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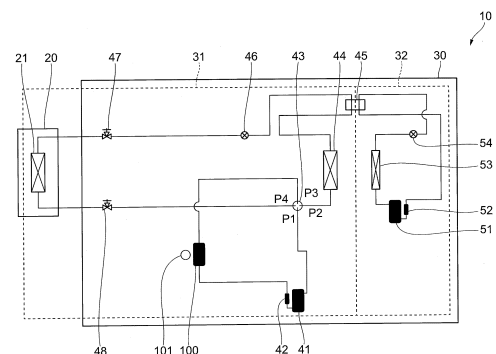
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(54) **REFRIGERATION CYCLE SYSTEM**

(57) A refrigeration cycle system includes: a compressor lubricated by lubricating oil and configured to compress refrigerant; an evaporator configured to allow the refrigerant having dissipated heat and having been decompressed after the compression by the compressor to pass therethrough and cause the passing refrigerant to exchange heat with an object; and a storage container provided between the evaporator and the compressor, the storage container being configured to store the refrigerant and the lubricating oil. The system is capable of supplying the lubricating oil stored in the storage container to the compressor even when an environmental temperature of an environment in which the storage container is installed becomes an inversion temperature at which a density of the lubricating oil and a density of the refrigerant in a liquid state are inverted.

FIG.2



Description

Technical Field

[0001] The present disclosure relates to a refrigeration cycle system.

Background Art

[0002] Patent Literature 1 discloses a liquid return prevention device in a refrigeration apparatus including a low-pressure receiver disposed between a compressor and an evaporator in a refrigerant circulation system, where an oil return port for returning lubricating oil accumulated in the low-pressure receiver to the compressor is formed in a compressor-side refrigerant pipe of the low-pressure receiver, and a communication pipe is provided between the bottom of the low-pressure receiver and the evaporator to allow liquid refrigerant accumulated in the low-pressure receiver to flow down to the evaporator during a stop of the compressor.

Citation List

Patent Literature

[0003] Patent Literature 1: Japanese Patent Application Laid-Open Publication No. S63-172870

Summary of Invention

Technical Problem

[0004] For example, a storage container capable of storing refrigerant in a liquid state (which may be referred to hereinafter as "liquid refrigerant") may be provided on a circuit in which the refrigerant circulates in a refrigeration cycle system, such as the low-pressure receiver disclosed in Patent Literature 1. To ensure lubrication in the compressor, such a storage container also stores lubricating oil that circulates in the circuit together with the refrigerant. If the liquid refrigerant and the lubricating oil are incompatible with each other, they are separated into an upper layer and a lower layer in the storage container, and the lubricating oil is supplied to the compressor through an oil supply mechanism, such as the oil return port disclosed in Patent Literature 1.

[0005] Depending on the combination of the liquid refrigerant and the lubricating oil, their densities may be inverted at a certain temperature, causing the upper and lower layers to switch places with each other. Such switch between the upper and lower layers makes it difficult for the conventional oil supply mechanism to supply oil to the compressor, resulting in lubrication failure in the compressor.

[0006] The present disclosure proposes a refrigeration cycle system that prevents lubrication failure in the compressor even when the environmental temperature be-

comes a temperature at which the density of the lubricating oil and the density of the refrigerant in a liquid state are inverted.

Solution to Problem

[0007] In a first aspect, the present invention relates to a refrigeration cycle system including: a compressor lubricated by lubricating oil and configured to compress refrigerant; an evaporator configured to allow the refrigerant having dissipated heat and having been decompressed after the compression by the compressor to pass therethrough and cause the passing refrigerant to exchange heat with an object; and a storage container provided between the evaporator and the compressor, the storage container being configured to store the refrigerant and the lubricating oil, wherein the system is capable of supplying the lubricating oil stored in the storage container to the compressor even when an environmental temperature of an environment in which the storage container is installed becomes an inversion temperature at which a density of the lubricating oil and a density of the refrigerant in a liquid state are inverted. This refrigeration cycle system prevents lubrication failure in the compressor even when the environmental temperature becomes the inversion temperature at which the density of the lubricating oil and the density of the refrigerant in a liquid state are inverted.

[0008] In a second aspect, the present invention relates to the refrigeration cycle system of the first aspect, further including a control unit configured to control a state of the refrigerant, wherein the control unit is capable of performing a control to apply superheat to the refrigerant flowing into the storage container in response to the environmental temperature becoming the inversion temperature. This facilitates the supply of the lubricating oil to the compressor compared to when no superheat is applied.

[0009] In a third aspect, the present invention relates to the refrigeration cycle system of the second aspect, further including an electric valve configured to adjust pressure of the refrigerant passing through the evaporator, wherein as the control to apply superheat to the refrigerant flowing into the storage container, the control unit is capable of controlling an opening degree of the electric valve to be smaller than before performing the control to apply superheat.

[0010] In a fourth aspect, the present invention relates to the refrigeration cycle system of the second aspect, wherein as the control to apply superheat to the refrigerant flowing into the storage container, the control unit is capable of controlling a frequency of motion for the compression in the compressor to be greater than before performing the control to apply superheat.

[0011] In a fifth aspect, the present invention relates to the refrigeration cycle system of any one of the first to fourth aspects, wherein the storage container includes an oil suction mechanism capable of sucking the lubri-

cating oil and supplying the lubricating oil to the compressor even when the environmental temperature becomes the inversion temperature to cause the refrigerant in a liquid state to become a layer below the lubricating oil in the storage container. This prevents lubricating failure in the compressor even when the layer of the lubricating oil becomes the lower layer.

[0012] In a sixth aspect, the present invention relates to the refrigeration cycle system of the fifth aspect, wherein the oil suction mechanism includes a plurality of ports located on piping for sucking out the lubricating oil in the storage container, the plurality of ports being at different heights from a bottom of the storage container, the oil suction mechanism is capable of sucking out the refrigerant in a liquid state and the lubricating oil through the plurality of ports, and the oil suction mechanism is configured to cause the sucked-out refrigerant in the liquid state and the sucked-out lubricating oil to exchange heat with a high-temperature portion in the system having a higher temperature than the inversion temperature and then supply the refrigerant and the lubricating oil to the compressor. This reduces the load on the compressor due to the inflow of the refrigerant in a liquid state compared to when no heat exchange takes place with the high-temperature portion.

[0013] In a seventh aspect, the present invention relates to the refrigeration cycle system of any one of the first to sixth aspects, wherein the system is capable of elevating temperatures of the refrigerant in a liquid state and the lubricating oil stored in the storage container to eliminate density inversion even when the environmental temperature becomes the inversion temperature. This facilitates the supply of the lubricating oil to the compressor compared to when the temperatures are not elevated.

[0014] In an eighth aspect, the present invention relates to the refrigeration cycle system of any one of the first to seventh aspects, further including a heater attached to the storage container, the heater being capable of elevating temperatures of the refrigerant in a liquid state and the lubricating oil stored in the storage container.

[0015] In a ninth aspect, the present invention relates to the refrigeration cycle system of any one of the first to eighth aspects, further including a radiator configured to allow the refrigerant compressed by the compressor to pass therethrough and extract and dissipate heat from the passing refrigerant, wherein the system is capable of causing a heat exchange between the storage container or the refrigerant in a liquid state stored in the storage container and the refrigerant after passing through the radiator. This improves the refrigeration capacity of the refrigeration cycle system compared to the absence of the radiator.

[0016] In a tenth aspect, the present invention relates to the refrigeration cycle system of any one of the first to ninth aspects, wherein the system is capable of causing a heat exchange between the storage container or the refrigerant in a liquid state stored in the storage container

and exhaust heat from the compressor. This can utilize exhaust heat from the compressor.

[0017] In an eleventh aspect, the present invention relates to the refrigeration cycle system of any one of the first to tenth aspects, wherein the lubricating oil is polyalkylene glycol.

Brief Description of the Drawings

[0018]

FIG. 1 illustrates an example schematic configuration of an air conditioning system according to an exemplary embodiment.

FIG. 2 illustrates an example configuration of an air conditioning unit according to the exemplary embodiment.

FIG. 3 illustrates relationship between the liquid refrigerant and the lubricating oil in terms of temperature and density.

FIGS. 4A and 4B illustrates sucking out of the lubricating oil stored in a low-pressure receiver, where FIG. 4A schematically illustrates a low-pressure receiver with an oil return pipe, and FIG. 4B schematically illustrates a low-pressure receiver with an oil return port in the path of a compressor-side pipe.

FIG. 5 is a flowchart illustrating an example of switching between a normal control mode and an under-inversion control mode according to the exemplary embodiment.

Description of Embodiments

<First Embodiment>

(Air conditioning system 1)

[0019] FIG. 1 illustrates an example schematic configuration of an air conditioning system 1 according to an exemplary embodiment.

[0020] As shown in the figure, the air conditioning system 1 according to the present embodiment includes an air conditioning unit 10 and a control unit 90. The air conditioning unit 10 includes a refrigerant circuit in which refrigerant circulates. The control unit 90 controls various devices (described below with reference to FIG. 2) included in the air conditioning unit 10. The control unit 90 is wired or wirelessly connected to the devices in the air conditioning unit 10 and can send control signals to the devices.

[0021] The air conditioning system 1 is an example of the refrigeration cycle system in the present embodiment.

[0022] The air conditioning system 1 provides a cooling function to cool a space by cooling the drawn air and supplying it as cold air to the space. More specifically, the air conditioning system 1 cools the air, which is an example of the object, by extracting heat from the air through a heat exchange between the refrigerant passing

through a heat exchanger (described below with reference to FIG. 2) of the air conditioning unit 10 and the air. The air conditioning system 1 then supplies the cooled air as cold air to the space from an outlet of an indoor unit (described below with reference to FIG. 2) or the like to cool the space.

[0023] The air conditioning system 1 also provides a heating function to warm a space by heating the drawn air and supplying it as warm air to the space. More specifically, the air conditioning system 1 heats the air by giving heat to the air through a heat exchange between the refrigerant passing through the heat exchanger of the air conditioning unit 10 and the air. The air conditioning system 1 then supplies the heated air as warm air to the space from the outlet of the indoor unit or the like to warm the space.

(Control unit 90)

[0024] The control unit 90 controls the various devices included in the air conditioning unit 10 by sending control signals to these devices included in the air conditioning unit 10. To further illustrate, the state of the refrigerant circulating in the refrigerant circuit of the air conditioning unit 10 is controlled according to how the various devices are controlled by the control unit 90. For example, the control unit 90 performs control according to measurements from a temperature sensor (described below with reference to FIG. 2) provided in the air conditioning unit 10.

[0025] The control unit 90 may also perform control according to operational inputs from users, such as those associated with temperature settings and air flow rate settings, entered via an operation panel or control unit to accept operations from the users. In addition, the control unit 90 may perform control according to measurements from a temperature sensor that measures the temperature of the space to be cooled/warmed.

[0026] The control unit 90 may obtain information relating to operations of the devices included in the air conditioning unit 10, such as the effective values of the operations relative to the control values, and may control the devices according to the obtained information. The control unit 90 may also control the volume and direction of the cold air/warm air supplied to the space by the air conditioning system 1.

(Configuration of the air conditioning unit 10)

[0027] FIG. 2 illustrates an example configuration of the air conditioning unit 10 according to the present embodiment.

[0028] As shown in the figure, the air conditioning unit 10 of the air conditioning system 1 according to the present embodiment includes a first refrigerant circuit 31 and a second refrigerant circuit 32. The first refrigerant circuit 31 is disposed over an indoor unit 20 and an outdoor unit 30.

[0029] The indoor unit 20 includes an indoor heat exchanger 21.

[0030] During heating operation, the indoor heat exchanger 21 functions as a radiator that heats an object with which the refrigerant exchanges heat, which is the air, by heat dissipation from the refrigerant to produce warm air. During cooling operation, the indoor heat exchanger 21 functions as a cooler that cools an object with which the refrigerant exchanges heat, which is the air, by heat absorption by the refrigerant to produce cold air. To further illustrate, when the indoor heat exchanger 21 functions as a radiator, the refrigerant itself is cooled as it dissipates heat, and when the indoor heat exchanger 21 functions as a cooler, the refrigerant itself is heated as it absorbs heat. The indoor heat exchanger 21 is an example of the evaporator configured to cause the refrigerant passing therethrough to exchange heat with the object.

[0031] The indoor unit 20 may also include an indoor fan (not shown) and other components.

[0032] The first refrigerant circuit 31 is connected to the indoor unit 20 with pipes respectively having first and second stop valves 47, 48. The second refrigerant circuit 32 functions as an assist circuit to increase the capacity of the first refrigerant circuit 31.

[0033] The first refrigerant circuit 31 according to the present embodiment has carbon dioxide circulating therein as an example of the refrigerant. The second refrigerant circuit 32 has propane circulating therein as an example of the refrigerant.

[0034] The first refrigerant circuit 31 is configured with a first compressor 41, a first sub-accumulator 42, a four-way valve 43, a first outdoor heat exchanger 44, a cascade heat exchanger 45 shared with the second refrigerant circuit 32, a first electric valve 46, the first stop valve 47, the indoor heat exchanger 21, the second stop valve 48, and a low-pressure receiver 100 connected in series.

[0035] The second refrigerant circuit 32 is configured with a second compressor 51, a second sub-accumulator 52, the cascade heat exchanger 45 shared with the first refrigerant circuit 31, a second outdoor heat exchanger 53, and a second electric valve 54 connected in series.

[0036] The configurations of the first and second refrigerant circuit 31, 32 are not limited to those described above. For example, the first and second refrigerant circuits 31, 32 may further be configured with filters, heat sinks, oil separators, etc. The circuits may also be configured with pressure/temperature sensors to detect the pressure/temperature of the refrigerant at various locations in the circuits, high-pressure switchgears as protective detectors, etc.

[0037] The first compressor 41 has its discharge side connected to a first port (P1) of the four-way valve 43 and its suction side connected to the first sub-accumulator 42. The first sub-accumulator 42 separates the refrigerant into gas and liquid phases and allows only the gaseous refrigerant to be sucked into the first compressor 41. The first compressor 41 compresses the sucked-in

gaseous refrigerant and discharges it from the discharge side. The discharged refrigerant has an increased temperature due to the gain of compression heat associated with the compression (such refrigerant may be referred to hereinafter as being "heated and compressed").

[0038] The first compressor 41 according to the present embodiment is controlled for, for example, the motion frequency and the volume of refrigerant to be sucked in/discharged according to control signals from the control unit 90. The "motion frequency" refers to the frequency of motion (operation) of the relevant component in the compressor performed to compress the refrigerant. Specifically, the motion frequency refers to, for example, the frequency of oscillation of the oscillating body in an oscillating compressor or the frequency of rotation of the rotating body in a scroll or rotary compressor.

[0039] The first compressor 41 is lubricated by lubricating oil, which is described below. More specifically, the lubricating oil ensures lubrication such that the motion of the component for compressing the refrigerant described above will have no problem. Examples of the lubricating oil include polyalkylene glycol (PAG).

[0040] The four-way valve 43 includes the first port (P1), a second port (P2), a third port (P3), and a fourth port (P4). The four-way valve 43 can switch between the state where the first port (P1) and the second port (P2) are in communication with each other and the third port (P3) and the fourth port (P4) are in communication with each other, and the state where the first port (P1) and the fourth port (P4) are in communication with each other and the second port (P2) and the third port (P3) are in communication with each other.

[0041] During cooling operation, the four-way valve 43 enables communication between the first port (P1) and the second port (P2) and communication between the third port (P3) and the fourth port (P4). During heating operation, the four-way valve 43 switches to enabling communication between the first port (P1) and the fourth port (P4) and communication between the second port (P2) and the third port (P3).

[0042] The first outdoor heat exchanger 44 exchanges heat between the refrigerant and the outdoor air. The first outdoor heat exchanger 44 functions as a cooler during heating operation and as a radiator during cooling operation. The first outdoor heat exchanger 44 may include an outdoor fan and other components. The first outdoor heat exchanger 44 is an example of the evaporator configured to cause the refrigerant passing therethrough to exchange heat with the object.

[0043] The cascade heat exchanger 45 exchanges heat between the first refrigerant circuit 31 and the second refrigerant circuit 32. The cascade heat exchanger 45 is, for example, a double-pipe heat exchanger composed of two pipes of different diameters, one inside and the other outside. Alternatively, the cascade heat exchanger 45 may be any other type of heat exchanger, such as a plate heat exchanger.

[0044] The first electric valve 46 includes a valve, such as a ball valve, and a motor for driving the valve. The first electric valve 46 regulates the pressure of the refrigerant passing therethrough as the motor adjusts the opening degree of the valve. More specifically, the first electric valve 46 is provided between a pipe connecting to the cascade heat exchanger 45 and a pipe connecting to the first stop valve 47, and decompresses the refrigerant flowing in from one pipe by throttle expansion according to the opening degree of the valve and flows the decompressed refrigerant into the other pipe. The refrigerant flowing into the other pipe has a reduced temperature due to the decompression by throttle expansion (such refrigerant may be referred to hereinafter as being "decompressed to a reduced temperature").

[0045] The opening degree of the first electric valve 46 is adjusted as the motor is driven according to control signals from the control unit 90. Other valves than the electric valve whose opening degrees can be controlled by the control unit 90 may include solenoid valves with a valve driven by a solenoid.

[0046] The low-pressure receiver 100 is a container capable of storing incoming refrigerant. The low-pressure receiver 100 stores the liquid refrigerant out of the incoming refrigerant and discharges the refrigerant in a gaseous state (which may be referred to as the "gaseous refrigerant") for circulation again. If the liquid refrigerant is sucked into and compressed by the above first compressor 41, it will cause a decrease in compression efficiency and operation failures. Therefore, the low-pressure receiver 100 separates the incoming refrigerant into the liquid refrigerant and the gaseous refrigerant and stores the liquid refrigerant to prevent the liquid refrigerant from being sucked into the first compressor 41. The low-pressure receiver 100 is an example of the storage container according to the present embodiment.

[0047] The outdoor unit 30 according to the present embodiment includes a temperature sensor 101 to measure the temperature of the environment in which the low-pressure receiver 100 is installed (which may be referred to hereinafter as the "environmental temperature"). FIG. 2 schematically illustrates the low-pressure receiver 100 and the temperature sensor 101 as being arranged side by side inside the outdoor unit 30. However, the location of the temperature sensor 101 is not limited to this. For example, the temperature sensor 101 may be attached to the outer side of the casing/housing of the outdoor unit 30. The temperature sensor 101 may be a thermistor, for example. The low-pressure receiver 100 and the temperature sensor 101 are detailed in subsequent paragraphs.

[0048] The second compressor 51, the second sub-accumulator 52, the second outdoor heat exchanger 53, and the second electric valve 54 in the second refrigerant circuit 32 have the similar configurations to the first compressor 41, the first sub-accumulator 42, the first outdoor heat exchanger 44, and the first electric valve 46 in the first refrigerant circuit 31, respectively.

(Refrigerant flow during cooling operation)

[0049] The flow of refrigerant in the first and second refrigerant circuits 31, 32 during cooling operation is now illustrated. During cooling operation, the four-way valve 43 enables communication between the first port (P1) and the second port (P2) and communication between the third port (P3) and the fourth port (P4).

[0050] In the first refrigerant circuit 31, the refrigerant is first compressed by the first compressor 41. The compressed refrigerant passes through the four-way valve 43 to enter the first outdoor heat exchanger 44. The first outdoor heat exchanger 44 functions as a radiator during cooling operation. The refrigerant leaving the first outdoor heat exchanger 44 enters the cascade heat exchanger 45. During cooling operation, the cascade heat exchanger 45 functions as a radiator in the first refrigerant circuit 31. The refrigerant leaving the cascade heat exchanger 45 is decompressed as it passes through the first electric valve 46 and enters the indoor heat exchanger 21 through the first stop valve 47. The indoor heat exchanger 21 functions as a cooler during cooling operation. The refrigerant leaving the indoor heat exchanger 21 passes through the second stop valve 48, the four-way valve 43, the low-pressure receiver 100, and the first sub-accumulator 42 to again enter the first compressor 41.

[0051] The flow of refrigerant in the second refrigerant circuit 32 is now described. In the second refrigerant circuit 32, the refrigerant is first compressed by the second compressor 51. The compressed refrigerant enters the second outdoor heat exchanger 53. The second outdoor heat exchanger 53 functions as a radiator during cooling operation. The refrigerant leaving the second outdoor heat exchanger 53 is decompressed as it passes through the second electric valve 54 and enters the cascade heat exchanger 45. During cooling operation, the cascade heat exchanger 45 functions as a cooler in the second refrigerant circuit 32. The refrigerant leaving the cascade heat exchanger 45 passes through the second sub-accumulator 52 to again enter the second compressor 51.

[0052] The air conditioning unit 10 according to the present embodiment has a dual circuit configuration provided by the first refrigerant circuit 31 and the second refrigerant circuit 32. More specifically, in the air conditioning unit 10 during cooling operation, the cascade heat exchanger 45 functions as a radiator in the first refrigerant circuit 31 and as a cooler in the second refrigerant circuit 32. In this case, the refrigerant flowing in the first refrigerant circuit 31 is heated and compressed by the first compressor 41, cooled by the first outdoor heat exchanger 44, further cooled by the cascade heat exchanger 45, and decompressed to a reduced temperature by the first electric valve 46, and then cools the air in the indoor heat exchanger 21.

(Refrigerant flow during heating operation)

[0053] The flow of refrigerant in the first and second

refrigerant circuits 31, 32 during heating operation is now illustrated. During heating operation, the four-way valve 43 enables communication between the first port (P1) and the fourth port (P4) and communication between the second port (P2) and the third port (P3).

[0054] In the first refrigerant circuit 31, the refrigerant is first heated and compressed by the first compressor 41. The compressed refrigerant passes through the four-way valve 43 and the second stop valve 48 to enter the indoor heat exchanger 21. The indoor heat exchanger 21 functions as a radiator during heating operation. The refrigerant leaving the indoor heat exchanger 21 enters the indoor unit 20 through the first stop valve 47 and is decompressed to a reduced temperature as it passes through the first electric valve 46. The decompressed refrigerant passes through the cascade heat exchanger 45 to enter the first outdoor heat exchanger 44. The first outdoor heat exchanger 44 functions as a cooler during heating operation. The refrigerant leaving the first outdoor heat exchanger 44 passes through the four-way valve 43, the low-pressure receiver 100, and the first sub-accumulator 42 to again enter the first compressor 41.

[0055] During heating operation, a heat exchange may also take place in the cascade heat exchanger 45. In this case, the cascade heat exchanger 45 functions as a cooler in the first refrigerant circuit 31.

(Lubricating oil storage)

[0056] By the way, the lubricating oil for ensuring lubrication in the first compressor 41 circulates in the first refrigerant circuit 31 together with the refrigerant. Accordingly, the low-pressure receiver 100 stores the lubricating oil flowing in with the liquid refrigerant.

[0057] If the lubricating oil stored in the low-pressure receiver 100 is not removed and the inflow and storage of the lubricating oil continues, the volume of lubricating oil supplied to the first compressor 41 gradually decreases. Eventually, it becomes difficult to supply the oil to the first compressor 41, possibly resulting in lubrication failure in the first compressor 41. Thus, the low-pressure receiver 100 needs to be provided with an oil supply mechanism capable of removing the stored lubricating oil and supplying it to the first compressor 41. On the other hand, as described above with reference to FIG. 2, it is undesirable for the liquid refrigerant to be sucked into the first compressor 41. Thus, the oil supply mechanism is preferably of capable of removing the lubricating oil while leaving the liquid refrigerant unremoved.

[0058] If the liquid refrigerant and the lubricating oil are incompatible with each other, they are separated into an upper layer and a lower layer in the low-pressure receiver 100. And depending on the combination of the liquid refrigerant and the lubricating oil, their densities may be inverted at a certain temperature (which may be referred to hereinafter as the "inversion temperature"), causing the upper and lower layers to switch places with each other.

[0059] FIG. 3 illustrates relationship between the liquid refrigerant and the lubricating oil in terms of temperature and density. In FIG. 3, the horizontal axis represents the temperature ($^{\circ}\text{C}$), and the vertical axis represents the density (kg/m^3). FIG. 3 illustrates an example where carbon dioxide is used as the liquid refrigerant and polyalkylene glycol is used as the lubricating oil.

[0060] As shown in FIG. 3, at temperatures above -20°C , the density of the lubricating oil is greater than that of the liquid refrigerant, resulting in the liquid refrigerant being the upper layer and the lubricating oil being the lower layer. On the other hand, at temperatures at or below -20°C , the density of the lubricating oil is smaller than that of the liquid refrigerant, resulting in the lubricating oil being the upper layer and the liquid refrigerant being the lower layer. The temperature of -20°C is an example of the inversion temperature.

[0061] As used herein, the term "incompatible" refers not only to the liquid refrigerant and the lubricating oil as being completely insoluble with each other, but refers to them as being insoluble with each other at least to the extent that they are separated as distinct layers in the low-pressure receiver 100. Also, they need not be incompatible in all temperature ranges, but may just be incompatible at normally expected environmental temperatures.

[0062] The air conditioning system 1 according to the present embodiment has a configuration that allows the lubricating oil stored in the low-pressure receiver 100 to be supplied to the first compressor 41 even when the environmental temperature falls to or below -20°C .

[0063] Referring to FIGS. 1 through 4, example configurations 100-1, 100-2 of the low-pressure receiver 100 as well as the extraction of the lubricating oil stored in the low-pressure receiver 100 are described. The example configurations 100-1, 100-2 of the low-pressure receiver 100 may be referred to as "low-pressure receiver 100" without distinction. Unless otherwise noted, the following description discusses, by way of example, the cooling operation of the air conditioning unit 10.

[0064] FIGS. 4A and 4B illustrate extraction of the lubricating oil stored in the low-pressure receiver 100, where FIG. 4A schematically illustrates the low-pressure receiver 100-1 with an oil return pipe 140, and FIG. 4B schematically illustrates the low-pressure receiver 100-2 with an oil return port 151 in the path of a compressor-side pipe 150. Components of the low-pressure receiver 100-2 similar to those of the low-pressure receiver 100-1 may be identified by the same names and reference numerals, and description thereof may be omitted.

[0065] As shown in FIG. 4A, the low-pressure receiver 100-1 includes a reservoir 110 capable of storing the liquid refrigerant, a heat exchanger-side pipe 120 to allow the refrigerant flowing in from the indoor heat exchanger 21 to flow into the reservoir 110, a compressor-side pipe 130 to discharge the gaseous refrigerant in the reservoir 110 to the first compressor 41, and an oil return pipe 140 provided at the bottom of the reservoir 110.

[0066] As shown on the left side of the page of FIG. 4A captioned "Non-inverted state," when the environmental temperature is higher than -20°C and the liquid refrigerant and the lubricating oil are not inverted, the low-pressure receiver 100-1 allows the lubricating oil in the lower layer to be sucked out through the oil return pipe 140 and supplied to the first compressor 41. However, when the environmental temperature falls to or below -20°C and the densities are inverted, the lubricating oil occupies the upper layer as shown on the right side of the page of FIG. 4A captioned "Inverted state." In this state, it will be difficult for the lubricating oil to be sucked out through the oil return pipe 140 without a configuration that allows the stored lubricating oil to be supplied to the first compressor 41, making it difficult to supply the lubricating oil to the first compressor 41.

[0067] As shown in FIG. 4B, the low-pressure receiver 100-2 includes the reservoir 110, the heat exchanger-side pipe 120, and a compressor-side pipe 150 extended to pass near the bottom of the reservoir 110. The compressor-side pipe 150 includes an oil return port 151 in its portion passing near the bottom of the reservoir 110.

[0068] As shown on the left side of the page of FIG. 4B captioned "Non-inverted state," when the environmental temperature is higher than -20°C and the liquid refrigerant and the lubricating oil are not inverted, the low-pressure receiver 100-2 allows the lubricating oil in the lower layer to be sucked out through the oil return port 151 and supplied to the first compressor 41. However, when the environmental temperature falls to or below -20°C and the densities are inverted, the lubricating oil occupies the upper layer as shown on the right side of the page of FIG. 4B captioned "Inverted state." In this state, it will be difficult for the lubricating oil to be sucked out through the oil return port 151 without a configuration that allows the stored lubricating oil to be supplied to the first compressor 41, making it difficult to supply the lubricating oil to the first compressor 41.

[0069] As described above, without a configuration that allows the stored lubricating oil to be supplied to the first compressor 41 at the environmental temperatures of -20°C or below, it may be difficult to remove the lubricating oil once the environmental temperature falls to or below -20°C .

[0070] Thus, as a configuration that allows the lubricating oil stored in the low-pressure receiver 100 to be supplied to the first compressor 41 even when the environmental temperature falls to or below -20°C , the control unit 90 of the air conditioning system 1 according to the present embodiment is capable of performing a control to apply superheat to the refrigerant flowing into the low-pressure receiver 100 in response to the environmental temperature falling to or below -20°C .

[0071] For example, in response to the measurement of the temperature sensor 101 falling to or below -20°C , the control unit 90 according to the present embodiment reduces the opening degree of the first electric valve 46 to a smaller degree than before the temperature fell to

or below -20°C to thereby increase the pressure and temperature of the refrigerant passing through the indoor heat exchanger 21. This can apply superheat to the refrigerant, turning the refrigerant flowing into the low-pressure receiver 100 into a gaseous refrigerant.

[0072] Alternatively, for example, in response to the measurement of the temperature sensor 101 falling to or below -20°C , the control unit 90 increases the motion frequency of the first compressor 41 to a higher frequency than before the temperature fell to or below -20°C to thereby increase the pressure and temperature of the refrigerant passing through the indoor heat exchanger 21. Such control can also apply superheat to refrigerant, turning the refrigerant flowing into the low-pressure receiver 100 into a gaseous refrigerant.

(Switching of control modes)

[0073] In the present embodiment, the control of the various devices included in the air conditioning unit 10 by the control unit 90 includes a normal control mode and an under-inversion control mode. When the liquid refrigerant and the lubricating oil are not inverted in the low-pressure receiver 100, the control unit 90 controls the various devices in the normal control mode. On the other hand, when there is a possibility of inversion between the liquid refrigerant and the lubricating oil, such as when the environmental temperature falls to or below -20°C , the control unit 90 controls the various devices in the under-inversion control mode. In the under-inversion control mode, the control unit 90 controls the devices such that superheat is applied to the refrigerant flowing into the low-pressure receiver 100. The switching between the normal control mode and the under-inversion control mode is described below with reference to FIG. 5.

[0074] FIG. 5 is a flowchart illustrating an example of switching between the normal control mode and the under-inversion control mode according to the present embodiment.

[0075] When the air conditioning unit 10 is put into operation, the control unit 90 controls the various devices included in the air conditioning unit 10 in the normal control mode (step S 1001). In the normal control mode, the control unit 90 controls the various devices included in the air conditioning unit 10 such that, for example, the outlet temperature of the first outdoor heat exchanger 44, which functions as a radiator during cooling operation, remains constant.

[0076] Then, the control unit 90 determines whether the measurement of the temperature sensor 101 is at or below the inversion temperature (step S1002). If the measurement of the temperature sensor 101 is at or above the inversion temperature (NO in step S1002), the process returns to step S 1001, where the control unit 90 controls the various devices included in air conditioning unit 10 in the normal control mode.

[0077] On the other hand, if the measurement of the temperature sensor 101 is at or below the inversion tem-

perature (YES in step S 1002), the control unit 90 switches the control mode and controls the various devices included the air conditioning unit 10 in the under-inversion control mode (step S1003). For example, the control unit 90 reduces the opening degree of the first electric valve 46 such that superheat is applied to the refrigerant flowing into the low-pressure receiver 100.

[0078] The control unit 90 then determines whether the measurement of the temperature sensor 101 is at or below the inversion temperature (step S1004). If the measurement of the temperature sensor 101 is at or below the inversion temperature (YES in step S1004), the process returns to step S1003, where the control unit 90 controls the various devices included in air conditioning unit 10 in the under-inversion control mode.

[0079] On the other hand, if the measurement of the temperature sensor 101 is at or above the inversion temperature (NO in step S1004), the control unit 90 switches the control mode and controls the various devices included in the air conditioning unit 10 in the normal control mode (step S1005).

[0080] As described above, in response to the measurement of the temperature sensor 101 falling to or below the inversion temperature, the control unit 90 according to the present embodiment controls the various devices such that superheat is applied to the refrigerant flowing into the low-pressure receiver 100. As a result, gaseous refrigerant flows into the low-pressure receiver 100, making it less likely that the liquid refrigerant is stored in the low-pressure receiver 100 and allowing the lubricating oil to be sucked out through the oil return pipe 140 or the oil return port 151 even when the measurement of the temperature sensor 101 is at or below the inversion temperature.

[0081] In FIG. 5, the condition for switching the control mode is based on the measurement of the temperature sensor 101. However, this is not limiting. For example, the control unit 90 may switch the control mode based on the low-side pressure, suction temperature, or the like of the refrigerant.

[0082] The above control is an example of the control to apply superheat to the refrigerant flowing into the low-pressure receiver 100, and other controls may be used.

<Second Embodiment>

[0083] As a configuration that allows the lubricating oil stored in the low-pressure receiver 100 to be supplied to the first compressor 41 even when the environmental temperature falls to or below -20°C , the second embodiment provides an oil suction mechanism that can suck out the lubricating oil and supply it to the first compressor 41 even when the liquid refrigerant becomes a layer below the lubricating oil in the low-pressure receiver 100.

[0084] For example, the outdoor unit 30 according to the second embodiment has a configuration that allows for sucking out both the liquid refrigerant and the lubricating oil in the low-pressure receiver 100. More specif-

ically, for example, the low-pressure receiver 100-2 shown in FIG. 4B may be provided with a plurality of ports on the compressor-side pipe 150 at different heights from the bottom of the reservoir 110, including the oil return port 151, and the liquid refrigerant and the lubricating oil may be sucked out through the plurality of ports. The sucked-out liquid refrigerant and lubricating oil exchange heat with a high-temperature portion in the air conditioning system 1 having a temperature at least higher than -20°C , more preferably having a temperature higher than the evaporation temperature of the sucked-out liquid refrigerant, and are then supplied to the first compressor 41. This allows the lubricating oil to be supplied to the first compressor 41 while preventing the liquid refrigerant from being sucked into the first compressor 41.

<Third Embodiment>

[0085] As a configuration that allows the lubricating oil stored in the low-pressure receiver 100 to be supplied to the first compressor 41 even when the environmental temperature falls to or below -20°C , the third embodiment provides the capability to elevate the temperatures of the liquid refrigerant and the lubricating oil stored in the low-pressure receiver 100 to eliminate inversion.

[0086] For example, the outdoor unit 30 according to the third embodiment includes a heater that can elevate the temperature of the liquid stored inside the low-pressure receiver 100. For example, the heater is provided in proximity or contact with the side or bottom of the reservoir 110 of the low-pressure receiver 100. The heater is turned on under control of the control unit 90 to heat the liquid stored in the low-pressure receiver 100 to an elevated temperature at least higher than the inversion temperature. In this case, for example, the control unit 90 may turn on the heater in response to the measurement of the temperature sensor 101 falling to or below -20°C . This can elevate the temperatures of the liquid refrigerant and the lubricating oil stored in the low-pressure receiver 100 to eliminate inversion.

[0087] In another example, the outdoor unit 30 according to the third embodiment may cause a heat exchange between the refrigerant compressed by the first compressor 41 and the low-pressure receiver 100 or the liquid refrigerant stored in the low-pressure receiver 100 to elevate the temperature of the stored liquid refrigerant. More specifically, the piping from the first compressor 41 to the four-way valve 43 may be extended to be brought into contact with, or wrapped around, the reservoir 110 of the low-pressure receiver 100 to cause a heat exchange between the refrigerant compressed by the first compressor 41 and the low-pressure receiver 100. Alternatively, a portion of the piping may be inserted into the reservoir 110 such that the extended piping passes through the interior of the reservoir 110 of the low-pressure receiver 100 to cause a heat exchange between the refrigerant compressed by the first compressor 41 and the low-pressure receiver 100.

[0088] In still another example, the outdoor unit 30 according to the third embodiment may elevate the temperature of the liquid refrigerant stored in the low-pressure receiver 100 by causing the low-pressure receiver 100 or the liquid refrigerant stored in the low-pressure receiver 100 to exchange heat with exhaust heat from the first compressor 41 or second compressor 51.

[0089] With any of these configurations, too, the liquid refrigerant and the lubricating oil stored in the low-pressure receiver 100 can have an elevated temperature due to the heat gained by the liquid refrigerant through the heat exchange. When the refrigerant compressed by the first compressor 41 is caused to exchange heat with the low-pressure receiver 100 or the liquid refrigerant stored in the low-pressure receiver 100, a temperature sensor such as a thermistor may be installed inside the reservoir 110 of the low-pressure receiver 100 to enable measurement of the temperature of the liquid refrigerant stored in the low-pressure receiver 100.

<Other variants>

[0090] The above embodiments have illustrated the refrigeration cycle system as being used in the air conditioning system 1. However, the scope of use of the refrigeration cycle system is not limited to this. Taking advantage of the heat absorption by the cooler, the refrigeration cycle system may be used in various types of equipment for cooling objects, such as cold storage warehouses, refrigerators, ice machines, etc. Also, taking advantage of the heat dissipation at the radiator, the refrigeration cycle system may also be used in various types of devices for heating objects, such as heaters, water boilers, and water heaters.

[0091] Carbon dioxide and propane have been provided as examples of the refrigerant circulating in each refrigerant circuit. However, the types of refrigerant are not limited to these. For example, a mixed refrigerant made of carbon dioxide and one or more other components or a single component refrigerant or mixed refrigerant free of carbon dioxide may be used in the first refrigerant circuit 31. However, the refrigerant circulating in the first refrigerant circuit 31 is assumed to be incompatible with the lubricating oil for the first compressor 41.

[0092] To further illustrate, the inversion temperature is not limited to -20°C described above as it depends on the combination of the refrigerant and the lubricating oil.

[0093] The above embodiments have illustrated the case where the liquid refrigerant occupies the upper layer and the lubricating oil occupies the lower layer at temperatures higher than the inversion temperature. However, depending on the combination of the refrigerant and the lubricating oil, the opposite may occur where the lubricating oil occupies the upper layer and the liquid refrigerant occupies the lower layer at temperatures higher than the inversion temperature. In this case, too, any of the above embodiments may be applied to provide a configuration that allows the lubricating oil to be supplied to

the first compressor 41 even at or below the inversion temperature.

[0094] The air conditioning unit 10 has been illustrated as having a dual circuit configuration. However, it may have a single circuit configuration without the second refrigerant circuit 32 and the cascade heat exchanger 45, for example. To further illustrate, the configurations of the refrigerant circuits are not limited to those described above, and other configurations may be employed.

[0095] The above embodiments have illustrated the use of the first electric valve 46 to enable control of the opening degree by the control unit 90. However, if control by the control unit 90 is not performed, a capillary tube or orifice plate may be used instead of the first electric valve 46.

[0096] While exemplary embodiments have been described above, it will be understood that various modifications can be made to the forms and details without departing from the spirit and scope of the appended claims.

[0097] For example, part of the configurations described above may be omitted, or other features may be added to the configurations described above. Also, for example, a configuration included in one embodiment may be replaced with a configuration included in another embodiment, or a configuration included in one embodiment may be added to another embodiment.

Reference Signs List

[0098]

- 1 Air conditioning system
- 10 Air conditioning unit
- 21 Indoor heat exchanger
- 31 First refrigerant circuit
- 32 Second refrigerant circuit
- 90 Control unit
- 100 Low-pressure receiver
- 101 Temperature sensor

Claims

1. A refrigeration cycle system comprising:

a compressor lubricated by lubricating oil and configured to compress refrigerant;
 an evaporator configured to allow the refrigerant having dissipated heat and having been decompressed after the compression by the compressor to pass therethrough and cause the passing refrigerant to exchange heat with an object; and
 a storage container provided between the evaporator and the compressor, the storage container being configured to store the refrigerant and the lubricating oil, wherein
 the system is capable of supplying the lubricat-

ing oil stored in the storage container to the compressor even when an environmental temperature of an environment in which the storage container is installed becomes an inversion temperature at which a density of the lubricating oil and a density of the refrigerant in a liquid state are inverted.

2. The refrigeration cycle system according to claim 1, further comprising a control unit configured to control a state of the refrigerant, wherein

the control unit is capable of performing a control to apply superheat to the refrigerant flowing into the storage container in response to the environmental temperature becoming the inversion temperature.

3. The refrigeration cycle system according to claim 2, further comprising an electric valve configured to adjust pressure of the refrigerant passing through the evaporator, wherein

as the control to apply superheat to the refrigerant flowing into the storage container, the control unit is capable of controlling an opening degree of the electric valve to be smaller than before performing the control to apply superheat.

4. The refrigeration cycle system according to claim 2, wherein, as the control to apply superheat to the refrigerant flowing into the storage container, the control unit is capable of controlling a frequency of motion for the compression in the compressor to be greater than before performing the control to apply superheat.

5. The refrigeration cycle system according to any one of claims 1 to 4, wherein the storage container comprises an oil suction mechanism capable of sucking out the lubricating oil and supplying the lubricating oil to the compressor even when the environmental temperature becomes the inversion temperature to cause the refrigerant in a liquid state to become a layer below the lubricating oil in the storage container.

6. The refrigeration cycle system according to claim 5, wherein

the oil suction mechanism comprises a plurality of ports located on piping for sucking out the lubricating oil in the storage container, the plurality of ports being at different heights from a bottom of the storage container,
 the oil suction mechanism is capable of sucking out the refrigerant in a liquid state and the lubricating oil through the plurality of ports, and
 the oil suction mechanism is configured to cause the sucked-out refrigerant in the liquid state and the sucked-out lubricating oil to exchange heat

with a high-temperature portion in the system having a higher temperature than the inversion temperature and then supply the refrigerant and the lubricating oil to the compressor.

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7. The refrigeration cycle system according to any one of claims 1 to 6, wherein the system is capable of elevating temperatures of the refrigerant in a liquid state and the lubricating oil stored in the storage container to eliminate density inversion even when the environmental temperature becomes the inversion temperature. 10
8. The refrigeration cycle system according to any one of claims 1 to 7, further comprising a heater attached to the storage container, the heater being capable of elevating temperatures of the refrigerant in a liquid state and the lubricating oil stored in the storage container. 15
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9. The refrigeration cycle system according to any one of claims 1 to 8, further comprising a radiator configured to allow the refrigerant compressed by the compressor to pass therethrough and extract and dissipate heat from the passing refrigerant, wherein 25
the system is capable of causing a heat exchange between the storage container or the refrigerant in a liquid state stored in the storage container and the refrigerant after passing through the radiator. 30
10. The refrigeration cycle system according to any one of claims 1 to 9, wherein the system is capable of causing a heat exchange between the storage container or the refrigerant in a liquid state stored in the storage container and exhaust heat from the compressor. 35
11. The refrigeration cycle system according to any one of claims 1 to 10, wherein the lubricating oil is polyalkylene glycol. 40

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FIG.1

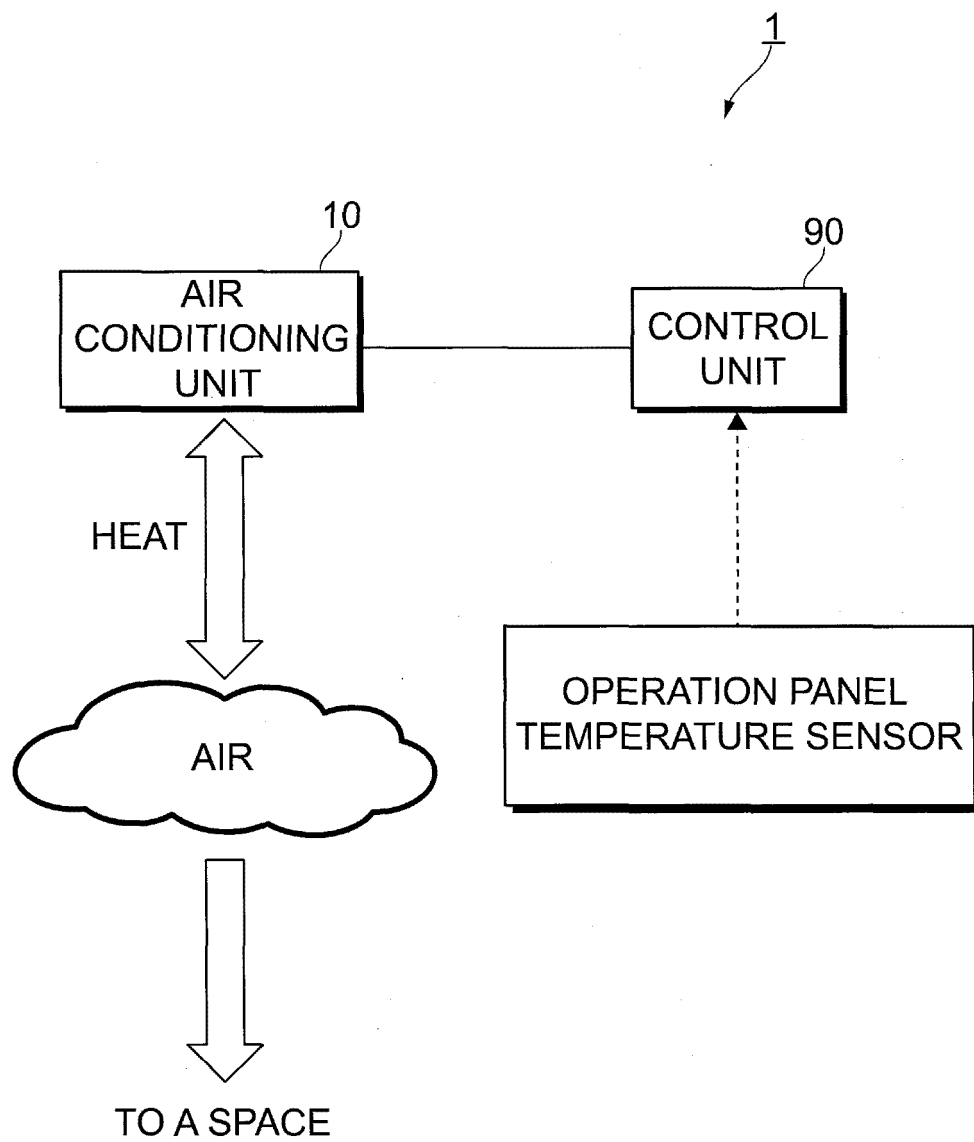


FIG.2

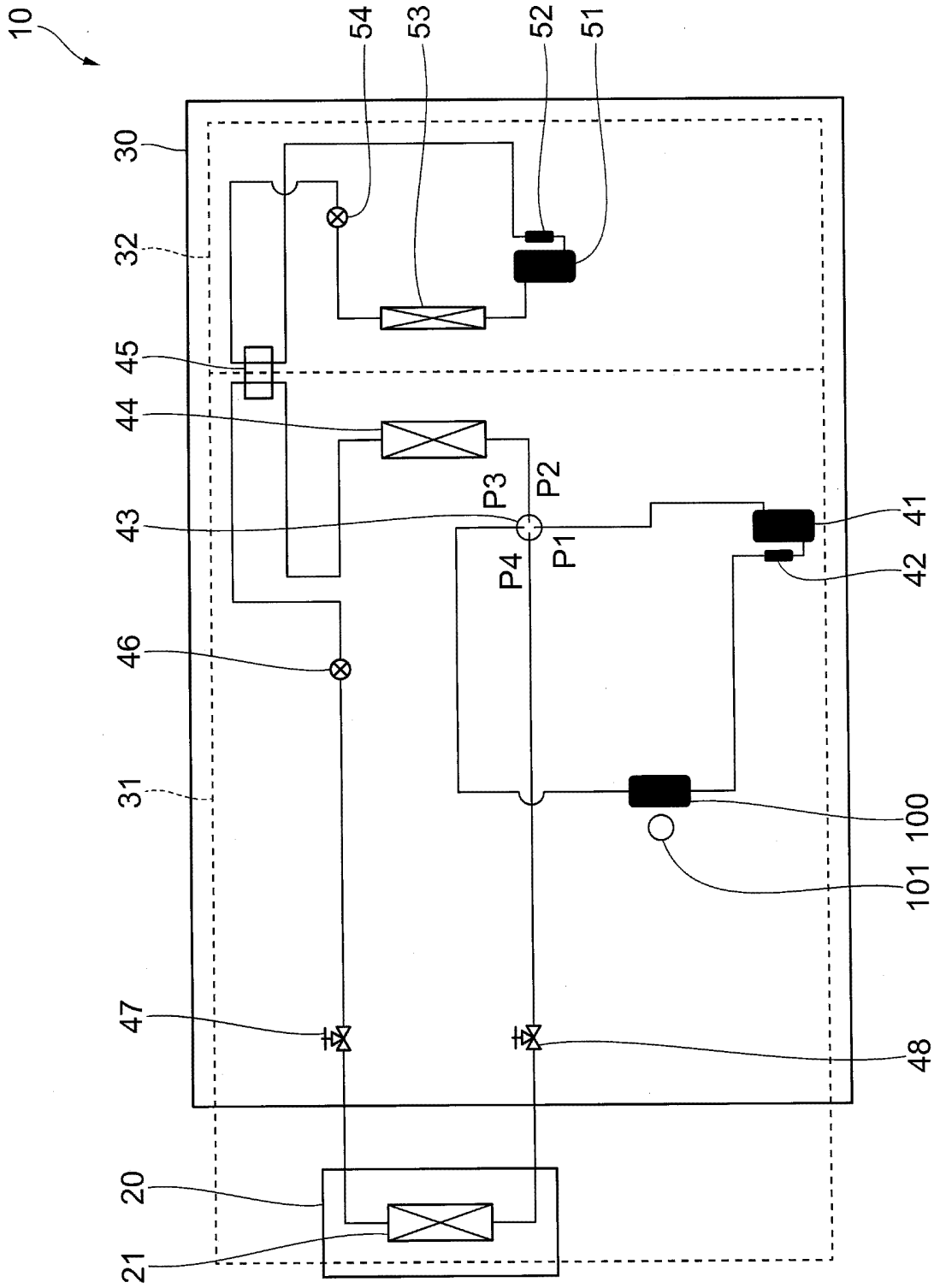


FIG.3

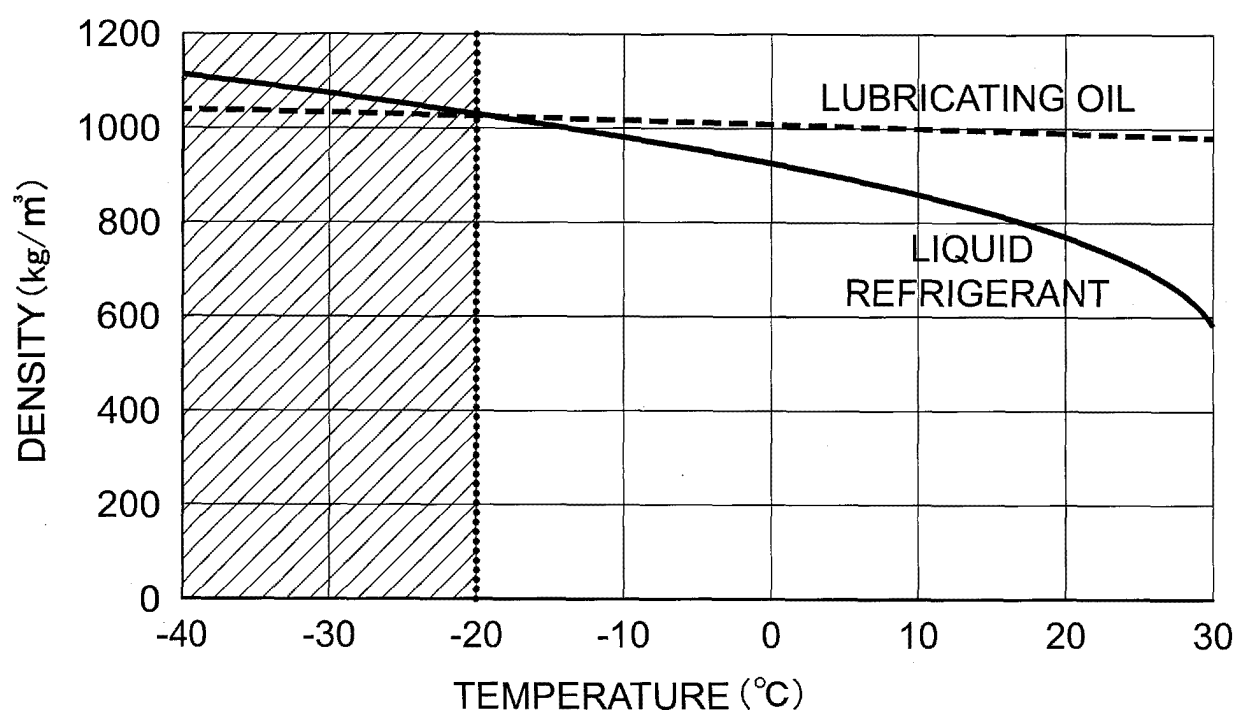


FIG.4A

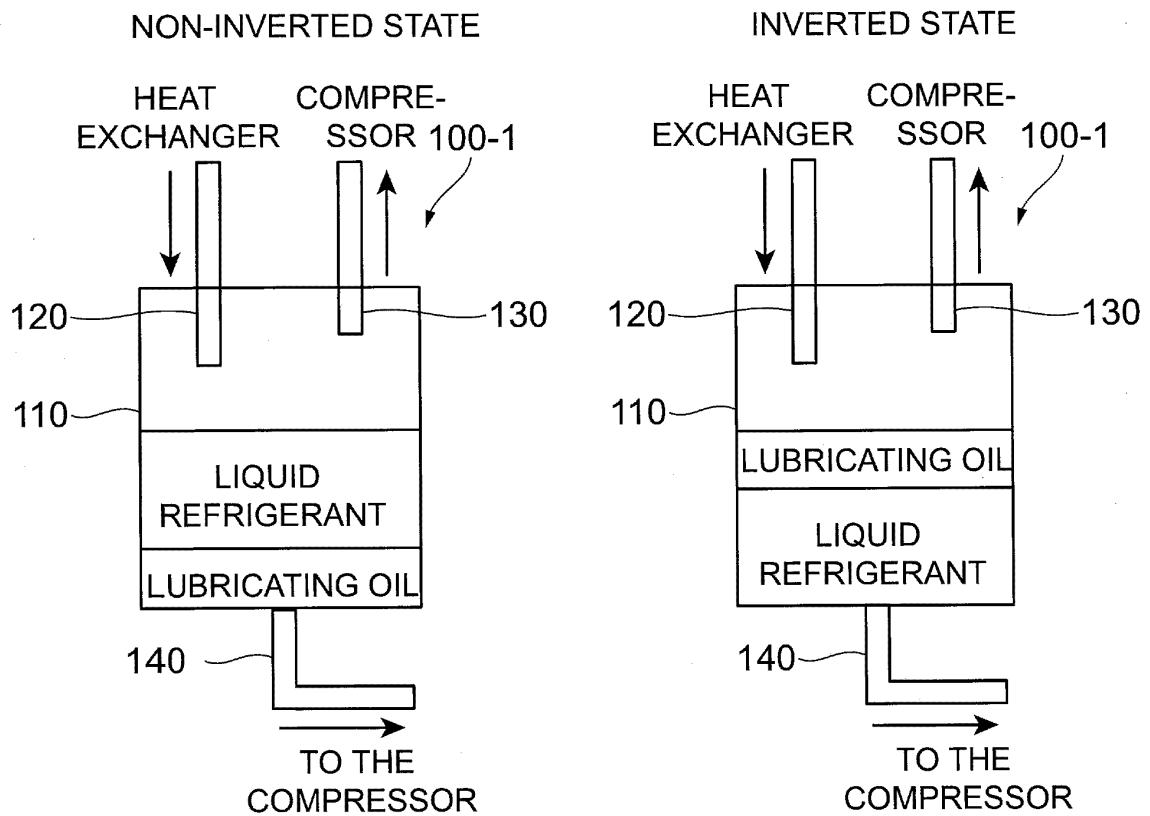


FIG.4B

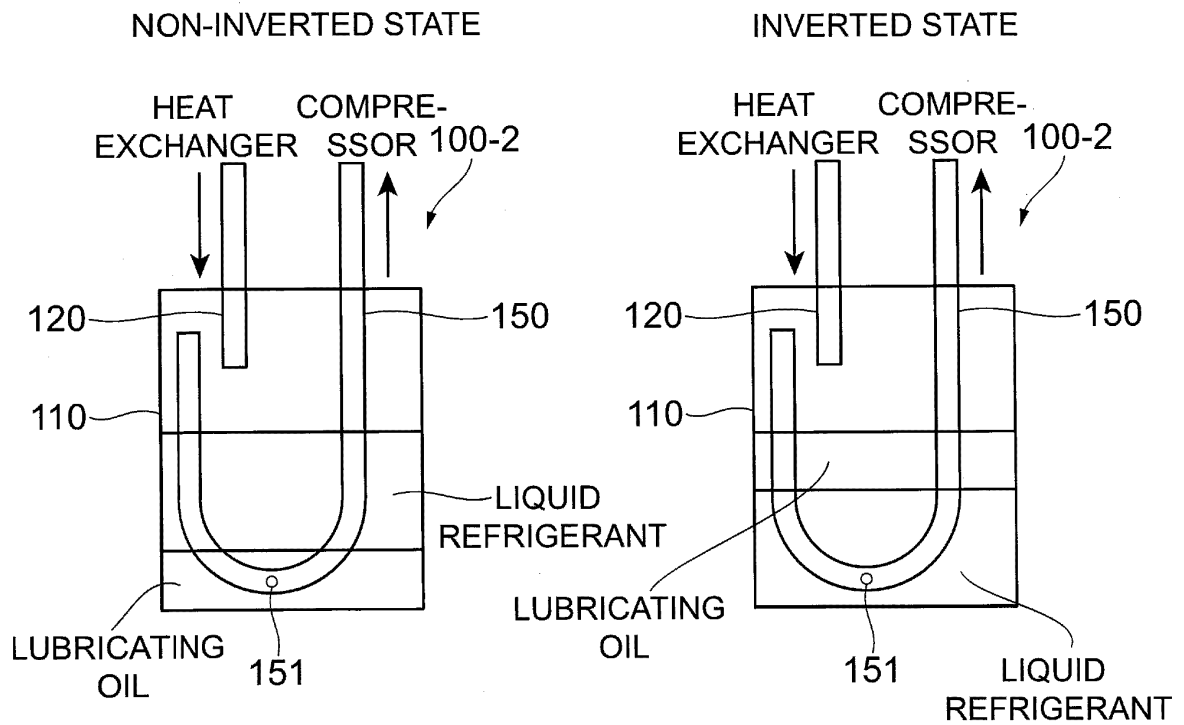
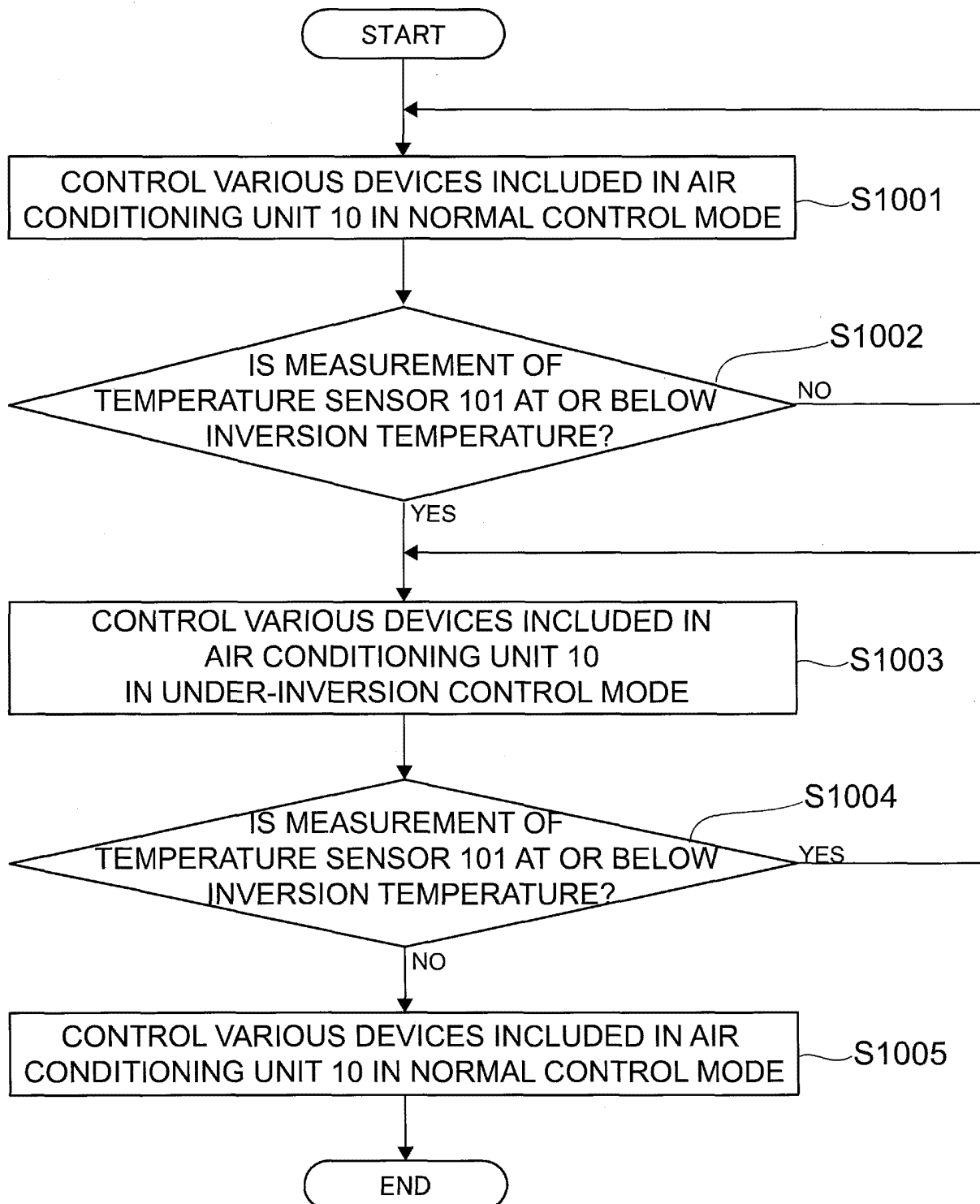


FIG.5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/012858

A. CLASSIFICATION OF SUBJECT MATTER		
<i>F25B 1/00</i> (2006.01)i; <i>F25B 43/00</i> (2006.01)i; <i>F25B 43/02</i> (2006.01)i FI: F25B1/00 387G; F25B1/00 304E; F25B1/00 321J; F25B43/00 G; F25B43/02 E; F25B1/00 371M According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) F25B1/00; F25B43/00; F25B43/02		
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 1971-2024 Registered utility model specifications of Japan 1996-2024 Published registered utility model applications of Japan 1994-2024		
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.
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Y		2-4, 6-10
Y	JP 2008-232564 A (DAIKIN INDUSTRIES, LTD.) 02 October 2008 (2008-10-02) paragraphs [0056]-[0060], fig. 1-4	2-4
Y	JP 2018-4093 A (HITACHI-JOHNSON CONTROLS AIR CONDITIONING, INC.) 11 January 2018 (2018-01-11) paragraphs [0042]-[0050], fig. 5	6
Y	JP 2005-155981 A (MITSUBISHI ELECTRIC CORPORATION) 16 June 2005 (2005-06-16) paragraphs [0015]-[0017]	7-10
Y	JP 2018-63055 A (DENSO CORPORATION) 19 April 2018 (2018-04-19) paragraphs [0064]-[0067]	9
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "D" document cited by the applicant in the international application "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 29 May 2024		Date of mailing of the international search report 11 June 2024
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan		Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2024/012858

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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