
    a first cascade condenser configured to perform heat exchange between the first refrigerant and the third refrigerant; and
    a second cascade condenser configured to perform heat exchange between the second refrigerant and the third refrigerant, wherein
    the first higher-stage refrigerant circuit comprises a first compressor, a first heat exchanger, and a first expansion valve, and is configured to circulate the first refrigerant in an order of the first compressor, the first heat exchanger, the first expansion valve, the first cascade condenser, and the first compressor,
    the second higher-stage refrigerant circuit comprises a second compressor, a second heat exchanger, and a second expansion valve, and is configured to circulate the second refrigerant in an order of the second compressor, the second heat exchanger, and the second expansion valve, the second cascade condenser, and the second compressor,
    the lower-stage refrigerant circuit comprises a third compressor, a third heat exchanger, and a third expansion valve, and is configured to circulate the third refrigerant in an order of the third compressor, the first cascade condenser, the second cascade condenser, the third expansion valve, the third heat exchanger, and the third compressor, and
    the first higher-stage refrigerant circuit and the second higher-stage refrigerant circuit are configured to have different maximum cooling capacities.

2. The two-stage refrigeration cycle apparatus according to claim 1, wherein the maximum cooling capacity of the second higher-stage refrigerant circuit is less than 50% of the maximum cooling capacities of the first higher-stage refrigerant circuit and the second higher-stage refrigerant circuit.

3. The two-stage refrigeration cycle apparatus according to claim 1 or 2, wherein at least one component of the second compressor, the second heat exchanger, the second expansion valve, and the second cascade condenser is constituted of a component having a capacity smaller than a capacity of a corresponding component of the first compressor, the first heat exchanger, the first expansion valve, and the first cascade condenser.

4. The two-stage refrigeration cycle apparatus according to any one of claims 1 to 3, wherein

    the maximum cooling capacity of the first higher-stage refrigerant circuit is larger than the maximum cooling capacity of the second higher-stage refrigerant circuit, and
    an upper limit value of a cooling capacity of the second higher-stage refrigerant circuit is included in a range of a cooling capacity of the first higher-stage refrigerant circuit.

5. The two-stage refrigeration cycle apparatus according to any one of claims 1 to 4, wherein the first heat exchanger and the second heat exchanger are constituted of an integrated heat exchanger.

6. The two-stage refrigeration cycle apparatus according to any one of claims 1 to 5, wherein the third refrigerant is carbon dioxide.

7. The two-stage refrigeration cycle apparatus according to any one of claims 1 to 6, wherein the second higher-stage refrigerant circuit is connected to an uninterruptible power supply device.

8. The two-stage refrigeration cycle apparatus according to any one of claims 1 to 7, wherein the first refrigerant is a different type of refrigerant from the second refrigerant.

9. The two-stage refrigeration cycle apparatus according to any one of claims 1 to 8, wherein

    the lower-stage refrigerant circuit further comprises

        a liquid receiver disposed between the second cascade condenser and the third expansion valve, and
        a return path through which the third refrigerant having flowed from the second cascade condenser into the liquid receiver is returned to the first cascade condenser or the second cascade condenser, and

    the return path is provided with a check valve configured to prevent the third refrigerant from flowing in a direction of the liquid receiver.

10. The two-stage refrigeration cycle apparatus according to claim 9, wherein the return path is connected to an upper portion of the liquid receiver.

11. The two-stage refrigeration cycle apparatus according to claim 9 or 10, wherein the liquid receiver is disposed at a position lower than a position of the second cascade condenser in a vertical direction.

FIG.1

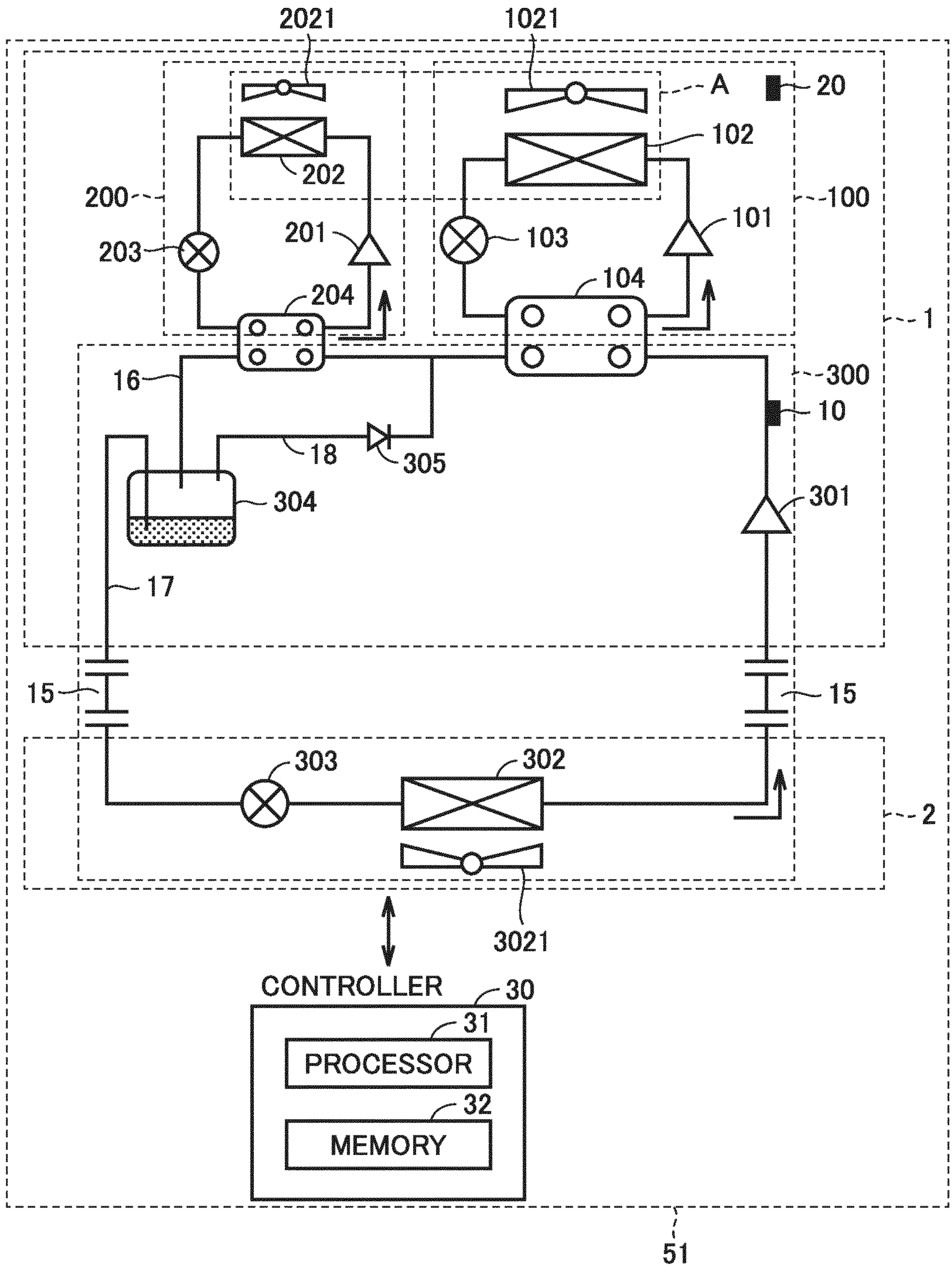

2021
1021
A
20
102
202
200
100
203
201
101
103
204
104
1
16
300
10
18
305
304
301
17
15
15
303
302
2
3021
CONTROLLER
30
31
PROCESSOR
32
MEMORY
51

FIG.2

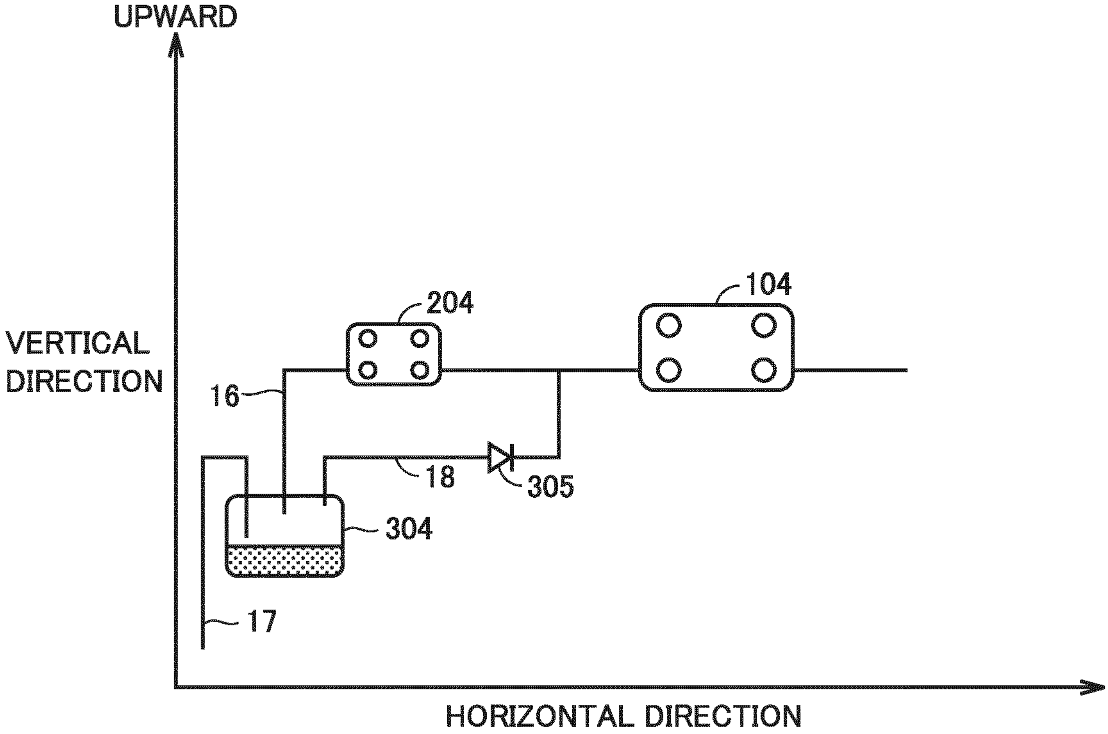

UPWARD
VERTICAL
DIRECTION
HORIZONTAL DIRECTION
204
104
16
18
305
304
17

FIG.3

REFRIGERANT CIRCUIT	RATED CAPACITY	LOWER LIMIT CAPACITY (25%)	CAPACITY RATIO (COOLING CAPACITY RATIO)	REFRIGERANT
FIRST HIGHER-STAGE REFRIGERANT CIRCUIT	41kW	10kW	ABOUT 80%	R1234yf
SECOND HIGHER-STAGE REFRIGERANT CIRCUIT	10kW	2.5kW	* ABOUT 20%	R32
LOWER-STAGE REFRIGERANT CIRCUIT	–	–	–	HIGH-PRESSURE REFRIGERANT (CO2)

* CAPACITY RATIO OF SECOND HIGHER-STAGE REFRIGERANT CIRCUIT MAY BE ANY RATIO AS LONG AS IT IS LESS THAN 50%, BUT IS PREFERABLY 35% OR LESS.

FIG.4

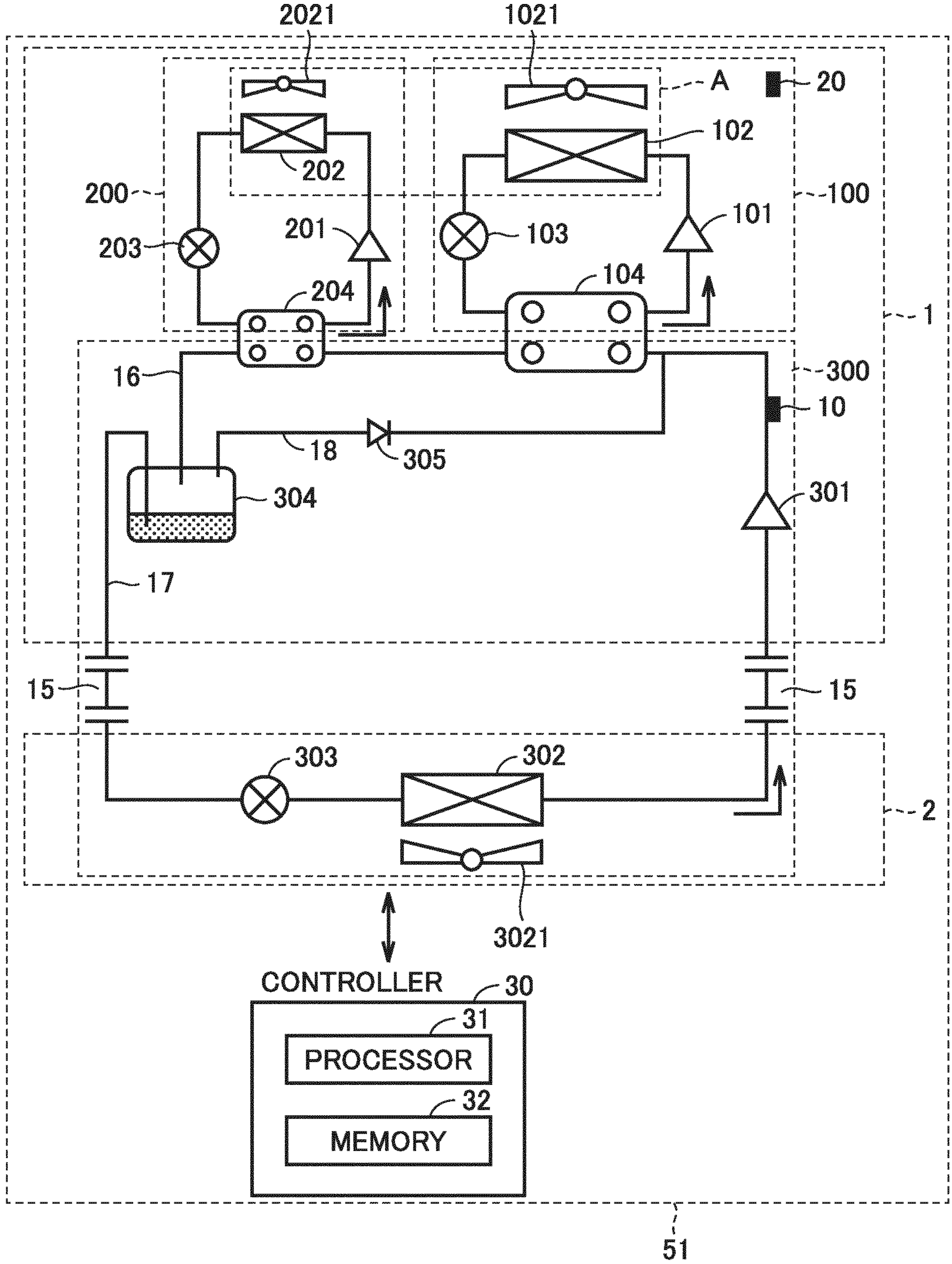

2021
1021
A
20
102
202
200
100
101
201
203
103
104
204
1
16
300
10
18
305
304
301
17
15
15
303
302
2
3021
CONTROLLER
30
31
PROCESSOR
32
MEMORY
51

FIG.5

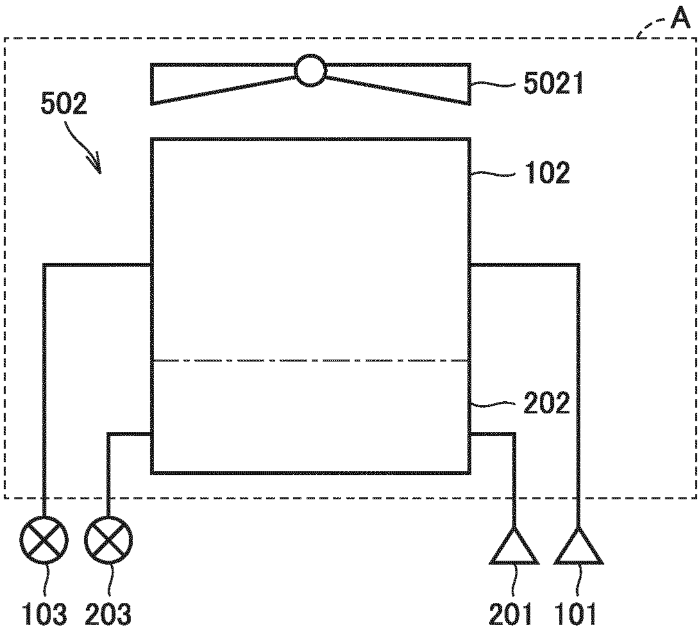


FIG.6

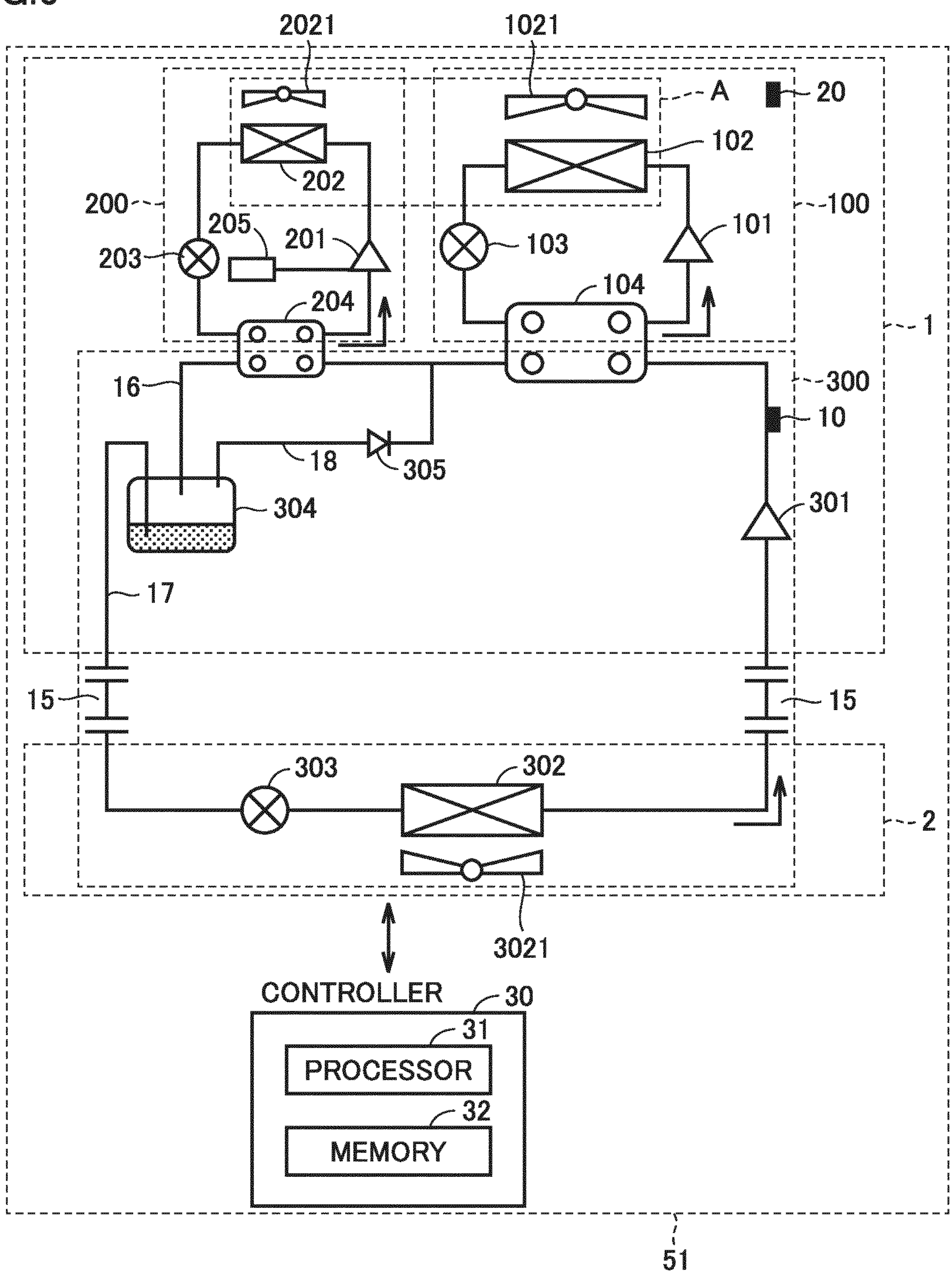

2021
1021
A
20
102
202
200
100
205
201
101
203
103
204
104
1
16
300
10
18
305
304
301
17
15
15
303
302
2
3021
CONTROLLER
30
31
PROCESSOR
32
MEMORY
51

FIG.7

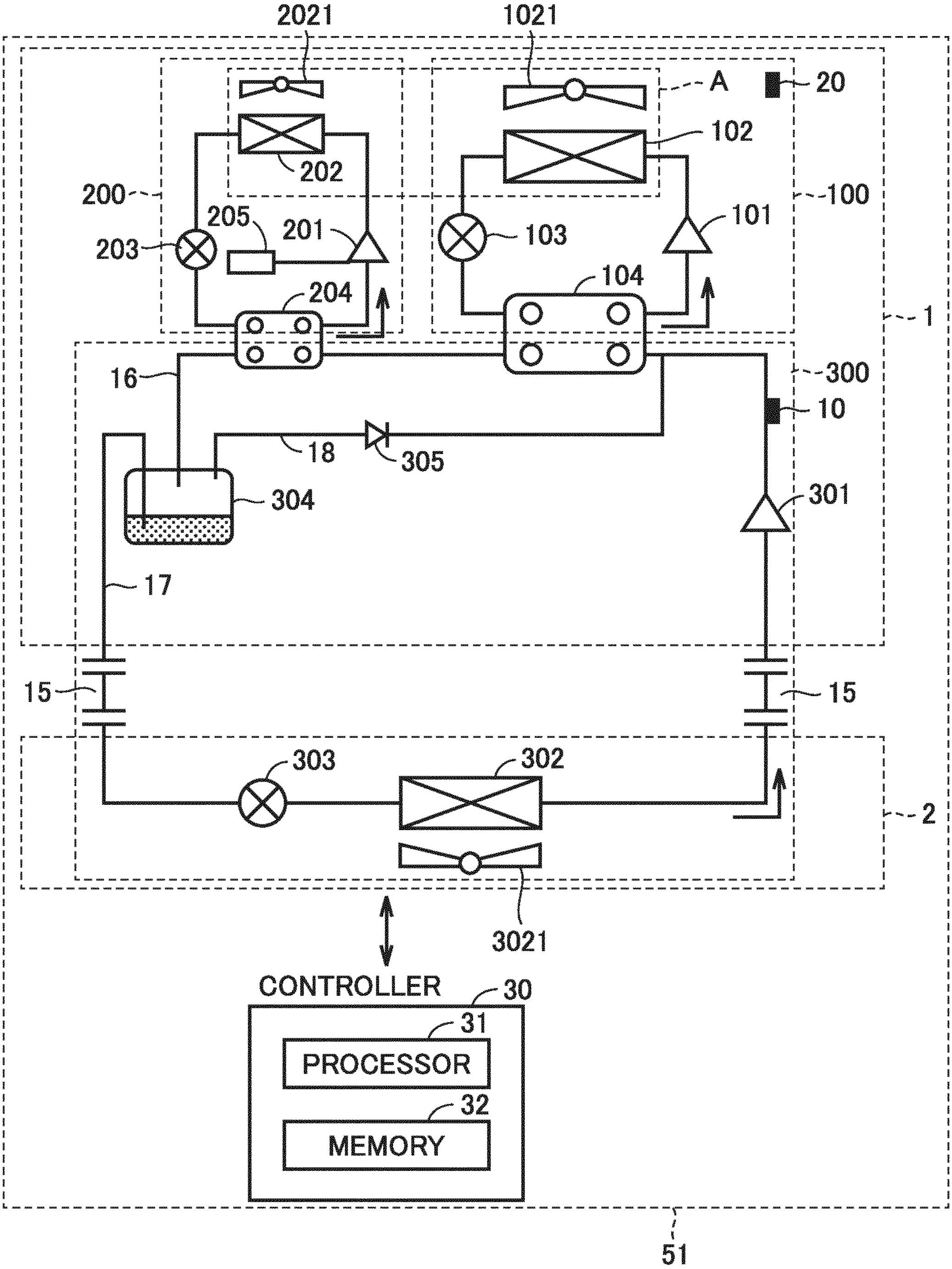

2021
1021
A
20
102
202
200
100
205
201
101
203
103
204
104
1
300
16
10
18
305
304
301
17
15
15
303
302
2
3021
CONTROLLER
30
31
PROCESSOR
32
MEMORY
51

FIG.8

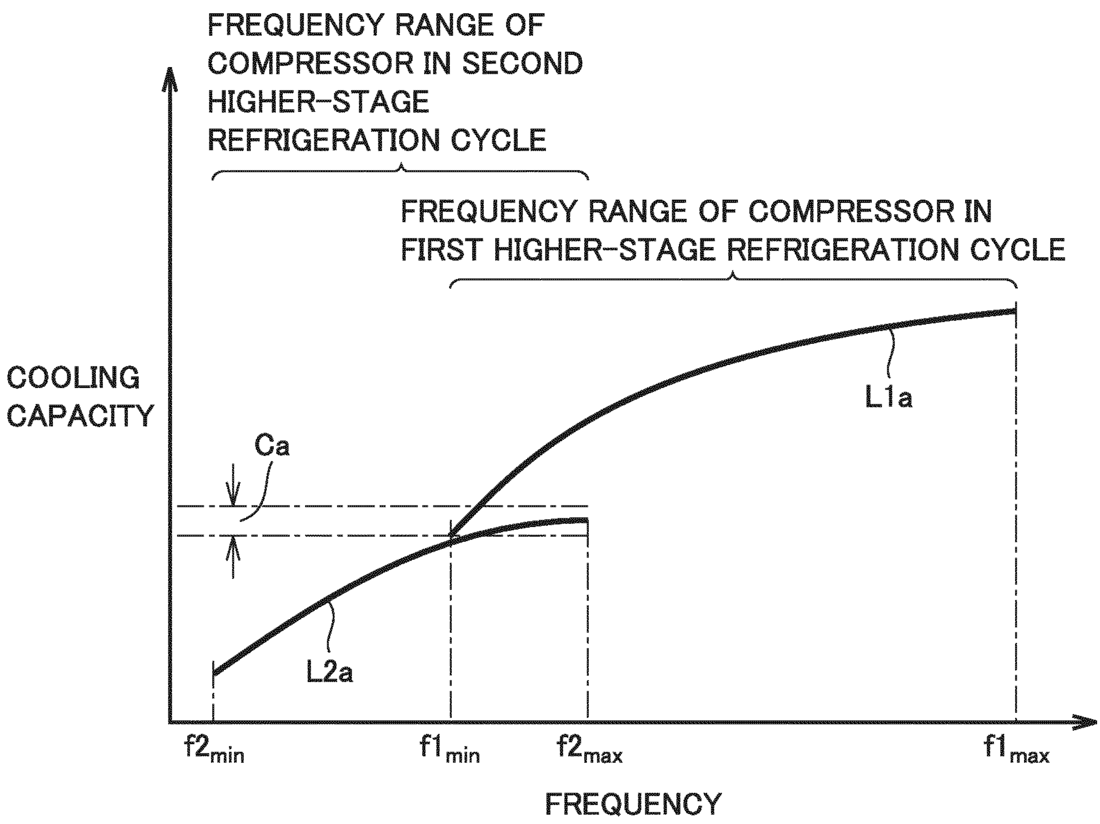

FREQUENCY RANGE OF COMPRESSOR IN SECOND HIGHER-STAGE REFRIGERATION CYCLE
FREQUENCY RANGE OF COMPRESSOR IN FIRST HIGHER-STAGE REFRIGERATION CYCLE
COOLING CAPACITY
Ca
L1a
L2a
$f2_{min}$
$f1_{min}$
$f2_{max}$
$f1_{max}$
FREQUENCY

FIG.9

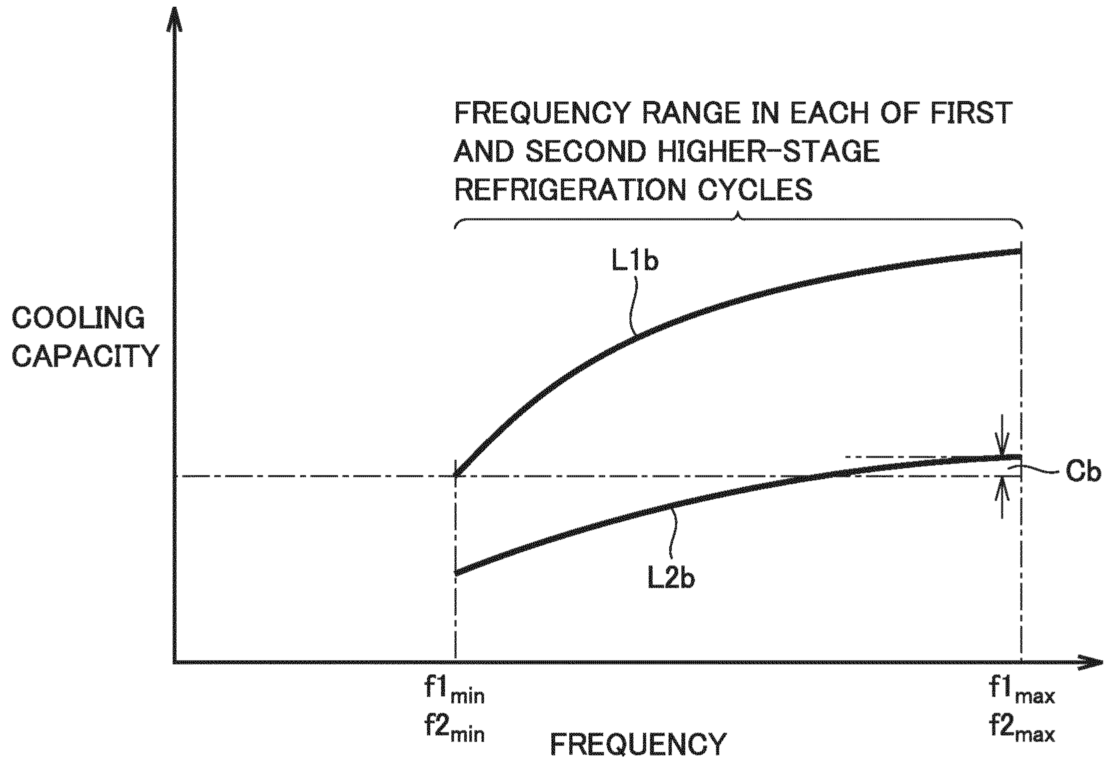

FREQUENCY RANGE IN EACH OF FIRST AND SECOND HIGHER-STAGE REFRIGERATION CYCLES
L1b
COOLING CAPACITY
Cb
L2b
f1min
f2min
FREQUENCY
f1max
f2max

FIG.10

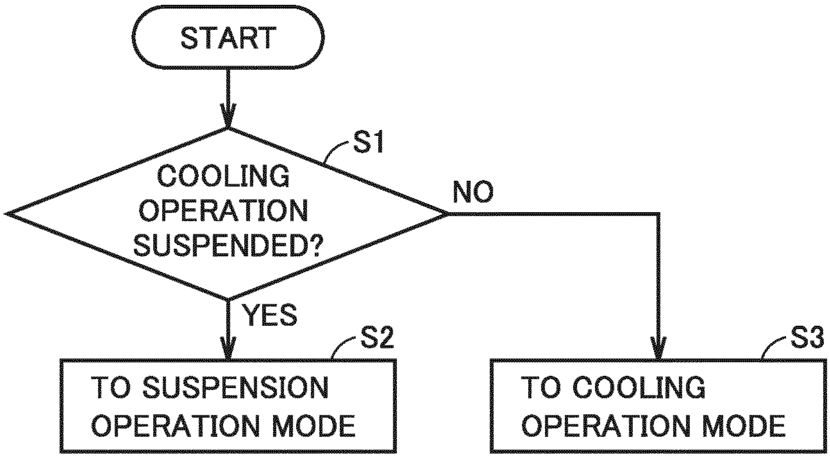

START
COOLING OPERATION SUSPENDED?
S1
NO
YES
S2
TO SUSPENSION OPERATION MODE
S3
TO COOLING OPERATION MODE

FIG.11

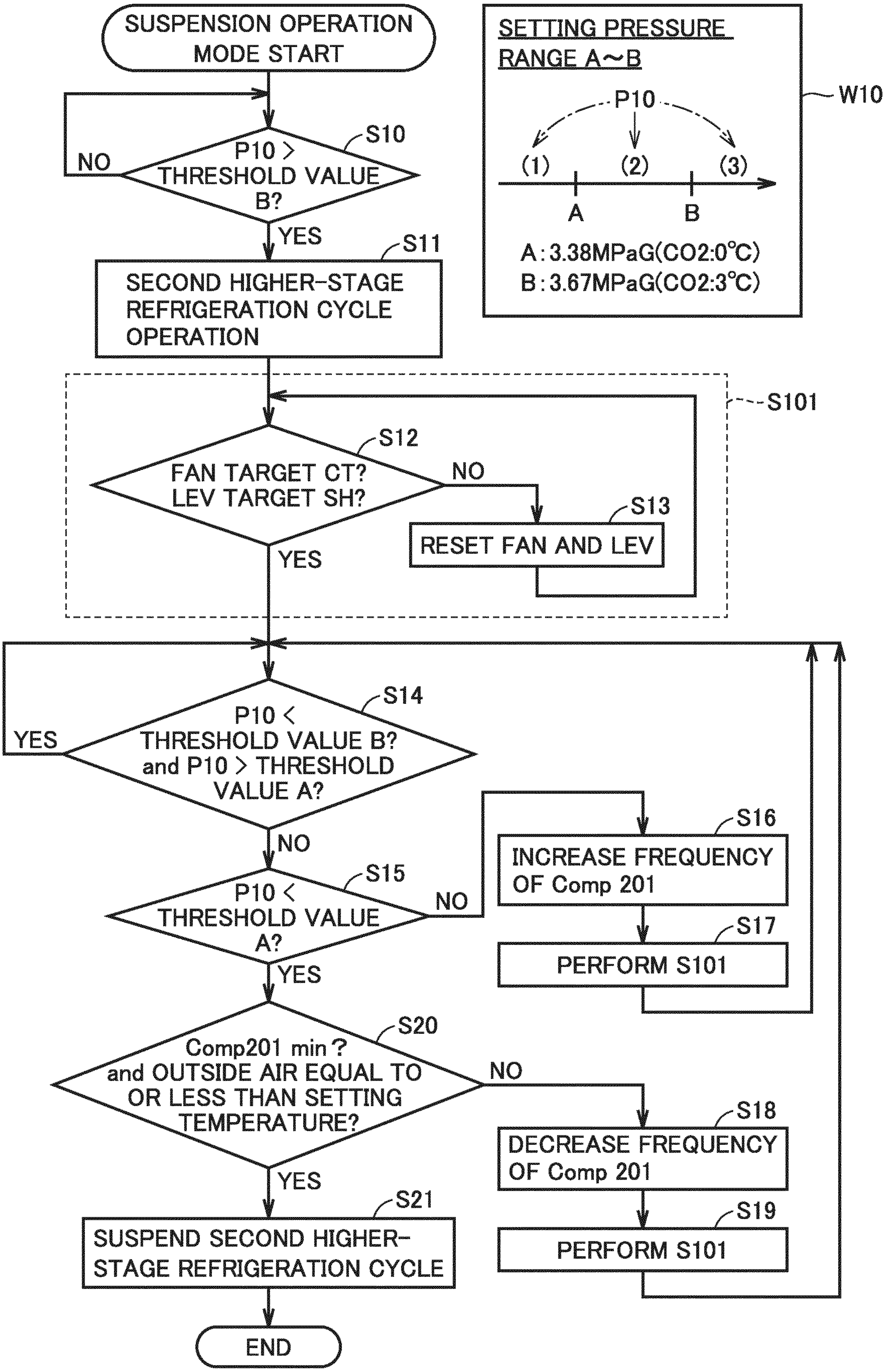

SUSPENSION OPERATION MODE START
P10 > THRESHOLD VALUE B?
S10
NO
YES
S11
SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATION
S101
S12
FAN TARGET CT? LEV TARGET SH?
NO
S13
RESET FAN AND LEV
YES
S14
P10 < THRESHOLD VALUE B? and P10 > THRESHOLD VALUE A?
YES
NO
S15
P10 < THRESHOLD VALUE A?
NO
S16
INCREASE FREQUENCY OF Comp 201
S17
PERFORM S101
YES
S20
Comp201 min? and OUTSIDE AIR EQUAL TO OR LESS THAN SETTING TEMPERATURE?
NO
S18
DECREASE FREQUENCY OF Comp 201
S19
PERFORM S101
YES
S21
SUSPEND SECOND HIGHER-STAGE REFRIGERATION CYCLE
END
SETTING PRESSURE RANGE A~B
P10
(1)
(2)
(3)
A
B
A: 3.38MPaG(CO2:0℃)
B: 3.67MPaG(CO2:3℃)
W10

FIG.12

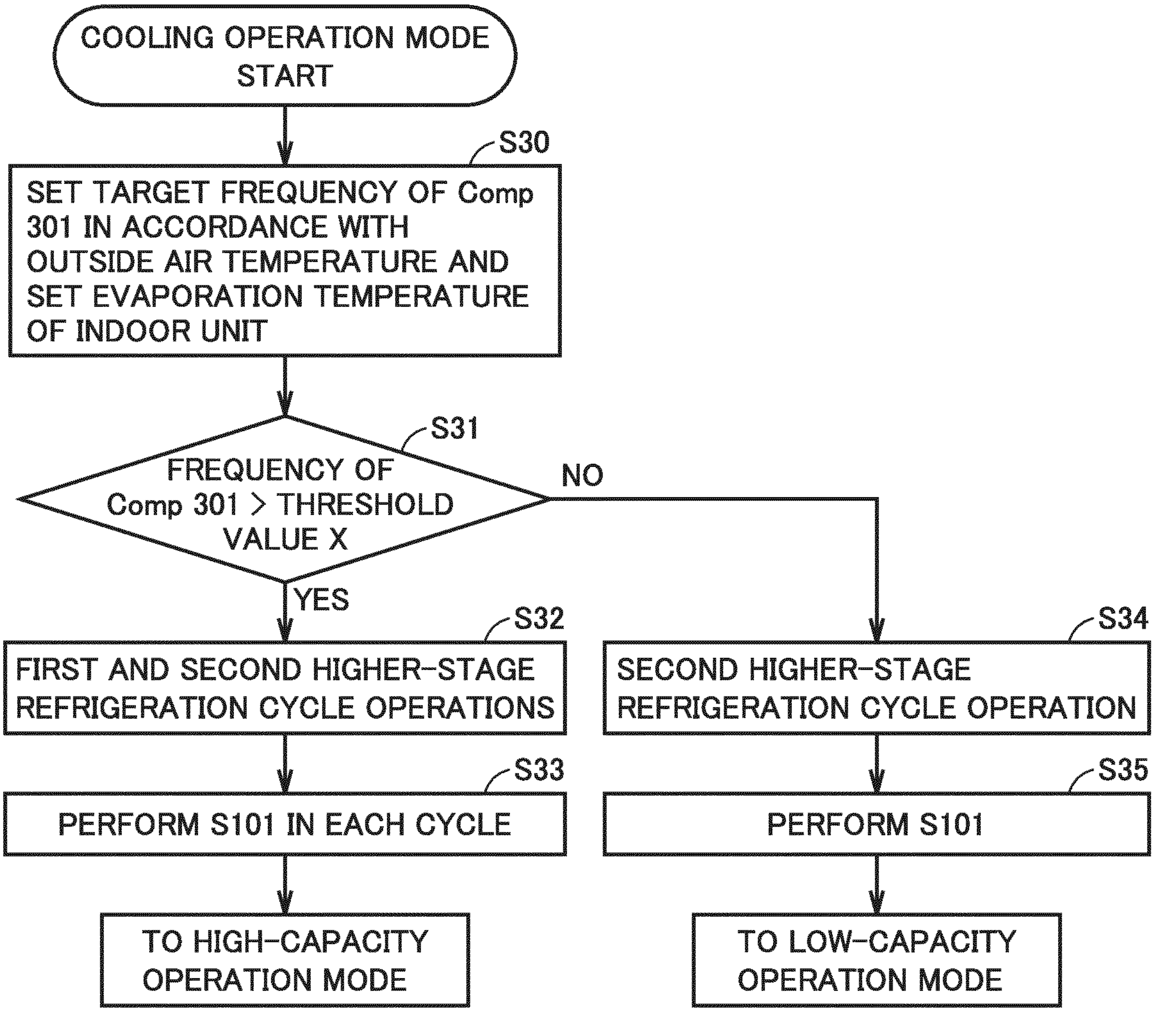

COOLING OPERATION MODE START
S30
SET TARGET FREQUENCY OF Comp 301 IN ACCORDANCE WITH OUTSIDE AIR TEMPERATURE AND SET EVAPORATION TEMPERATURE OF INDOOR UNIT
S31
FREQUENCY OF Comp 301 > THRESHOLD VALUE X
NO
YES
S32
FIRST AND SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATIONS
S33
PERFORM S101 IN EACH CYCLE
TO HIGH-CAPACITY OPERATION MODE
S34
SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATION
S35
PERFORM S101
TO LOW-CAPACITY OPERATION MODE

FIG.13

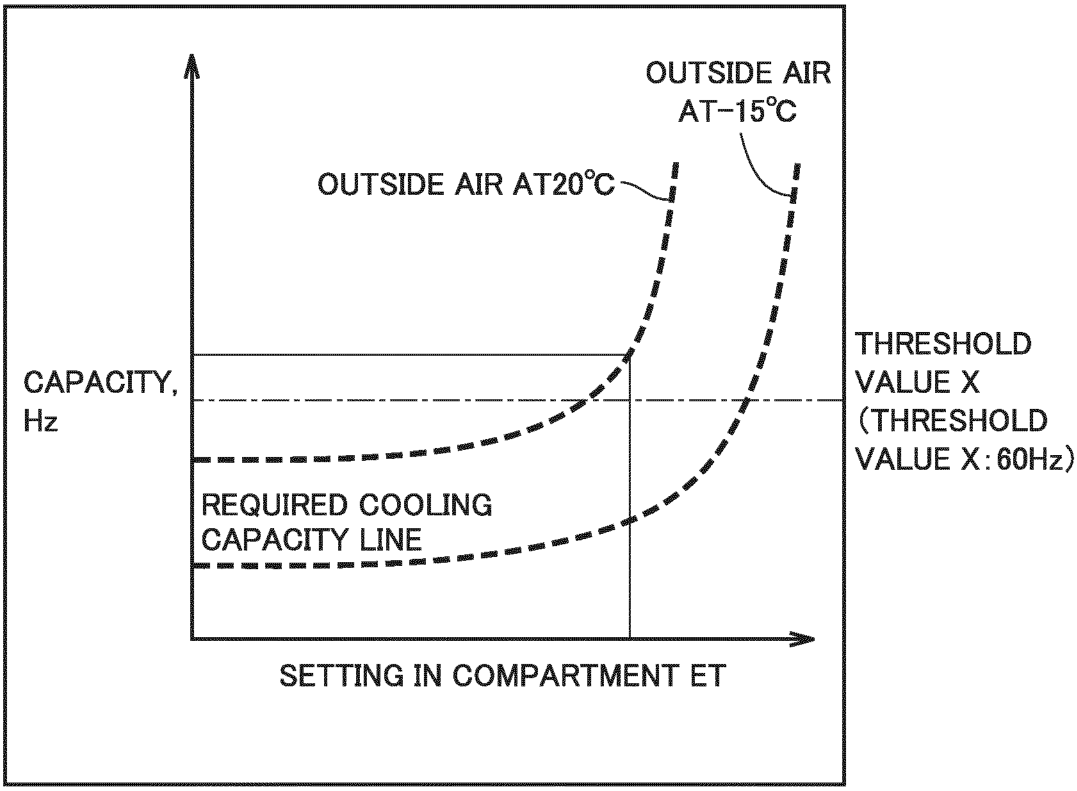

OUTSIDE AIR
AT-15°C
OUTSIDE AIR AT20°C
CAPACITY,
Hz
THRESHOLD
VALUE X
(THRESHOLD
VALUE X:60Hz)
REQUIRED COOLING
CAPACITY LINE
SETTING IN COMPARTMENT ET

FIG.14

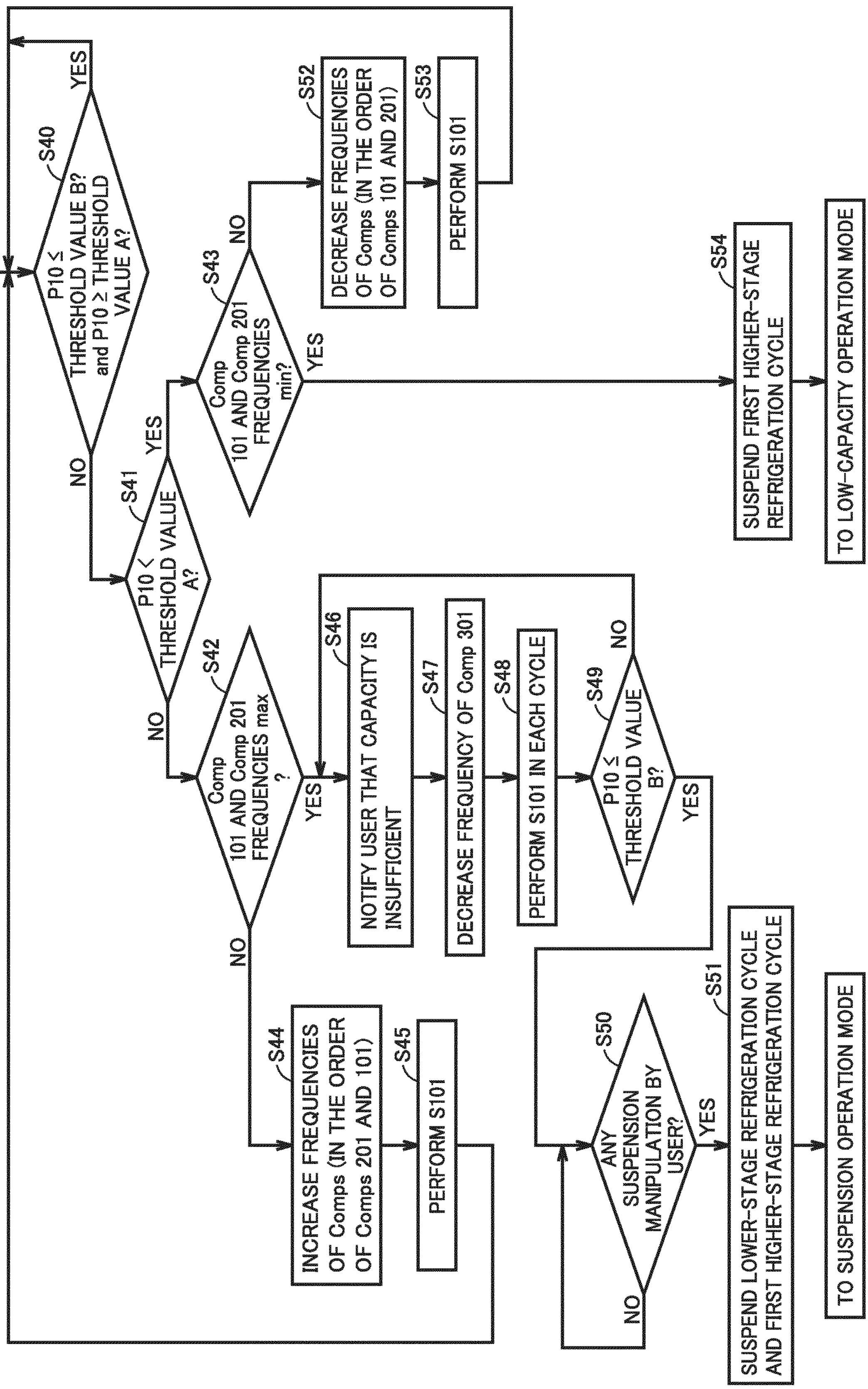

HIGH-CAPACITY OPERATION MODE START
S40
P10 ≤ THRESHOLD VALUE B? and P10 ≥ THRESHOLD VALUE A?
YES
NO
S41
P10 < THRESHOLD VALUE A?
YES
NO
S43
Comp 101 AND Comp 201 FREQUENCIES min?
NO
YES
S52
DECREASE FREQUENCIES OF Comps (IN THE ORDER OF Comps 101 AND 201)
S53
PERFORM S101
S54
SUSPEND FIRST HIGHER-STAGE REFRIGERATION CYCLE
TO LOW-CAPACITY OPERATION MODE
S42
Comp 101 AND Comp 201 FREQUENCIES max ?
YES
NO
S46
NOTIFY USER THAT CAPACITY IS INSUFFICIENT
S47
DECREASE FREQUENCY OF Comp 301
S48
PERFORM S101 IN EACH CYCLE
S49
P10 ≤ THRESHOLD VALUE B?
NO
YES
S44
INCREASE FREQUENCIES OF Comps (IN THE ORDER OF Comps 201 AND 101)
S45
PERFORM S101
S50
ANY SUSPENSION MANIPULATION BY USER?
NO
YES
S51
SUSPEND LOWER-STAGE REFRIGERATION CYCLE AND FIRST HIGHER-STAGE REFRIGERATION CYCLE
TO SUSPENSION OPERATION MODE

FIG.15

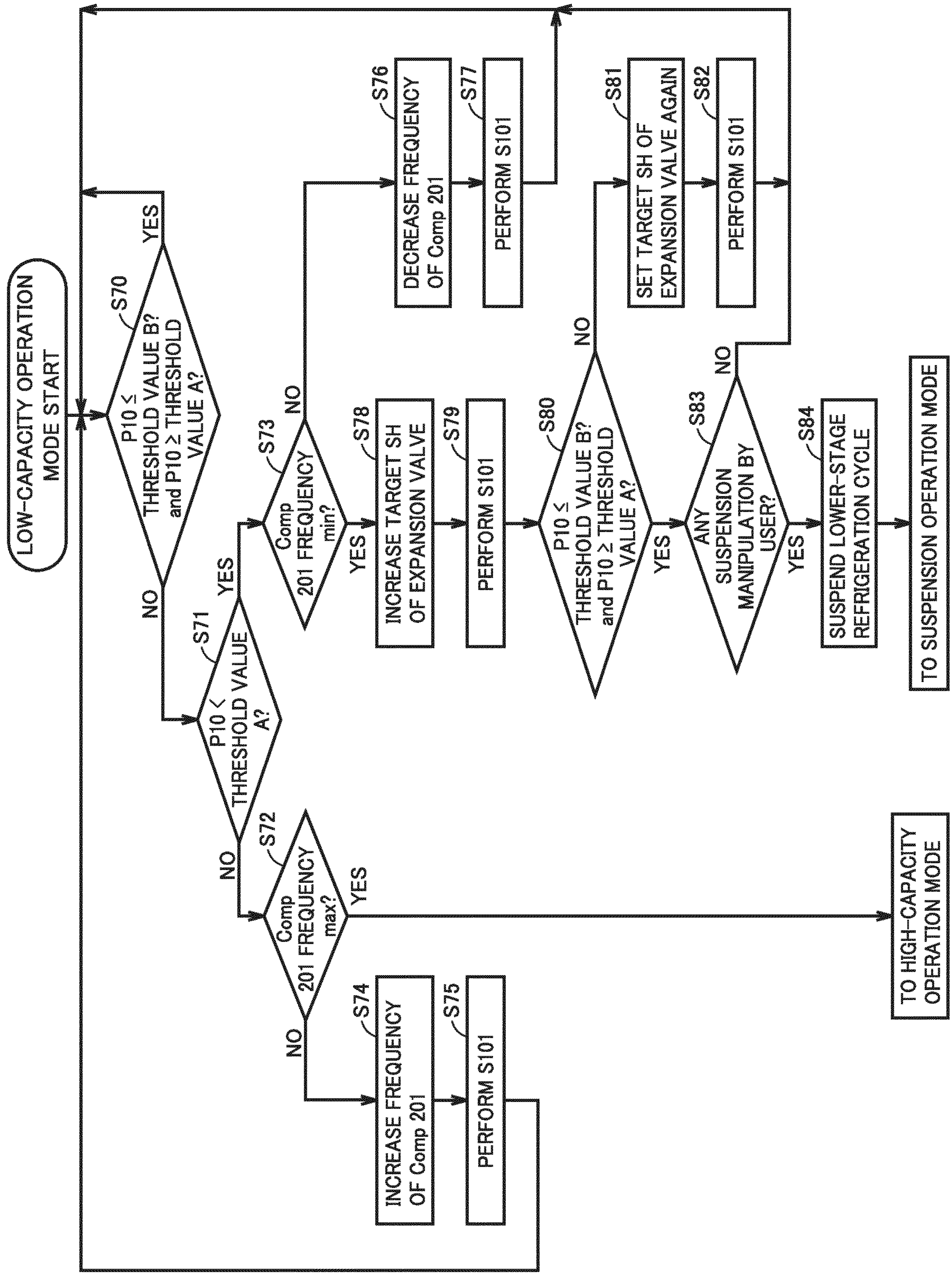

LOW-CAPACITY OPERATION MODE START
S70
P10 ≤ THRESHOLD VALUE B? and P10 ≥ THRESHOLD VALUE A?
YES
NO
S71
P10 < THRESHOLD VALUE A?
YES
NO
S72
Comp 201 FREQUENCY max?
YES
NO
S73
Comp 201 FREQUENCY min?
YES
NO
S74
INCREASE FREQUENCY OF Comp 201
S75
PERFORM S101
S76
DECREASE FREQUENCY OF Comp 201
S77
PERFORM S101
S78
INCREASE TARGET SH OF EXPANSION VALVE
S79
PERFORM S101
S80
P10 ≤ THRESHOLD VALUE B? and P10 ≥ THRESHOLD VALUE A?
YES
NO
S81
SET TARGET SH OF EXPANSION VALVE AGAIN
S82
PERFORM S101
S83
ANY SUSPENSION MANIPULATION BY USER?
YES
NO
S84
SUSPEND LOWER-STAGE REFRIGERATION CYCLE
TO SUSPENSION OPERATION MODE
TO HIGH-CAPACITY OPERATION MODE

FIG.16

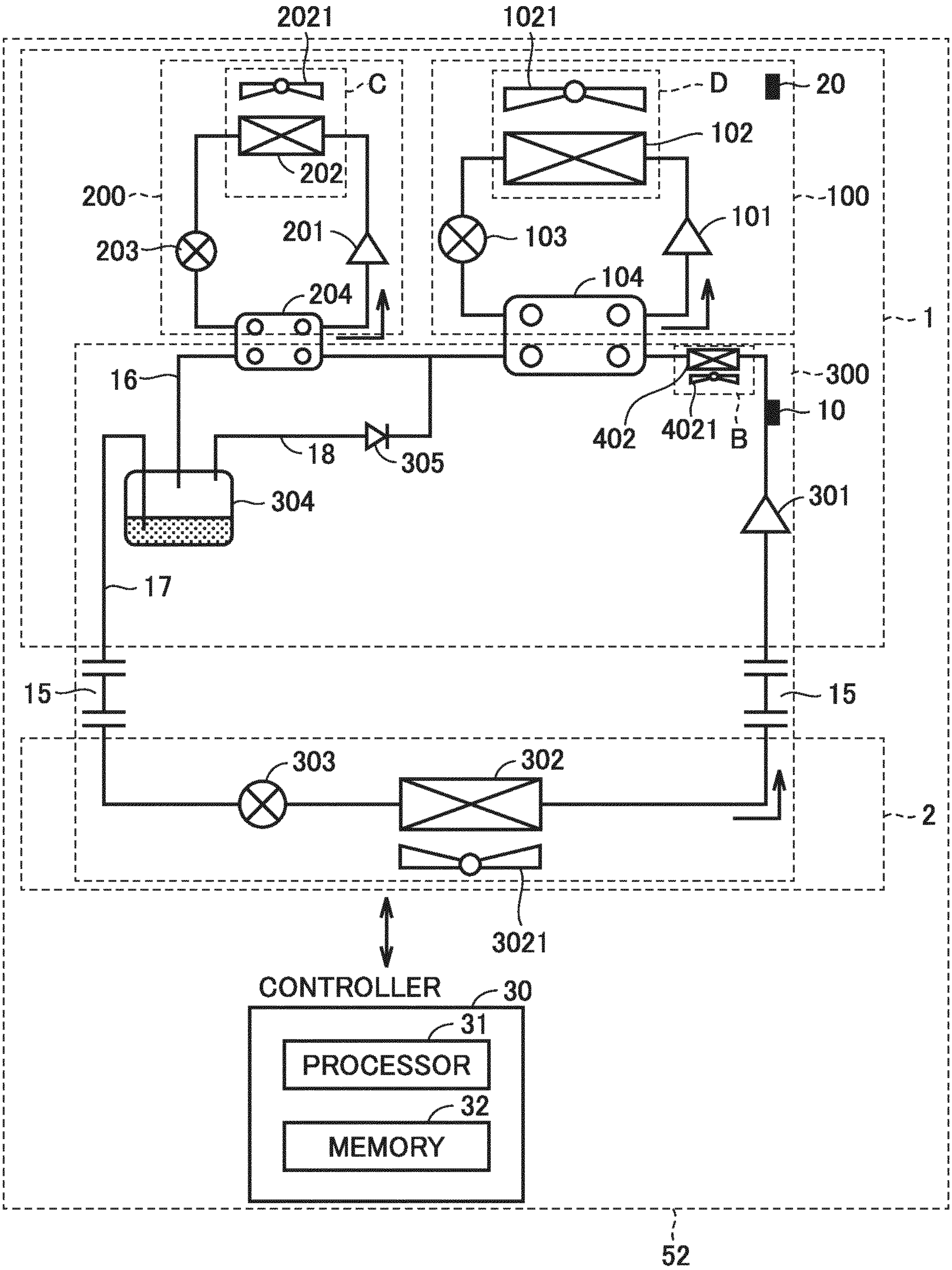

2021
1021
C
D
20
102
202
200
100
101
203
201
103
204
104
1
16
300
402
4021
10
B
18
305
304
301
17
15
15
303
302
2
3021
CONTROLLER
30
31
PROCESSOR
32
MEMORY
52

FIG.17

(PATTERN 1)

	HEAT TRANSFER AREA RATIO (%)
FIRST AND SECOND HEAT EXCHANGERS	97～50
FOURTH HEAT EXCHANGER	3～50

(PATTERN 2)

	HEAT TRANSFER AREA RATIO (%)
FIRST AND SECOND HEAT EXCHANGERS	92～70
FOURTH HEAT EXCHANGER	8～30

FIG.18

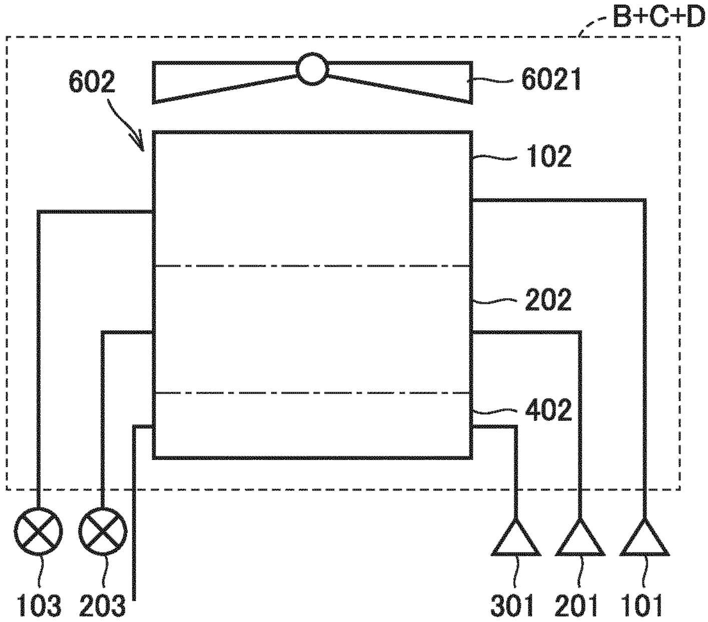


FIG.19

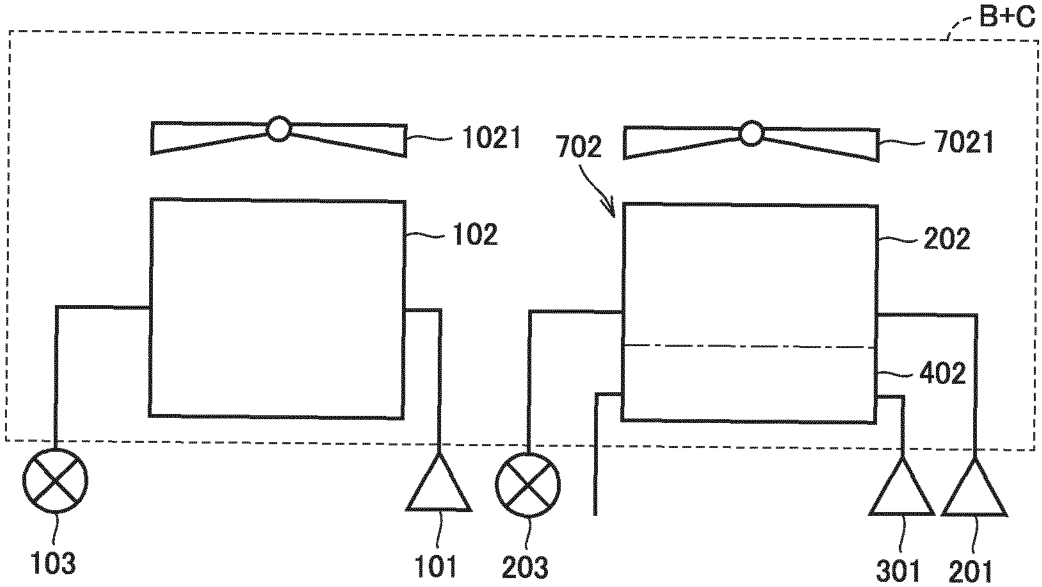


FIG.20

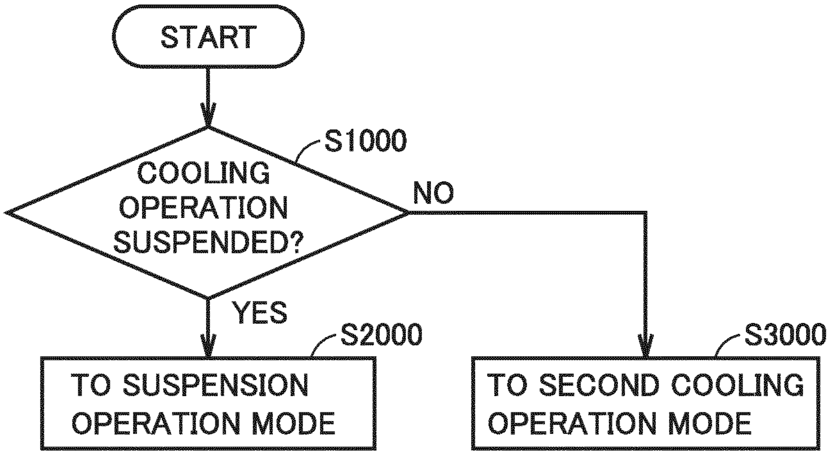

START
S1000
COOLING OPERATION SUSPENDED?
NO
YES
S2000
TO SUSPENSION OPERATION MODE
S3000
TO SECOND COOLING OPERATION MODE

FIG.21

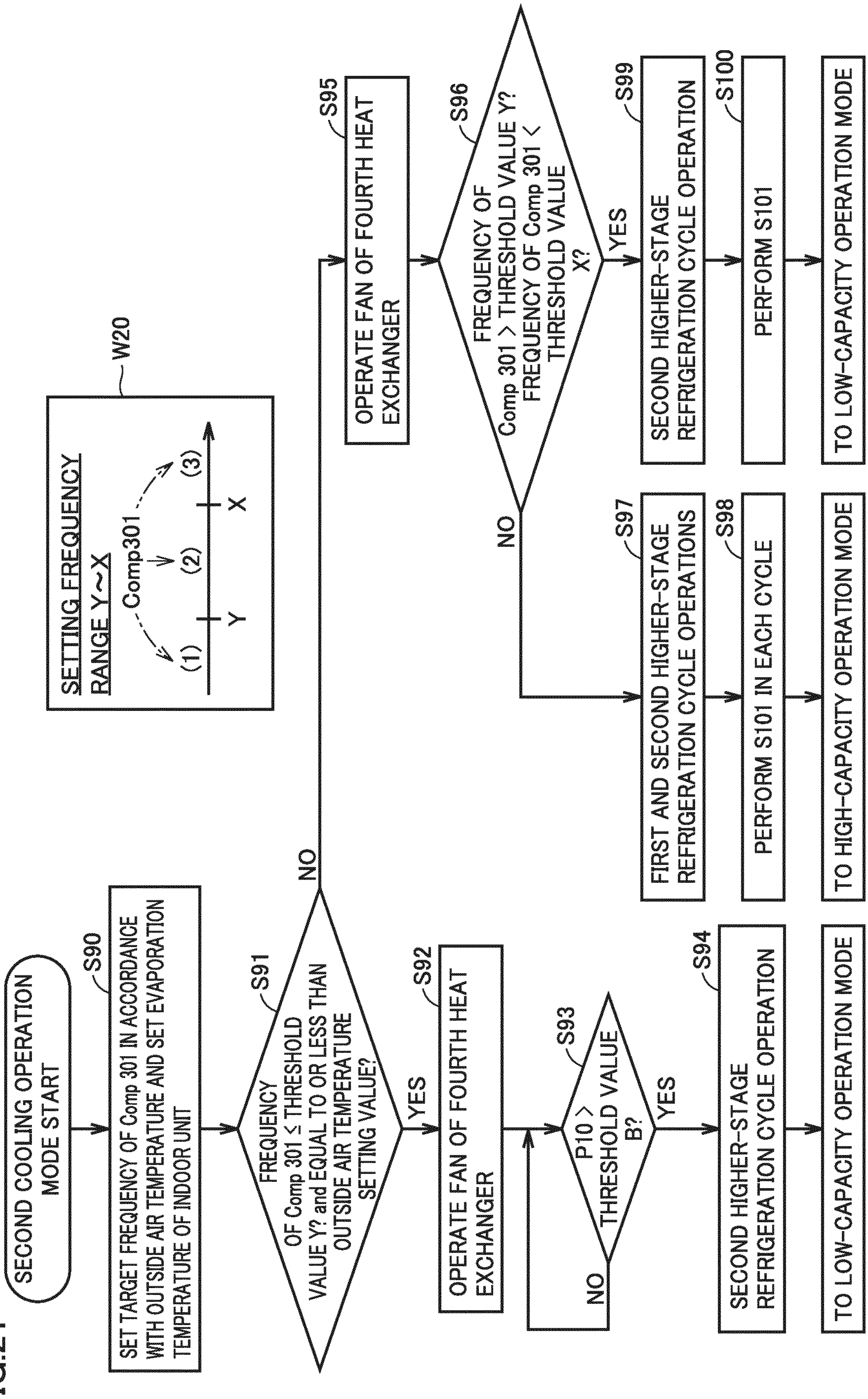
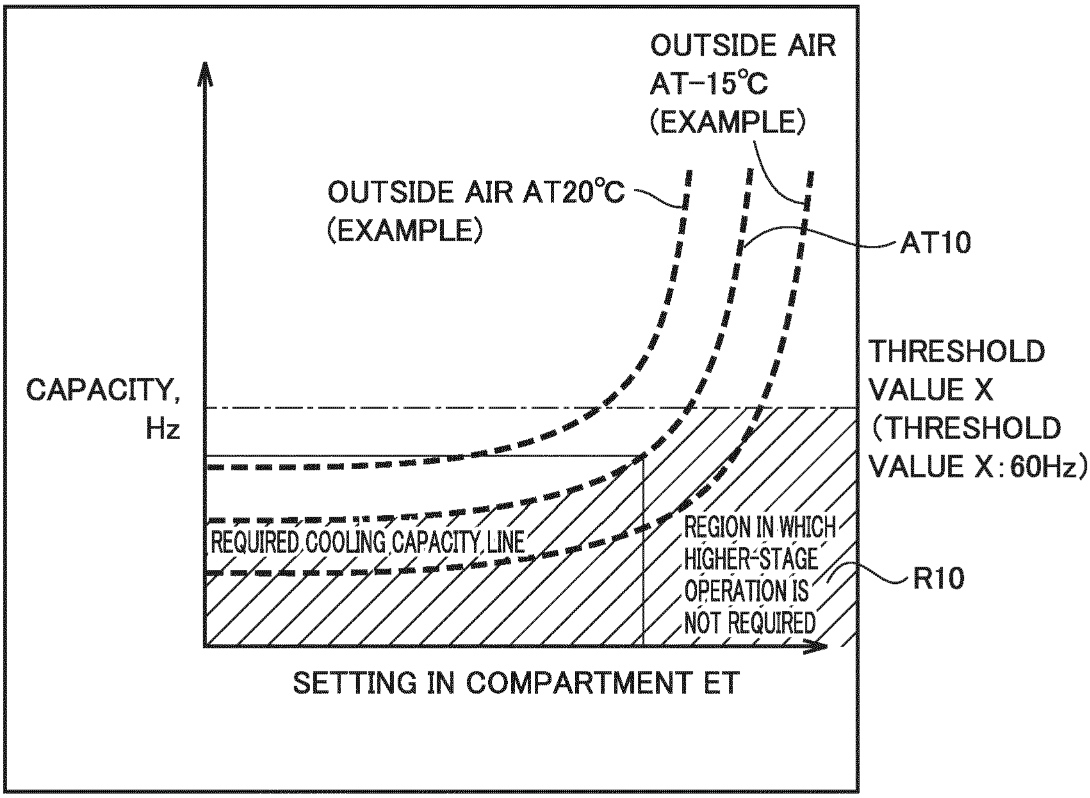

SECOND COOLING OPERATION MODE START
S90
SET TARGET FREQUENCY OF Comp 301 IN ACCORDANCE WITH OUTSIDE AIR TEMPERATURE AND SET EVAPORATION TEMPERATURE OF INDOOR UNIT
S91
FREQUENCY OF Comp 301 ≤ THRESHOLD VALUE Y? and EQUAL TO OR LESS THAN OUTSIDE AIR TEMPERATURE SETTING VALUE?
YES
NO
S92
OPERATE FAN OF FOURTH HEAT EXCHANGER
S93
P10 > THRESHOLD VALUE B?
YES
NO
S94
SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATION
TO LOW-CAPACITY OPERATION MODE
W20
SETTING FREQUENCY RANGE Y~X
Comp301
(1)
(2)
(3)
Y
X
S95
OPERATE FAN OF FOURTH HEAT EXCHANGER
S96
FREQUENCY OF Comp 301 > THRESHOLD VALUE Y? FREQUENCY OF Comp 301 < THRESHOLD VALUE X?
YES
NO
S97
FIRST AND SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATIONS
S98
PERFORM S101 IN EACH CYCLE
TO HIGH-CAPACITY OPERATION MODE
S99
SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATION
S100
PERFORM S101
TO LOW-CAPACITY OPERATION MODE

FIG.22



OUTSIDE AIR
AT-15°C
(EXAMPLE)
OUTSIDE AIR AT20°C
(EXAMPLE)
AT10
THRESHOLD
VALUE X
(THRESHOLD
VALUE X: 60Hz)
CAPACITY,
Hz
REQUIRED COOLING CAPACITY LINE
REGION IN WHICH
HIGHER-STAGE
OPERATION IS
NOT REQUIRED
R10
SETTING IN COMPARTMENT ET

FIG.23

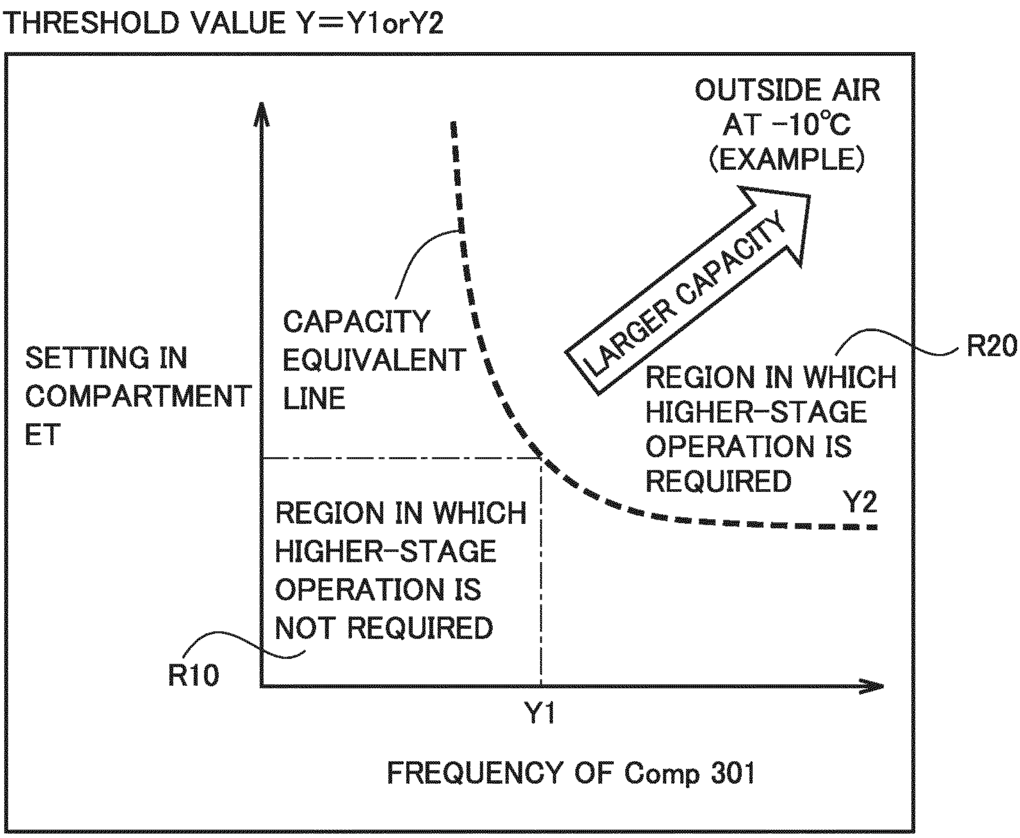
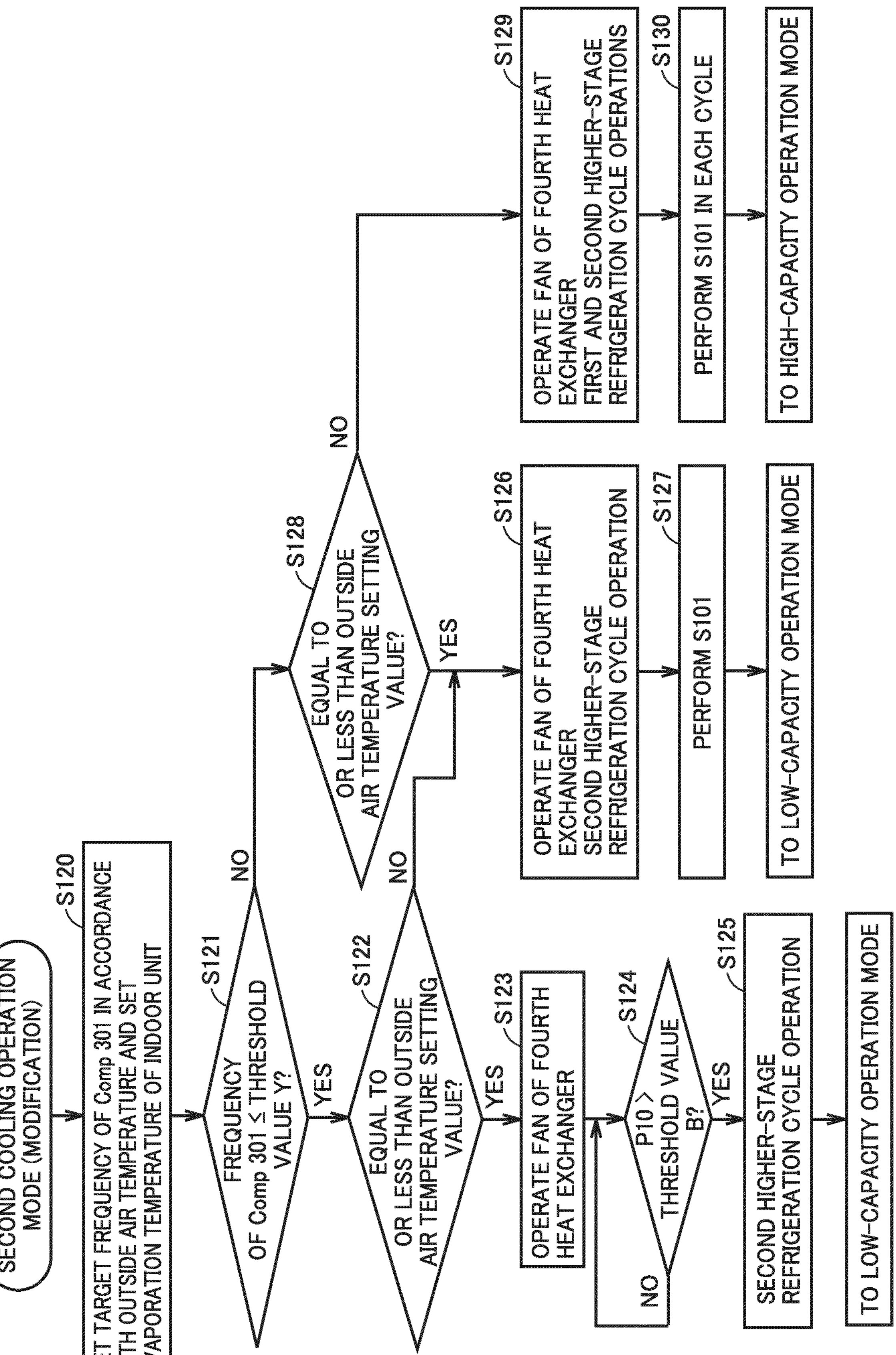

THRESHOLD VALUE Y=Y1orY2
OUTSIDE AIR AT -10℃ (EXAMPLE)
LARGER CAPACITY
CAPACITY EQUIVALENT LINE
SETTING IN COMPARTMENT ET
REGION IN WHICH HIGHER-STAGE OPERATION IS REQUIRED
R20
Y2
REGION IN WHICH HIGHER-STAGE OPERATION IS NOT REQUIRED
R10
Y1
FREQUENCY OF Comp 301

FIG.24


SECOND COOLING OPERATION MODE (MODIFICATION)
S120
SET TARGET FREQUENCY OF Comp 301 IN ACCORDANCE WITH OUTSIDE AIR TEMPERATURE AND SET EVAPORATION TEMPERATURE OF INDOOR UNIT
S121
FREQUENCY OF Comp 301 ≤ THRESHOLD VALUE Y?
YES
NO
S122
EQUAL TO OR LESS THAN OUTSIDE AIR TEMPERATURE SETTING VALUE?
YES
NO
S123
OPERATE FAN OF FOURTH HEAT EXCHANGER
S124
P10 > THRESHOLD VALUE B?
YES
NO
S125
SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATION
TO LOW-CAPACITY OPERATION MODE
S128
EQUAL TO OR LESS THAN OUTSIDE AIR TEMPERATURE SETTING VALUE?
YES
NO
S126
OPERATE FAN OF FOURTH HEAT EXCHANGER
SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATION
S127
PERFORM S101
TO LOW-CAPACITY OPERATION MODE
S129
OPERATE FAN OF FOURTH HEAT EXCHANGER
FIRST AND SECOND HIGHER-STAGE REFRIGERATION CYCLE OPERATIONS
S130
PERFORM S101 IN EACH CYCLE
TO HIGH-CAPACITY OPERATION MODE

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/016203

A. CLASSIFICATION OF SUBJECT MATTER

F25B 6/04(2006.01)i; F25B 7/00(2006.01)i; F25B 43/00(2006.01)i; F25B 1/00(2006.01)i
FI: F25B7/00 D; F25B6/04 Z; F25B1/00 396D; F25B43/00 M

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)
F25B6/04; F25B7/00; F25B43/00; F25B1/00

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

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	WO 2012/066763 A1 (MITSUBISHI ELECTRIC CORPORATION) 24 May 2012 (2012-05-24) abstract	1-11
A	EP 3492838 A1 (JTL SYSTEMS LIMITED) 05 June 2019 (2019-06-05) fig. 2	1-11
A	JP 4-6350 A (HITACHI LTD) 10 January 1992 (1992-01-10) claim 1	1-11
A	WO 2015/133622 A1 (MITSUBISHI ELECTRIC CORP) 11 September 2015 (2015-09-11) abstract	1-11

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 May 2021 (28.05.2021)	08 June 2021 (08.06.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application no.
PCT/JP2021/016203

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
WO 2012/066763 A1	24 May 2012	US 2013/0180278 A1 abstract EP 2642220 A1 CN 103221760 A	
EP 3492838 A1	05 Jun. 2019	GB 2568990 A fig. 2	
JP 4-6350 A	10 Jan. 1992	(Family: none)	
WO 2015/133622 A1	11 Sep. 2015	US 2016/0363354 A1 abstract EP 3118541 A1 CN 106068427 A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2012066763 A **[0003]**