

DESCRIPTION

REFRIGERATION DEVICE

TECHNICAL FIELD

The present invention relates to a refrigeration apparatus.

5 BACKGROUND ART

As described in PTL 1 (Japanese Unexamined Patent Application Publication No. 2016-128734), there is a known refrigeration apparatus that uses carbon dioxide as a refrigerant and includes a two-stage compression mechanism including a low-stage side compressor and a high-stage side compressor. This refrigeration apparatus is used to cool the
10 air in a target space by a heat absorbing action of an evaporator for a refrigerant installed in the target space.

SUMMARY OF THE INVENTION

<Technical Problem>

When the above-described refrigeration apparatus is used in an environment in which
15 there is a large difference between the set temperature of the target space and the outside air temperature, the pressure of the refrigerant on the high-pressure side needs to be maintained high during a pull-down operation in which the difference between the temperature of the target space and the outside air temperature is small and a high refrigerating capacity is required. However, since the pressure of the refrigerant in a gas-liquid separator needs to be
20 lower than the critical pressure of the refrigerant, the compression ratio of the low-stage side compressor may decrease during the pull-down operation in which the evaporation temperature of the refrigerant is high, and the refrigerating capacity may decrease.

<Solution to Problem>

A refrigeration apparatus according to a first aspect includes a refrigerant circuit in
25 which a first compressor, a second compressor, a first heat exchanger, an expansion mechanism, and a second heat exchanger are sequentially connected. The first heat exchanger functions as a radiator of a refrigerant compressed by the first compressor or the second compressor. The second heat exchanger functions as a heat absorber for a refrigerant

decompressed by the expansion mechanism. The refrigerant circuit includes a gas-liquid separator or a third heat exchanger, a first channel, a second channel, and a third channel. The gas-liquid separator separates a refrigerant in a gas-liquid two-phase state decompressed by the expansion mechanism into a liquid refrigerant and a gas refrigerant. The third heat exchanger exchanges heat between a refrigerant decompressed by a decompression mechanism after radiating heat in the first heat exchanger and a refrigerant after radiating heat in the first heat exchanger and before being decompressed by the expansion mechanism. The first channel connects the gas-liquid separator or the third heat exchanger to a suction side of the second compressor. The second channel connects a discharge side of the first compressor to the suction side of the second compressor. The third channel connects the discharge side of the first compressor to a discharge side of the second compressor. The first channel guides the gas refrigerant in the gas-liquid separator or the refrigerant decompressed by the decompression mechanism and heat-exchanged in the third heat exchanger to the suction side of the second compressor. The second channel guides a refrigerant discharged from the first compressor to the suction side of the second compressor. The third channel guides the refrigerant discharged from the first compressor to the discharge side of the second compressor in a state where the refrigerant discharged from the first compressor does not flow through the second channel.

The refrigeration apparatus according to the first aspect may perform the two-stage compression operation using the low-stage side compressor and the high-stage side compressor and the single-stage compression operation using only the low-stage side compressor. By performing the single-stage compression operation during the pull-down operation in which the difference between the temperature of the target space and the outside air temperature is small, the refrigeration apparatus may secure the compression ratio of the low-stage side compressor and maintain the high pressure of the refrigerant on the high-pressure side. Therefore, the refrigeration apparatus according to the first aspect may suppress a decrease in the capacity during the pull-down operation.

A refrigeration apparatus according to a second aspect is the refrigeration apparatus

according to the first aspect and further includes a control unit that switches the refrigerant circuit between a first state and a second state. In the first state, the refrigerant discharged from the first compressor flows through the second channel, merges with the gas refrigerant flowing through the first channel, and is suctioned into the second compressor. In the second state, the refrigerant discharged from the first compressor flows through the third channel without flowing through the second channel and merges with a refrigerant discharged from the second compressor. The refrigerant circuit further includes a first valve provided in the second channel and a second valve that is a check valve provided in the third channel. The control unit opens the first valve in the first state and closes the first valve in the second state.

In the refrigeration apparatus according to the second aspect, switching between a state where the two-stage compression operation is performed and a state where the single-stage compression operation is performed may be performed by controlling opening and closing of the valve provided in the refrigerant circuit.

A refrigeration apparatus according to a third aspect is the refrigeration apparatus according to the second aspect, and when the refrigerant circuit is in the second state, the control unit switches the refrigerant circuit from the second state to the first state in a case where a temperature of the refrigerant suctioned into the first compressor decreases to a first value and a temperature of the refrigerant discharged from the first compressor increases to a second value.

The refrigeration apparatus according to the third aspect transitions to a state where the two-stage compression operation is performed when the load on the low-stage side compressor increases in a state where the single-stage compression operation is performed. Therefore, the refrigeration apparatus according to the third aspect may reduce the load on the low-stage side compressor and suppress a decrease in the reliability of the low-stage side compressor.

A refrigeration apparatus according to a fourth aspect is the refrigeration apparatus according to the second aspect or the third aspect, and when the refrigerant circuit is in the first state, the control unit switches the refrigerant circuit from the first state to the second

state in a case where a temperature of the refrigerant suctioned into the first compressor increases to a third value, or in a case where a number of rotations of the first compressor falls below a number of rotations of the second compressor.

The refrigeration apparatus according to the fourth aspect transitions to a state where the single-stage compression operation is performed when the load on the high-stage side compressor increases in a state where the two-stage compression operation is performed. Therefore, the refrigeration apparatus according to the fourth aspect may reduce the load on the high-stage side compressor and suppress a decrease in the reliability of the high-stage side compressor.

A refrigeration apparatus according to a fifth aspect is the refrigeration apparatus according to any one of the second to fourth aspects, and the control unit switches the refrigerant circuit among the first state, the second state, and a third state. In the third state, the refrigerant is not suctioned into the second compressor, and the refrigerant discharged from the first compressor flows through the third channel without flowing through the second channel. The refrigerant circuit further includes a third valve provided in the first channel. The control unit opens the third valve in the first state or the second state and closes the third valve in the third state.

In the refrigeration apparatus according to the fifth aspect, in a state where the single-stage compression operation is performed, switching between a state where a degassing operation is performed, in which the gas refrigerant in the gas-liquid separator is compressed by the high-stage side compressor, and a state where the degassing operation is not performed may be performed by controlling opening and closing of the valve provided in the refrigerant circuit.

A refrigeration apparatus according to a sixth aspect is the refrigeration apparatus according to the fifth aspect, and the control unit switches the refrigerant circuit to the third state, the second state, and the first state in this order when the first compressor and the second compressor are activated.

The refrigeration apparatus according to the sixth aspect does not perform the

degassing operation when the amount of refrigerant on the high-pressure side is small at the time of activation and performs control to start the degassing operation when the amount of refrigerant on the high-pressure side increases. Therefore, the refrigeration apparatus according to the sixth aspect may reduce the load on the high-stage side compressor and suppress a decrease in the capacity.

A refrigeration apparatus according to a seventh aspect is the refrigeration apparatus according to any one of the first to sixth aspects, and the refrigerant circuit includes a gas-liquid separator and further includes a fourth channel. The fourth channel connects the gas-liquid separator to the first channel. The fourth channel guides refrigerating machine oil in the gas-liquid separator to the suction side of the second compressor via the first channel together with the liquid refrigerant in the gas-liquid separator.

The refrigeration apparatus according to the seventh aspect may prevent a shortage of refrigerating machine oil in the high-pressure side compressor.

A refrigeration apparatus according to an eighth aspect is the refrigeration apparatus according to any one of the first to seventh aspects, and the refrigerant circuit further includes a fifth channel. The fifth channel connects the discharge side of the second compressor to the suction side of the second compressor. The fifth channel guides the refrigerating machine oil discharged from the second compressor to the suction side of the second compressor. The fifth channel is provided with an oil separator that separates the refrigerating machine oil from a mixture of the refrigerant and the refrigerating machine oil.

The refrigeration apparatus according to the eighth aspect may prevent a shortage of the refrigerating machine oil in the high-pressure side compressor.

A refrigeration apparatus according to a ninth aspect is the refrigeration apparatus according to any one of the first to eighth aspects, and the refrigerant circuit includes a gas-liquid separator and further includes a fourth heat exchanger. The fourth heat exchanger heats the gas refrigerant in the gas-liquid separator by exchanging heat with a refrigerant after radiating heat in the first heat exchanger and before being decompressed by the expansion mechanism.

In the refrigeration apparatus according to the ninth aspect, the high performance of the radiator may be maintained by increasing the degree of superheating of the refrigerant suctioned into the high-stage side compressor and increasing the difference between the temperature of the radiator and the outside air temperature. Further, in the refrigeration apparatus according to the ninth aspect, the dryness of the refrigerant decompressed by the expansion mechanism is decreased to prevent a shortage of the refrigerant to be suctioned into the low-stage side compressor, and thus a decrease in the reliability of the compressor may be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[Fig. 1] Fig. 1 is a diagram illustrating an example of an overall configuration of a refrigeration apparatus 100 according to a first embodiment.

[Fig. 2] Fig. 2 is a block diagram of a control unit 70 according to the first embodiment.

[Fig. 3] Fig. 3 is a Mollier diagram during a two-stage compression operation according to the first embodiment.

[Fig. 4] Fig. 4 is a Mollier diagram during a single-stage compression/degassing operation according to the first embodiment.

[Fig. 5] Fig. 5 is a Mollier diagram during a single-stage compression operation according to a second embodiment.

[Fig. 6] Fig. 6 is a diagram illustrating an example of an overall configuration of a refrigeration apparatus 200 according to a third embodiment.

[Fig. 7] Fig. 7 is a block diagram of the control unit 70 according to the third embodiment.

[Fig. 8] Fig. 8 is a diagram illustrating an example of an overall configuration of a refrigeration apparatus 300 according to Modification B.

[Fig. 9] Fig. 9 is a Mollier diagram during a single-stage compression/degassing operation according to Modification B.

DESCRIPTION OF EMBODIMENTS

-First Embodiment-

(1) Configuration of Refrigeration Apparatus 100

As illustrated in Fig. 1, the refrigeration apparatus 100 includes a heat source unit 2, a utilization unit 3, a liquid-side connection pipe 6, a gas-side connection pipe 7, a remote controller 8, and a control unit 70. In the refrigeration apparatus 100, the heat source unit 2 and the utilization unit 3 are connected to each other via the liquid-side connection pipe 6 and the gas-side connection pipe 7, and thus a refrigerant circuit 10 is configured, in which a refrigerant circulates.

In the refrigeration apparatus 100, a vapor compression refrigeration cycle is performed, in which the refrigerant sealed in the refrigerant circuit 10 is compressed, condensed, decompressed, evaporated, and then compressed again. The refrigeration apparatus 100 cools the air in the target space by evaporation of the refrigerant circulating in the refrigeration cycle. The refrigeration apparatus 100 is attached to, for example, a marine container and cools the air in the target space inside the container.

The refrigeration apparatus 100 may include the plurality of utilization units 3. In this case, the plurality of utilization units 3 is connected in parallel to the one heat source unit 2 so that the refrigerant circuit 10 is configured.

The refrigerant sealed in the refrigerant circuit 10 is carbon dioxide (R744). Carbon dioxide is a non-flammable natural refrigerant having a low global warming potential (GWP) compared to fluorine-containing refrigerants. In the refrigerant circuit 10, the high-pressure refrigerant in the refrigeration cycle is in a supercritical state where the pressure is higher than the critical pressure.

(1-1) Heat Source Unit 2

The heat source unit 2 is installed in a space outside the target space. The heat source unit 2 is installed outdoors, for example. As illustrated in Fig. 1, the heat source unit 2 includes a first compressor 21, a first accumulator 21b, a second compressor 22, a second accumulator 22b, a heat-source side heat exchanger 23, a heat-source side fan 24, a first heat-source side expansion valve 25a, a second heat-source side expansion valve 25b, a gas-liquid

separator 26, an intermediate heat exchanger 27, a liquid-side shutoff valve 28, a gas-side shutoff valve 29, a gas vent valve 41, a first shutoff valve 43, and a second shutoff valve 44.

The heat source unit 2 includes a first pipe 51 to a sixth pipe 56 and a bypass pipe 59 through which the refrigerant circulating in the refrigerant circuit 10 flows. The first pipe 51 connects the gas-side shutoff valve 29 to the suction side of the first compressor 21. The second pipe 52 connects the discharge side of the first compressor 21 to the suction side of the second compressor 22. The third pipe 53 connects the discharge side of the second compressor 22 to the inlet side of the heat-source side heat exchanger 23. The fourth pipe 54 connects the outlet side of the heat-source side heat exchanger 23 to the inlet side of the gas-liquid separator 26. The fifth pipe 55 connects the liquid outlet side of the gas-liquid separator 26 to the liquid-side shutoff valve 28. The sixth pipe 56 connects the gas outlet side of the gas-liquid separator 26 to the second pipe 52. The bypass pipe 59 connects the second pipe 52 to the third pipe 53.

The first compressor 21 and the second compressor 22 constitute a compression mechanism of the refrigeration apparatus 100 and compress a low-pressure refrigerant in the refrigeration cycle to a high-pressure refrigerant. When the refrigeration apparatus 100 performs a two-stage compression operation described below, a low-pressure refrigerant in the refrigeration cycle is compressed by the first compressor 21 to become an intermediate-pressure refrigerant. The intermediate-pressure refrigerant is compressed by the second compressor 22 to become a high-pressure refrigerant. The intermediate pressure in the refrigeration cycle is a pressure between the low pressure and the high pressure. The intermediate-pressure refrigerant in the refrigeration cycle is in a state where the pressure thereof is lower than the critical pressure. The first compressor 21 and the second compressor 22 have a hermetic structure in which compression elements of a volume variable type such as a rotary type or a scroll type are rotationally driven by a first compressor motor 21a and a second compressor motor 22a, respectively. The operating frequencies of the first compressor motor 21a and the second compressor motor 22a (the numbers of rotations of the first compressor 21 and the second compressor 22) may be controlled by inverters.

The first accumulator 21b is provided in the first pipe 51. The second accumulator 22b is provided in the second pipe 52. The first accumulator 21b and the second accumulator 22b are refrigerant containers capable of temporarily storing a surplus refrigerant in the refrigerant circuit 10 as a liquid refrigerant.

5 The heat-source side heat exchanger 23 is a gas cooler that functions as a radiator (condenser) of a high-pressure refrigerant in the refrigeration cycle.

 The heat-source side fan 24 supplies the air (outside air or the like) outside the target space to the heat-source side heat exchanger 23, causes the air to exchange heat with the refrigerant in the heat-source side heat exchanger 23, and then generates the air flow to be
10 discharged to outside of the heat source unit 2. The heat-source side fan 24 is rotationally driven by a heat-source side fan motor 24a.

 The first heat-source side expansion valve 25a is provided in the fourth pipe 54. The second heat-source side expansion valve 25b is provided in the fifth pipe 55. The first heat-source side expansion valve 25a and the second heat-source side expansion valve 25b
15 constitute an expansion mechanism of the refrigeration apparatus 100 and decompress a high-pressure refrigerant in the refrigeration cycle to a low-pressure refrigerant. The high-pressure refrigerant in the refrigeration cycle is decompressed by the first heat-source side expansion valve 25a to become an intermediate-pressure refrigerant. The intermediate-pressure refrigerant is decompressed by the second heat-source side expansion valve 25b to become a
20 low-pressure refrigerant. The first heat-source side expansion valve 25a and the second heat-source side expansion valve 25b are electric expansion valves whose opening degrees is adjustable under the control of the control unit 70.

 The gas-liquid separator 26 is a container that separates the refrigerant, which is decompressed by the first heat-source side expansion valve 25a into a gas-liquid two-phase state, into a liquid refrigerant and a gas refrigerant. The refrigerant in a gas-liquid two-phase state, which passes through the first heat-source side expansion valve 25a, flows into the gas-liquid separator 26 from the inlet side of the gas-liquid separator 26. The gas refrigerant separated by the gas-liquid separator 26 flows out from the gas outlet side of the gas-liquid
25

separator 26. The liquid refrigerant separated by the gas-liquid separator 26 flows out from the liquid outlet side of the gas-liquid separator 26.

The intermediate heat exchanger 27 exchanges heat between the refrigerant after radiating heat in the heat-source side heat exchanger 23 and before being decompressed by the first heat-source side expansion valve 25a and the gas refrigerant having flowed out from the gas outlet side of the gas-liquid separator 26. The refrigerant before being decompressed by the first heat-source side expansion valve 25a radiates heat due to heat exchange in the intermediate heat exchanger 27. The gas refrigerant flowing out from the gas outlet side of the gas-liquid separator 26 is heated by heat exchange in the intermediate heat exchanger 27.

The liquid-side shutoff valve 28 is a manual valve provided at a connection portion with the liquid-side connection pipe 6.

The gas-side shutoff valve 29 is a manual valve provided at a connection portion with the gas-side connection pipe 7.

The gas vent valve 41 is provided in the sixth pipe 56. The gas vent valve 41 is provided between the gas-liquid separator 26 and the intermediate heat exchanger 27. The gas vent valve 41 adjusts the amount of gas refrigerant flowing through the sixth pipe 56. The gas vent valve 41 is an electric expansion valve whose opening degree is adjustable under the control of the control unit 70.

The first shutoff valve 43 is provided in the second pipe 52. As illustrated in Fig. 1, in the second pipe 52, a connection portion with the bypass pipe 59, the first shutoff valve 43, and a connection portion with the sixth pipe 56 are provided in this order from the discharge side of the first compressor 21 toward the suction side of the second compressor 22. The first shutoff valve 43 is an electric expansion valve whose opening degree is adjustable under the control of the control unit 70. While being closed, the first shutoff valve 43 shuts off the flow of the refrigerant from the discharge side of the first compressor 21 toward the suction side of the second compressor 22.

The second shutoff valve 44 is provided in the bypass pipe 59. The second shutoff valve 44 is a check valve. The second shutoff valve 44 allows the refrigerant to flow from the

second pipe 52 toward the third pipe 53. The second shutoff valve 44 shuts off the flow of the refrigerant from the third pipe 53 toward the second pipe 52. The second shutoff valve 44 may be an electric expansion valve whose opening degree is adjustable under the control of the control unit 70.

5 The heat source unit 2 includes a heat-source unit control unit 20 that controls the operation of each component included in the heat source unit 2. The heat-source unit control unit 20 configures the control unit 70. The heat-source unit control unit 20 is, for example, a microcomputer including a CPU, a memory, and the like. The heat-source unit control unit 20 is connected to a utilization-unit control unit 30 of the utilization unit 3 via a communication
10 line, and transmits and receives control signals and the like.

 Further, the heat source unit 2 further includes a first temperature sensor 61 to a fifth temperature sensor 65.

 The first temperature sensor 61 is attached to the third pipe 53. The first temperature sensor 61 is attached, for example, near the inlet of the heat-source side heat exchanger 23.
15 The first temperature sensor 61 measures a first temperature, which is the temperature of the refrigerant at the inlet of the heat-source side heat exchanger 23. The first temperature is substantially equal to the temperature of the refrigerant before flowing into the heat-source side heat exchanger 23 and undergoing heat exchange in the heat-source side heat exchanger 23.

20 The second temperature sensor 62 is installed outdoors. The second temperature sensor 62 is attached to, for example, the outer surface of a casing of the heat source unit 2. The second temperature sensor 62 measures a second temperature, which is the temperature of the air that exchanges heat with the refrigerant in the heat-source side heat exchanger 23. The second temperature is substantially equal to the outside air temperature.

25 The third temperature sensor 63 is installed in the target space. The third temperature sensor 63 is attached to, for example, the outer surface of a casing of the utilization unit 3. The third temperature sensor 63 measures a third temperature, which is the temperature of the target space in which the utilization unit 3 is installed.

The fourth temperature sensor 64 is attached to the first pipe 51. The fourth temperature sensor 64 is attached, for example, near the suction side of the first compressor 21. The fourth temperature sensor 64 measures a fourth temperature that is the temperature of the refrigerant suctioned into the first compressor 21. The fourth temperature is substantially equal to the evaporation temperature of the refrigerant.

The fifth temperature sensor 65 is attached to the second pipe 52. The fifth temperature sensor 65 is attached, for example, near the discharge side of the first compressor 21. The fifth temperature sensor 65 measures a fifth temperature that is the temperature of the refrigerant discharged from the first compressor 21.

(1-2) Utilization Unit 3

The utilization unit 3 is installed in the target space. As illustrated in Fig. 1, the utilization unit 3 includes a utilization-side heat exchanger 31 and a utilization-side fan 32.

The utilization-side heat exchanger 31 functions as a heat absorber (evaporator) for the low-pressure refrigerant in the refrigeration cycle. A pipe extending from the inlet side of the utilization-side heat exchanger 31 is connected to the liquid-side connection pipe 6. A pipe extending from the outlet side of the utilization-side heat exchanger 31 is connected to the gas-side connection pipe 7. As a result, in the refrigerant circuit 10, the first compressor 21, the second compressor 22, the heat-source side heat exchanger 23, the first heat-source side expansion valve 25a, the second heat-source side expansion valve 25b, and the utilization-side heat exchanger 31 are sequentially connected to form a refrigerant circulation channel.

The utilization-side fan 32 supplies the air in the target space to the utilization-side heat exchanger 31, causes the air to exchange heat with the refrigerant in the utilization-side heat exchanger 31, and then generates the air flow to be discharged into the target space. The utilization-side fan 32 is rotationally driven by a utilization-side fan motor 32a.

The utilization unit 3 includes a utilization-unit control unit 30 that controls the operation of each component included in the utilization unit 3. The utilization-unit control unit 30 configures the control unit 70. The utilization-unit control unit 30 is, for example, a microcomputer including a CPU, a memory, and the like. The utilization-unit control unit 30

is connected to the heat-source unit control unit 20 of the heat source unit 2 via a communication line, and transmits and receives control signals and the like.

(1-3) Remote Controller 8

The remote controller 8 functions as an input device for a user of the refrigeration apparatus 100 to input various instructions to the refrigeration apparatus 100. For example, the user operates the remote controller 8 to adjust the set temperature and the set humidity of the target space. The remote controller 8 also functions as a display device that displays the operating state of the refrigeration apparatus 100 and predetermined notification information. The remote controller 8 is connected to the heat-source unit control unit 20 and the utilization-unit control unit 30 via a communication line, and mutually transmits and receives signals.

(1-4) Control Unit 70

In the refrigeration apparatus 100, the heat-source unit control unit 20 and the utilization-unit control unit 30 are connected via a communication line, and thus the control unit 70 is formed, which is hardware to control the operation of the refrigeration apparatus 100. The control by the control unit 70 is realized by integral operation of the heat-source unit control unit 20 and the utilization-unit control unit 30.

As illustrated in Fig. 2, the control unit 70 is electrically connected to actuators included in the heat source unit 2. Specifically, the actuators included in the heat source unit 2 are the first compressor motor 21a, the second compressor motor 22a, the heat-source side fan motor 24a, the first heat-source side expansion valve 25a, the second heat-source side expansion valve 25b, the gas vent valve 41, and the first shutoff valve 43. The control unit 70 is also electrically connected to the first temperature sensor 61 to the fifth temperature sensor 65, the remote controller 8, and an actuator included in the utilization unit 3. Specifically, the actuator included in the utilization unit 3 is the utilization-side fan motor 32a.

As illustrated in Fig. 2, the control unit 70 includes a storage unit 71, a communication unit 72, an actuator control unit 74, and a display control unit 75. Each of these elements realizes a specific function of the control unit 70. The control unit 70 executes these functions

by executing a control program stored in a ROM, a RAM, a flash memory, or the like.

The storage unit 71 stores predetermined information in a predetermined storage area in response to a request from another element of the control unit 70. The predetermined information is, for example, a result of calculation executed by the control unit 70 and a
5 command input to the remote controller 8.

The communication unit 72 functions as a communication interface to transmit and receive signals to and from each device connected to the control unit 70. In response to the request from the actuator control unit 74, the communication unit 72 transmits a predetermined signal to the designated actuator. The communication unit 72 receives a signal
10 output from the remote controller 8 or the like and requests the storage unit 71 to store the signal in a predetermined storage area. In addition, the communication unit 72 receives the temperatures measured by the first temperature sensor 61 to the fifth temperature sensor 65 from the first temperature sensor 61 to the fifth temperature sensor 65.

The actuator control unit 74 controls the operation of each actuator included in the
15 refrigeration apparatus 100 based on a control program. Specifically, the actuator control unit 74 has a function to control in real time the number of rotations of the first compressor 21, the number of rotations of the second compressor 22, the number of rotations of the heat-source side fan 24, the opening degree of the first heat-source side expansion valve 25a, the opening degree of the second heat-source side expansion valve 25b, the number of rotations
20 of the utilization-side fan 32, the opening degree of the gas vent valve 41, and the opening degree of the first shutoff valve 43.

The display control unit 75 is a functional unit that controls the operation of the remote controller 8 as a display device. The display control unit 75 causes the remote controller 8 to output predetermined information in order to notify the user of the information
25 related to the operating state and situation of the refrigeration apparatus 100, etc. For example, the display control unit 75 displays the set temperature and the like on a display of the remote controller 8.

(2) Operation of Refrigeration Apparatus 100

Next, changes in the state of the refrigerant circulating through the refrigerant circuit 10 of the refrigeration apparatus 100 will be described with reference to the Mollier diagrams illustrated in Figs. 3 and 4. Figs. 3 and 4 illustrate a saturated liquid line L1, a dry saturated vapor line L2, and a critical point CP of the refrigerant. The critical point CP is an end point on the high-pressure side of the saturated liquid line L1 and the dry saturated vapor line L2. The refrigerant having a pressure higher than the critical point CP is in a supercritical state.

During the operation of the refrigeration apparatus 100, the refrigerant circuit 10 is in any one of a first state and a second state. In the first state, the gas vent valve 41 is closed and the first shutoff valve 43 is opened. In the second state, the gas vent valve 41 is opened, and the first shutoff valve 43 is closed.

Fig. 3 is a Mollier diagram when the refrigerant circuit 10 is in the first state. The first state is a state where the refrigeration apparatus 100 performs a two-stage compression operation. The two-stage compression operation is an operation in which the gas refrigerant heat-exchanged in the utilization-side heat exchanger 31 is compressed by the first compressor 21 and the second compressor 22.

During the two-stage compression operation, the low-pressure refrigerant in the refrigeration cycle is sequentially compressed by the first compressor 21 on the low-stage side and the second compressor 22 on the high-stage side to become a high-pressure refrigerant in the refrigeration cycle. Specifically, during the two-stage compression operation, the first compressor 21 suctions and compresses the low-pressure refrigerant flowing through the first pipe 51 and discharges the intermediate-pressure refrigerant to the second pipe 52. The intermediate-pressure refrigerant discharged to the second pipe 52 passes through the first shutoff valve 43. The second compressor 22 suctions and compresses the intermediate-pressure refrigerant flowing through the second pipe 52 and discharges the high-pressure refrigerant to the third pipe 53.

Fig. 4 is a Mollier diagram when the refrigerant circuit 10 is in the second state. The second state is a state where the refrigeration apparatus 100 performs a single-stage compression/degassing operation. In the single-stage compression/degassing operation, a

single-stage compression operation and a degassing operation are performed. The single-stage compression operation is an operation in which the gas refrigerant heat-exchanged in the utilization-side heat exchanger 31 is compressed by the first compressor 21. The degassing operation is an operation in which the gas refrigerant separated by the gas-liquid separator 26 is compressed by the second compressor 22.

During the single-stage compression operation, a low-pressure refrigerant in the refrigeration cycle is compressed by the first compressor 21 to become a high-pressure refrigerant in the refrigeration cycle. Specifically, the first compressor 21 suctions and compresses the low-pressure refrigerant flowing through the first pipe 51 and discharges the high-pressure refrigerant to the second pipe 52. The high-pressure refrigerant discharged to the second pipe 52 cannot pass through the first shutoff valve 43 and flows into the bypass pipe 59. The high-pressure refrigerant flowing into the bypass pipe 59 passes through the second shutoff valve 44 and flows into the third pipe 53.

During the degassing operation, the intermediate-pressure refrigerant in the refrigeration cycle is compressed by the second compressor 22 to become a high-pressure refrigerant in the refrigeration cycle. Specifically, the second compressor 22 suctions and compresses the intermediate-pressure gas refrigerant flowing into the second pipe 52 from the gas-liquid separator 26 via the sixth pipe 56 and discharges the high-pressure refrigerant to the third pipe 53.

During the single-stage compression/degassing operation, the high-pressure refrigerant discharged from the first compressor 21 by the single-stage compression operation merges with the high-pressure refrigerant discharged from the second compressor 22 by the degassing operation in the third pipe 53. The refrigerant merged in the third pipe 53 flows into the heat-source side heat exchanger 23.

(2-1) Change in State of Refrigerant in First State

As illustrated in Fig. 3, in the heat source unit 2, the low-pressure refrigerant flowing through the refrigerant circuit 10 is compressed by the first compressor 21 to become an intermediate-pressure refrigerant (P1 → P2). The intermediate-pressure refrigerant

discharged from the first compressor 21 slightly radiates heat when passing through the second pipe 52 ($P2 \rightarrow P3$). Then, the intermediate-pressure refrigerant is compressed by the second compressor 22 to become a high-pressure refrigerant ($P3 \rightarrow P4$). The high-pressure refrigerant discharged from the second compressor 22 flows into the heat-source side heat exchanger 23. The high-pressure refrigerant flowing into the heat-source side heat exchanger 23 exchanges heat with the outside air and radiates heat ($P4 \rightarrow P5$).

The refrigerant having radiated heat in the heat-source side heat exchanger 23 is decompressed by the first heat-source side expansion valve 25a to become an intermediate-pressure refrigerant ($P5 \rightarrow P6$). The refrigerant decompressed by the first heat-source side expansion valve 25a into a gas-liquid two-phase state flows into the gas-liquid separator 26 and is separated into a liquid refrigerant and a gas refrigerant ($P6 \rightarrow P7, P8$). The liquid refrigerant separated by the gas-liquid separator 26 is further decompressed by the second heat-source side expansion valve 25b to become a low-pressure refrigerant ($P7 \rightarrow P9$). The liquid refrigerant decompressed by the second heat-source side expansion valve 25b passes through the liquid-side shutoff valve 28 and the liquid-side connection pipe 6, flows into the utilization unit 3, and flows into the utilization-side heat exchanger 31. The low-pressure liquid refrigerant flowing into the utilization-side heat exchanger 31 exchanges heat with the air in the target space in which the utilization unit 3 is installed, absorbs heat, and becomes a gas refrigerant ($P9 \rightarrow P1$). The refrigerant having absorbed heat in the utilization-side heat exchanger 31 passes through the gas-side connection pipe 7 and flows into the heat source unit 2 from the gas-side shutoff valve 29. The low-pressure refrigerant flowing into the heat source unit 2 is suctioned into the first compressor 21.

(2-2) Change in State of Refrigerant in Second State

As illustrated in Fig. 4, in the heat source unit 2, the low-pressure refrigerant flowing through the refrigerant circuit 10 is compressed by the first compressor 21 to become a high-pressure refrigerant ($P1 \rightarrow P2$). The intermediate-pressure refrigerant, which is the gas refrigerant separated by the gas-liquid separator 26 and heated by the intermediate heat exchanger 27, is compressed by the second compressor 22 to become a high-pressure

refrigerant (P3 → P4). The high-pressure refrigerants discharged from the first compressor 21 and the second compressor 22 merge with each other and flow into the heat-source side heat exchanger 23. The high-pressure refrigerant flowing into the heat-source side heat exchanger 23 exchanges heat with the outside air and radiates heat (P2, P4 → P5).

5 The refrigerant having radiated heat in the heat-source side heat exchanger 23 exchanges heat with the gas refrigerant separated by the gas-liquid separator 26 in the intermediate heat exchanger 27 and further radiates heat (P5 → P6). Then, the refrigerant having radiated heat in the intermediate heat exchanger 27 is decompressed by the first heat-source side expansion valve 25a to become an intermediate-pressure refrigerant (P6 → P7).

10 The refrigerant decompressed by the first heat-source side expansion valve 25a into a gas-liquid two-phase state flows into the gas-liquid separator 26 and is separated into a liquid refrigerant and a gas refrigerant (P7 → P8, P9). The liquid refrigerant separated by the gas-liquid separator 26 is further decompressed by the second heat-source side expansion valve 25b to become a low-pressure refrigerant (P8 → P10). The liquid refrigerant decompressed
15 by the second heat-source side expansion valve 25b passes through the liquid-side shutoff valve 28 and the liquid-side connection pipe 6, flows into the utilization unit 3, and flows into the utilization-side heat exchanger 31. The low-pressure liquid refrigerant flowing into the utilization-side heat exchanger 31 exchanges heat with the air in the target space in which the utilization unit 3 is installed, absorbs heat, and becomes a gas refrigerant (P10 → P11). The
20 refrigerant having absorbed heat in the utilization-side heat exchanger 31 passes through the gas-side connection pipe 7 and flows into the heat source unit 2 from the gas-side shutoff valve 29. The low-pressure refrigerant flowing into the heat source unit 2 is suctioned into the first compressor 21.

 The gas refrigerant separated by the gas-liquid separator 26 flows through the sixth
25 pipe 56 and is slightly decompressed when passing through the gas vent valve 41 (P9 → P11). The decompressed gas refrigerant is heated in the intermediate heat exchanger 27 by exchanging heat with the refrigerant before being decompressed by the first heat-source side expansion valve 25a and is suctioned into the second compressor 22 (P11 → P3).

(3) Control Of Refrigeration Apparatus 100

During the operation of the refrigeration apparatus 100, the control unit 70 controls the state of the refrigerant circuit 10 in real time based on at least one of the first temperature to the fifth temperature acquired from the first temperature sensor 61 to the fifth temperature sensor 65.

Immediately after the refrigeration apparatus 100 is activated, the refrigerant circuit 10 is in the second state, and the refrigeration apparatus 100 performs the single-stage compression/degassing operation. When the refrigeration apparatus 100 is activated, a pull-down operation is performed. The pull-down operation is an operation in which the difference between the temperature of the target space of the refrigeration apparatus 100 and the outside air temperature is small and a high refrigerating capacity is required to lower the temperature of the target space to the set temperature of the target space. At the start of the pull-down operation, for example, the difference between the temperature of the target space and the outside air temperature is zero.

The control unit 70 switches the refrigerant circuit 10 from the second state to the first state when a predetermined first condition is satisfied while the refrigeration apparatus 100 performs the single-stage compression/degassing operation. Accordingly, the refrigeration apparatus 100 stops the single-stage compression/degassing operation and starts the two-stage compression operation. The control unit 70 switches the refrigerant circuit 10 from the second state to the first state by closing the gas vent valve 41 and opening the first shutoff valve 43. The first condition is satisfied when the temperature of the refrigerant suctioned into the first compressor 21 decreases to a first value and the temperature of the refrigerant discharged from the first compressor 21 increases to a second value. The control unit 70 uses the fourth temperature measured by the fourth temperature sensor 64 as the temperature of the refrigerant suctioned into the first compressor 21. The control unit 70 uses the fifth temperature measured by the fifth temperature sensor 65 as the temperature of the refrigerant discharged from the first compressor 21.

When a predetermined second condition is satisfied while the refrigeration apparatus

100 performs the two-stage compression operation, the control unit 70 switches the refrigerant circuit 10 from the first state to the second state. Accordingly, the refrigeration apparatus 100 stops the two-stage compression operation and starts the single-stage compression/degassing operation. The control unit 70 switches the refrigerant circuit 10 from the first state to the second state by opening the gas vent valve 41 and closing the first shutoff valve 43. The second condition is satisfied when the temperature of the refrigerant suctioned into the first compressor 21 increases to a third value, or when the number of rotations of the first compressor 21 falls below the number of rotations of the second compressor 22. The control unit 70 uses the fourth temperature measured by the fourth temperature sensor 64 as the temperature of the refrigerant suctioned into the first compressor 21. The control unit 70 acquires the numbers of rotations of the first compressor 21 and the second compressor 22 from the actuator control unit 74.

(4) Effect of Refrigeration Apparatus 100

(4-1)

Conventionally, refrigeration apparatuses including a refrigeration cycle in which carbon dioxide circulates as a refrigerant have been used. When the refrigeration apparatus is used in an environment where the outside air temperature is high, a two-stage compression mechanism is employed to increase the temperature and pressure of the refrigerant flowing into a radiator of the refrigeration cycle. Further, when the refrigeration apparatus is used in an environment in which the difference between the outside air temperature and the set temperature of the target space is large, a gas-liquid separator is preferably provided. In this case, it is necessary to make the pressure of the refrigerant in the gas-liquid separator lower than the pressure of the refrigerant at the critical point (31.1°C, 7.38 MPa). Therefore, in the refrigeration apparatus that includes the two-stage compression mechanism and the gas-liquid separator and uses carbon dioxide as a refrigerant, during a pull-down operation in which the evaporation temperature of the refrigerant is high, the desired compression ratio of the low-stage side compressor may decrease, and the refrigerating capacity may be insufficient.

The refrigeration apparatus 100 according to the present embodiment may perform the

two-stage compression operation and the single-stage compression/degassing operation. The control unit 70 of the refrigeration apparatus 100 may control the gas vent valve 41 and the first shutoff valve 43 to reciprocally switch between the first state where the two-stage compression operation is performed and the second state where the single-stage compression/degassing operation is performed.

During the pull-down operation of the refrigeration apparatus 100, a high refrigerating capacity is required, and therefore, the pressure of the refrigerant on the high-pressure side of the refrigeration cycle needs to be maintained high. The refrigeration apparatus 100 performs the single-stage compression/degassing operation during the pull-down operation so as to sufficiently secure the compression ratio of the first compressor 21 as illustrated in Fig. 4. Therefore, the refrigeration apparatus 100 may maintain the high pressure of the refrigerant on the high-pressure side of the refrigeration cycle during the pull-down operation.

Therefore, during the pull-down operation, the refrigeration apparatus 100 may suppress a decrease in the refrigerating capacity due to the fact that the compression ratio of the first compressor 21 on the low-stage side cannot be sufficiently secured.

(4-2)

When the load on the first compressor 21 increases while the refrigerant circuit 10 is in the second state, the control unit 70 switches from the second state where the refrigeration apparatus 100 performs the single-stage compression/degassing operation to the first state where the refrigeration apparatus 100 performs the two-stage compression operation. When it is determined that the above-described first condition is satisfied, the control unit 70 performs switching from the second state to the first state. The first condition is satisfied when the temperature of the refrigerant suctioned into the first compressor 21 (the evaporation temperature of the refrigerant) decreases to a predetermined value and the temperature of the refrigerant discharged from the first compressor 21 increases to a predetermined value.

The control unit 70 may use the fourth temperature measured by the fourth temperature sensor 64 as the temperature of the refrigerant suctioned into the first compressor 21. The control unit 70 may use the fifth temperature measured by the fifth temperature

sensor 65 as the temperature of the refrigerant discharged from the first compressor 21. In this case, when it is detected that the first condition is satisfied during the single-stage compression/degassing operation, the control unit 70 controls the gas vent valve 41 and the first shutoff valve 43 to switch from the second state to the first state. Accordingly, the refrigeration apparatus 100 stops the single-stage compression/degassing operation and starts the two-stage compression operation.

When the refrigeration apparatus 100 performs the single-stage compression/degassing operation during the pull-down operation, the evaporation temperature of the refrigerant decreases, the compression ratio of the first compressor 21 increases, and the temperature of the refrigerant on the high-pressure side of the refrigeration cycle (the temperature of the refrigerant discharged from the first compressor 21) increases. As a result, the load on the first compressor 21 increases, and the reliability of the first compressor 21 may decrease. When it is determined that the compression ratio of the first compressor 21 has become sufficiently large and the temperature of the refrigerant discharged from the first compressor 21 has become sufficiently high during execution of the single-stage compression/degassing operation, the refrigeration apparatus 100 stops the single-stage compression/degassing operation and starts the two-stage compression operation.

Therefore, during execution of the single-stage compression/degassing operation, the refrigeration apparatus 100 may reduce the load on the first compressor 21 on the low-stage side and suppress a decrease in the reliability of the first compressor 21. Accordingly, since the refrigeration apparatus 100 may effectively utilize the first compressor 21, the first compressor 21 having a small capacity may be adopted, and the cost and the power consumption may be reduced.

(4-3)

When the load on the second compressor 22 increases when the refrigerant circuit 10 is in the first state, the control unit 70 switches from the first state where the refrigeration apparatus 100 performs the two-stage compression operation to the second state where the refrigeration apparatus 100 performs the single-stage compression/degassing operation.

When it is determined that the above-described second condition is satisfied, the control unit 70 performs switching from the first state to the second state. The second condition is satisfied when the temperature of the refrigerant suctioned into the first compressor 21 (the evaporation temperature of the refrigerant) increases to a predetermined value, or when the number of rotations of the first compressor 21 falls below the number of rotations of the second compressor 22.

The control unit 70 may use the fourth temperature measured by the fourth temperature sensor 64 as the temperature of the refrigerant suctioned into the first compressor 21. In this case, when it is detected that the second condition is satisfied during the two-stage compression operation, the control unit 70 controls the gas vent valve 41 and the first shutoff valve 43 to switch from the first state to the second state. Accordingly, the refrigeration apparatus 100 stops the two-stage compression operation and starts the single-stage compression/degassing operation.

While the refrigeration apparatus 100 performs the two-stage compression operation, the temperature of the refrigerant suctioned into the first compressor 21 (the evaporation temperature of the refrigerant) may gradually increase. The pressure of the refrigerant in the gas-liquid separator 26 (the pressure of the intermediate-pressure refrigerant) needs to be lower than the critical pressure (7.38 MPa) of the refrigerant, and therefore needs to be suppressed to about 7 MPa at the highest. Therefore, when the evaporation temperature of the refrigerant increases during the two-stage compression operation, the compression ratio of the first compressor 21 may decrease. When it is determined that the temperature of the refrigerant suctioned into the first compressor 21 has become sufficiently high during execution of the two-stage compression operation, the refrigeration apparatus 100 stops the two-stage compression operation and starts the single-stage compression/degassing operation.

Therefore, the refrigeration apparatus 100 may sufficiently secure the compression ratio of the first compressor 21 on the low-stage side and suppress a decrease in the refrigerating capacity.

In addition, while the refrigeration apparatus 100 performs the two-stage compression

operation, the number of rotations of the first compressor 21 may fall below the number of rotations of the second compressor 22, and the load on the second compressor 22 may become excessive. In this case, the load on the second compressor 22 may be reduced by causing the second compressor 22 to execute the degassing operation. When it is determined
5 that the number of rotations of the first compressor 21 falls below the number of rotations of the second compressor 22 during the execution of the two-stage compression operation, the refrigeration apparatus 100 stops the two-stage compression operation and starts the single-stage compression/degassing operation.

Therefore, during the execution of the two-stage compression operation, the
10 refrigeration apparatus 100 may reduce the load on the second compressor 22 on the high-stage side and suppress a decrease in the reliability of the second compressor 22. Accordingly, since the refrigeration apparatus 100 may effectively utilize the second compressor 22, the second compressor 22 having a small capacity may be adopted, and the cost and the power consumption may be reduced.

15 (4-4)

During the execution of the single-stage compression/degassing operation, the refrigeration apparatus 100 uses the intermediate heat exchanger 27 to cool the refrigerant at the outlet of the heat-source side heat exchanger 23 by heat exchange with the gas refrigerant separated by the gas-liquid separator 26. This reduces the dryness of the refrigerant
20 decompressed after passing through the first heat-source side expansion valve 25a.

Thus, the refrigeration apparatus 100 may prevent a shortage of the refrigerant suctioned into the first compressor 21 on the low-stage side.

(4-5)

The refrigeration apparatus 100 may determine whether to perform the single-stage
25 compression/degassing operation or the two-stage compression operation in accordance with the outside air temperature and the temperature of the target space. The control unit 70 may use the second temperature measured by the second temperature sensor 62 as the outside air temperature. The control unit 70 may use the third temperature measured by the third

temperature sensor 63 as the temperature of the target space. In this case, the control unit 70 starts the single-stage compression/degassing operation as the pull-down operation when the second temperature is equal to or more than a predetermined value and the difference between the second temperature and the third temperature is equal to or less than a predetermined value at the time of activation of the refrigeration apparatus 100. Further, the control unit 70 starts the two-stage compression operation for the pull-down operation when the second temperature is less than the predetermined value or the difference between the second temperature and the third temperature is more than the predetermined value at the time of activation of the refrigeration apparatus 100.

Therefore, the refrigeration apparatus 100 may suppress a decrease in the refrigerating capacity by performing the pull-down operation in consideration of the balance between the load on the first compressor 21 on the low-stage side and the load on the second compressor 22 on the high-stage side.

-Second Embodiment-

The basic configuration and operation of the refrigeration apparatus 100 according to the present embodiment are the same as those of the refrigeration apparatus 100 according to the first embodiment. Hereinafter, the differences between the refrigeration apparatus 100 according to the present embodiment and the refrigeration apparatus 100 according to the first embodiment will be mainly described.

(1) Configuration of Refrigeration Apparatus 100

The refrigeration apparatus 100 according to the present embodiment has the configuration illustrated in Fig. 1, as in the first embodiment. The control unit 70 of the refrigeration apparatus 100 according to the present embodiment has the configuration illustrated in Fig. 2, as in the first embodiment.

(2) Operation of Refrigeration Apparatus 100

During the operation of the refrigeration apparatus 100, the refrigerant circuit 10 is in any one of a first state, a second state, and a third state. The first state is a state where the refrigeration apparatus 100 performs the two-stage compression operation illustrated in Fig.

3, as in the first embodiment. The second state is a state where the refrigeration apparatus 100 performs the single-stage compression/degassing operation illustrated in Fig. 4, as in the first embodiment.

Fig. 5 is a Mollier diagram when the refrigerant circuit 10 is in the third state. Fig. 5 illustrates the saturated liquid line L1, the dry saturated vapor line L2, and the critical point CP of the refrigerant. The critical point CP is an end point on the high-pressure side of the saturated liquid line L1 and the dry saturated vapor line L2. The third state is a state where the refrigeration apparatus 100 performs the single-stage compression operation. In the third state, the degassing operation is not performed. In the third state, the gas vent valve 41 and the first shutoff valve 43 are closed.

Next, changes in the state of the refrigerant in the third state will be described.

In the heat source unit 2, the low-pressure refrigerant flowing through the refrigerant circuit 10 is compressed by the first compressor 21 to become a high-pressure refrigerant ($P1 \rightarrow P2$). The high-pressure refrigerant discharged from the first compressor 21 flows into the heat-source side heat exchanger 23. The high-pressure refrigerant flowing into the heat-source side heat exchanger 23 exchanges heat with the outside air and radiates heat ($P2 \rightarrow P3$).

The refrigerant having radiated heat in the heat-source side heat exchanger 23 is decompressed by the first heat-source side expansion valve 25a to become an intermediate-pressure refrigerant ($P3 \rightarrow P4$). The refrigerant decompressed by the first heat-source side expansion valve 25a into a gas-liquid two-phase state flows into the gas-liquid separator 26 and is separated into a liquid refrigerant and a gas refrigerant ($P4 \rightarrow P5, P6$). The liquid refrigerant separated by the gas-liquid separator 26 is further decompressed by the second heat-source side expansion valve 25b to become a low-pressure refrigerant ($P5 \rightarrow P7$). The liquid refrigerant decompressed by the second heat-source side expansion valve 25b passes through the liquid-side shutoff valve 28 and the liquid-side connection pipe 6, flows into the utilization unit 3, and flows into the utilization-side heat exchanger 31. The low-pressure liquid refrigerant flowing into the utilization-side heat exchanger 31 exchanges heat with the

air in the target space in which the utilization unit 3 is installed, absorbs heat, and becomes a gas refrigerant (P7 → P1). The refrigerant having absorbed heat in the utilization-side heat exchanger 31 passes through the gas-side connection pipe 7 and flows into the heat source unit 2 from the gas-side shutoff valve 29. The low-pressure refrigerant flowing into the heat source unit 2 is suctioned into the first compressor 21.

(3) Control Of Refrigeration Apparatus 100

The control unit 70 switches the state of the refrigerant circuit 10 to the third state, the second state, and the first state in this order when the first compressor 21 and the second compressor 22 are activated. Specifically, when the refrigeration apparatus 100 is activated, the control unit 70 controls the gas vent valve 41 and the first shutoff valve 43 such that the single-stage compression operation, the single-stage compression/degassing operation, and the two-stage compression operation are performed in this order. The control unit 70 stops the single-stage compression operation and starts the single-stage compression/degassing operation by performing control to open the gas vent valve 41 in a state where the refrigeration apparatus 100 performs the single-stage compression operation.

(4) Effect of Refrigeration Apparatus 100

Immediately after the refrigeration apparatus 100 is activated, the amount of refrigerant on the high-pressure side of the refrigeration cycle is small, and therefore the amount of gas refrigerant in the gas-liquid separator 26 is small. For this reason, the refrigeration apparatus 100 does not perform the degassing operation when the amount of refrigerant on the high-pressure side of the refrigeration cycle is small at the time of activation, and starts the degassing operation when a predetermined time has elapsed after activation and the amount of refrigerant on the high-pressure side of the refrigeration cycle has increased to a predetermined amount. As a result, the refrigeration apparatus 100 may reduce the load on the second compressor 22 due to the degassing operation and suppress a decrease in the refrigerating capacity.

-Third Embodiment-

The basic configuration and operation of a refrigeration apparatus 200 according to the

present embodiment are the same as those of the refrigeration apparatus 100 according to the first embodiment. Hereinafter, the differences between the refrigeration apparatus 200 according to the present embodiment and the refrigeration apparatus 100 according to the first embodiment will be mainly described.

5 (1) Configuration of Refrigeration Apparatus 200

The main differences between the refrigeration apparatus 200 and the refrigeration apparatus 100 according to the first embodiment are the heat source unit 2 and the control unit 70.

As illustrated in Fig. 6, the heat source unit 2 of the refrigeration apparatus 200 has a
10 configuration in which a seventh pipe 57, a liquid injection valve 42, an oil return pipe 58, and an oil separator 60 are further added to the heat source unit 2 of the refrigeration apparatus 100 according to the first embodiment.

The seventh pipe 57 is a pipe through which the refrigerant circulating in the refrigerant circuit 10 flows. The seventh pipe 57 connects the fifth pipe 55 to the sixth pipe
15 56. An end of the seventh pipe 57 is connected to the fifth pipe 55 between the gas-liquid separator 26 and the second heat-source side expansion valve 25b. The other end of the seventh pipe 57 is connected to the sixth pipe 56 between the connection portion with the second pipe 52 and the intermediate heat exchanger 27.

The liquid injection valve 42 is provided in the seventh pipe 57. The liquid injection
20 valve 42 adjusts the amount of liquid refrigerant flowing through the seventh pipe 57. The liquid injection valve 42 is an electric expansion valve whose opening degree is adjustable under the control of the control unit 70.

The oil return pipe 58 is a pipe through which the refrigerant circulating in the refrigerant circuit 10 flows. The oil return pipe 58 connects the second pipe 52 to the third
25 pipe 53. One end of the oil return pipe 58 is connected to the second pipe 52 between the connection portion with the sixth pipe 56 and the second compressor 22. The other end of the oil return pipe 58 is connected to the third pipe 53 between the connection portion with the bypass pipe 59 and the heat-source side heat exchanger 23.

The oil separator 60 is provided in the oil return pipe 58. The oil separator 60 separates the refrigerating machine oil from the mixture of the refrigerant and the refrigerating machine oil.

As illustrated in Fig. 7, the actuator control unit 74 of the control unit 70 has a
5 function to control in real time the number of rotations of the first compressor 21, the number of rotations of the second compressor 22, the number of rotations of the heat-source side fan 24, the opening degree of the first heat-source side expansion valve 25a, the opening degree of the second heat-source side expansion valve 25b, the number of rotations of the utilization-side fan 32, the opening degree of the gas vent valve 41, the opening degree of the liquid
10 injection valve 42, and the opening degree of the first shutoff valve 43.

(2) Operation of Refrigeration Apparatus 200

In the refrigeration apparatus 200, a part of the liquid refrigerant separated by the gas-liquid separator 26 flows into the seventh pipe 57 together with the refrigerating machine oil in the refrigerant circuit 10. The refrigerant and the refrigerating machine oil having passed
15 through the liquid injection valve 42 in the seventh pipe 57 merges with the refrigerant flowing through the sixth pipe 56 after exchanging heat in the intermediate heat exchanger 27. Thus, the mixture of the refrigerant and the refrigerating machine oil flows into the second pipe 52 via the seventh pipe 57 and the sixth pipe 56.

Furthermore, a part of the gas refrigerant discharged from the first compressor 21 and
20 the second compressor 22 flows through the third pipe 53 and flows into the oil return pipe 58 together with the refrigerating machine oil in the refrigerant circuit 10. Thus, the mixture of the refrigerant and the refrigerating machine oil flows through the oil return pipe 58. A mixture of the refrigerant and the refrigerating machine oil flows into the oil separator 60 provided in the oil return pipe 58. In the oil separator 60, the refrigerating machine oil is
25 separated from the mixture of the refrigerant and the refrigerating machine oil. The refrigerating machine oil separated by the oil separator 60 flows through the oil return pipe 58 and flows into the second pipe 52.

In this way, in the refrigeration apparatus 200, the refrigerating machine oil mixed

with the refrigerant discharged from the first compressor 21 and the second compressor 22 in the heat source unit 2 is returned to the suction side of the second compressor 22.

(3) Control of Refrigeration Apparatus 200

The control unit 70 of the refrigeration apparatus 200 performs the same control as the control unit 70 according to the first embodiment. Furthermore, during the operation of the refrigeration apparatus 200, the control unit 70 controls the opening degree of the liquid injection valve 42 to adjust the amount of the mixture of the refrigerant and the refrigerating machine oil flowing through the seventh pipe 57.

(4) Effect of Refrigeration Apparatus 200

The refrigeration apparatus 200 may return the refrigerating machine oil flowing through the refrigerant circuit 10 to the suction side of the second compressor 22. Therefore, the refrigeration apparatus 200 may prevent a shortage of the refrigerating machine oil in the second compressor 22.

-Modification-

(1) Modification A

The refrigeration apparatuses 100, 200 according to the first to third embodiments may further perform a degassing operation when the refrigerant circuit 10 is in the first state. In other words, the refrigeration apparatuses 100, 200 may simultaneously perform both the two-stage compression operation and the degassing operation. In this case, the control unit 70 may simultaneously perform both the two-stage compression operation and the degassing operation by opening both the gas vent valve 41 and the first shutoff valve 43.

According to the present modification, while the refrigeration apparatuses 100, 200 simultaneously perform both the two-stage compression operation and the degassing operation, in the intermediate heat exchanger 27, the gas refrigerant separated by the gas-liquid separator 26 is heated by heat exchange with the refrigerant at the outlet of the heat-source side heat exchanger 23. The refrigerant heated in the intermediate heat exchanger 27 flows into the second pipe 52 and is mixed with the refrigerant before being suctioned into the second compressor 22. As a result, the degree of superheating of the refrigerant suctioned

into the second compressor 22 increases, and thus the temperature of the refrigerant discharged from the second compressor 22 increases. Therefore, the refrigeration apparatuses 100, 200 may keep the high performance of the heat-source side heat exchanger 23 by increasing the difference between the first temperature and the second temperature.

5 (2) Modification B

 (2-1) Configuration of Refrigeration Apparatus 300

The refrigeration apparatuses 100, 200 according to the first to third embodiments may omit the gas-liquid separator 26. The refrigeration apparatus 300 according to the present modification is the refrigeration apparatus 100 according to the first embodiment, and
10 does not include the gas-liquid separator 26. The main differences between the refrigeration apparatus 300 and the refrigeration apparatus 100 according to the first embodiment are the heat source unit 2 and the control unit 70.

As illustrated in Fig. 8, the heat source unit 2 includes the first compressor 21, the first accumulator 21b, the second compressor 22, the second accumulator 22b, the heat-source
15 side heat exchanger 23, the heat-source side fan 24, the second heat-source side expansion valve 25b, a cooler 127, the liquid-side shutoff valve 28, the gas-side shutoff valve 29, a decompression valve 141, the first shutoff valve 43, and the second shutoff valve 44.

The heat source unit 2 includes the first pipe 51 to the sixth pipe 56 which are pipes through which the refrigerant circulating in the refrigerant circuit 10 flows. The first pipe 51
20 to the third pipe 53 are the same as the first pipe 51 to the third pipe 53 according to the first embodiment. One end of the fourth pipe 54 is connected to the outlet side of the heat-source side heat exchanger 23. The other end of the fourth pipe 54 is connected to one end of the fifth pipe 55 and one end of the sixth pipe 56. The fifth pipe 55 connects the fourth pipe 54 to the liquid-side shutoff valve 28. The sixth pipe 56 connects the fourth pipe 54 to the second
25 pipe 52.

The second heat-source side expansion valve 25b is provided in the fifth pipe 55. The second heat-source side expansion valve 25b configures an expansion mechanism of the refrigeration apparatus 300 and reduces the pressure of the high-pressure refrigerant in the

refrigeration cycle to become a low-pressure refrigerant.

The decompression valve 141 is provided in the sixth pipe 56. The decompression valve 141 reduces the pressure of the high-pressure refrigerant in the refrigeration cycle to become an intermediate-pressure refrigerant. The decompression valve 141 adjusts the amount of liquid refrigerant flowing through the sixth pipe 56. The decompression valve 141 is an electric expansion valve whose opening degree is adjustable under the control of the control unit 70.

The cooler 127 exchanges heat between the refrigerant decompressed by the decompression valve 141 after radiating heat in the heat-source side heat exchanger 23 and the refrigerant after radiating heat in the heat-source side heat exchanger 23 and before being decompressed by the second heat-source side expansion valve 25b.

The actuator control unit 74 of the control unit 70 has a function to control in real time the number of rotations of the first compressor 21, the number of rotations of the second compressor 22, the number of rotations of the heat-source side fan 24, the opening degree of the second heat-source side expansion valve 25b, the number of rotations of the utilization-side fan 32, the opening degree of the decompression valve 141, and the opening degree of the first shutoff valve 43.

In the degassing operation performed by the refrigeration apparatus 300, the intermediate-pressure refrigerant decompressed by the decompression valve 141 and heated by heat exchange in the cooler 127 flows through the sixth pipe 56 and the second pipe 52 and is suctioned into the second compressor 22. The degassing operation performed by the refrigeration apparatus 300 has the same effect as the degassing operation performed by the refrigeration apparatuses 100, 200 according to the first to third embodiments.

(2-2) Operation of Refrigeration Apparatus 300

During the operation of the refrigeration apparatus 300, the refrigerant circuit 10 is in any one of a first state and a second state. The first state is a state where the refrigeration apparatus 300 performs the two-stage compression operation. The second state is a state where the refrigeration apparatus 300 performs the single-stage compression/degassing

operation. In the first state, the decompression valve 141 is closed, and the first shutoff valve 43 is opened. In the second state, the decompression valve 141 is opened, and the first shutoff valve 43 is closed.

Fig. 9 is a Mollier diagram when the refrigerant circuit 10 is in the second state. Fig. 9 illustrates the saturated liquid line l1, the dry saturated vapor line l2, and the critical point cp of the refrigerant. The critical point CP is an end point on the high-pressure side of the saturated liquid line L1 and the dry saturated vapor line L2.

Next, changes in the state of the refrigerant in the second state will be described.

In the heat source unit 2, the low-pressure refrigerant flowing through the refrigerant circuit 10 is compressed by the first compressor 21 to become a high-pressure refrigerant ($P1 \rightarrow P2$). The high-pressure refrigerant discharged from the first compressor 21 merges with the high-pressure refrigerant discharged from the second compressor 22 and flows into the heat-source side heat exchanger 23. The high-pressure refrigerant flowing into the heat-source side heat exchanger 23 exchanges heat with the outside air and radiates heat ($P2 \rightarrow P3$).

The refrigerant having radiated heat in the heat-source side heat exchanger 23 flows through the fourth pipe 54 and is then divided into the fifth pipe 55 and the sixth pipe 56. The refrigerant flowing through the fifth pipe 55 is decompressed by the decompression valve 141 and flows into the cooler 127 ($P3 \rightarrow P4$). The refrigerant flowing through the sixth pipe 56 flows into the cooler 127 before being decompressed by the second heat-source side expansion valve 25b. The cooler 127 exchanges heat between the refrigerant decompressed by the decompression valve 141 and flowing through the fifth pipe 55 and the refrigerant flowing through the sixth pipe 56. The refrigerant flowing through the fifth pipe 55 is heated by heat exchange ($P4 \rightarrow P5$). The refrigerant flowing through the sixth pipe 56 is cooled by heat exchange ($P3 \rightarrow P6$).

The refrigerant flowing through the sixth pipe 56 is cooled by the cooler 127 and is then decompressed by the second heat-source side expansion valve 25b to become a low-pressure refrigerant ($P6 \rightarrow P7$). The liquid refrigerant decompressed by the second heat-

source side expansion valve 25b passes through the liquid-side shutoff valve 28 and the liquid-side connection pipe 6, flows into the utilization unit 3, and flows into the utilization-side heat exchanger 31. The low-pressure liquid refrigerant flowing into the utilization-side heat exchanger 31 exchanges heat with the air in the target space in which the utilization unit 3 is installed, absorbs heat, and becomes a gas refrigerant (P7 → P1). The refrigerant having absorbed heat in the utilization-side heat exchanger 31 passes through the gas-side connection pipe 7 and flows into the heat source unit 2 from the gas-side shutoff valve 29. The low-pressure refrigerant flowing into the heat source unit 2 is suctioned into the first compressor 21.

The refrigerant flowing through the fifth pipe 55 is heated by the cooler 127, then flows through the second pipe 52, and is compressed by the second compressor 22 to become a high-pressure refrigerant (P5 → P8). The refrigerant compressed by the second compressor 22 merges with the refrigerant compressed by the first compressor 21 before flowing into the heat-source side heat exchanger 23 (P8 → P2).

The second embodiment and Modification A may be applied to the present modification. The oil return pipe 58 and the oil separator 60 according to the third embodiment may be applied to the present modification.

(3) Modification C

The refrigeration apparatus 200 according to the third embodiment, Modification A, and Modification B includes the seventh pipe 57 and the oil return pipe 58 to return the refrigerating machine oil from the discharge side to the suction side of the second compressor 22. However, the refrigeration apparatus 200 may include only any one of the seventh pipe 57 and the oil return pipe 58.

(4) Modification D

The refrigeration apparatuses 100, 200 according to the first to third embodiments, Modification A, and Modification C may omit the intermediate heat exchanger 27.

(5) Modification E

In the first to third embodiments and Modifications A to D, the first shutoff valve 43

and the second shutoff valve 44 may be any members that may switch the state of the refrigerant circuit 10 (the first to third states). For example, a three-way switch valve or a four-way switch valve may be used as the first shutoff valve 43 and the second shutoff valve 44.

5 Although the embodiments of the present disclosure are described above, it is understood that various changes may be made to forms and details without departing from the spirit and scope of the present disclosure described in the scope of claims.

REFERENCE SIGNS LIST

	10	REFRIGERANT CIRCUIT
10	21	FIRST COMPRESSOR
	22	SECOND COMPRESSOR
	23	HEAT-SOURCE SIDE HEAT EXCHANGER (FIRST HEAT EXCHANGER)
	25a	FIRST HEAT-SOURCE SIDE EXPANSION VALVE (EXPANSION MECHANISM)
15	25b	SECOND HEAT-SOURCE SIDE EXPANSION VALVE (EXPANSION MECHANISM)
	26	GAS-LIQUID SEPARATOR
	27	INTERMEDIATE HEAT EXCHANGER (FOURTH HEAT EXCHANGER)
	31	UTILIZATION-SIDE HEAT EXCHANGER (SECOND HEAT EXCHANGER)
20	41	GAS VENT VALVE (THIRD VALVE)
	43	FIRST SHUTOFF VALVE (FIRST VALVE)
	44	SECOND SHUTOFF VALVE (SECOND VALVE)
	52	SECOND PIPE (SECOND CHANNEL)
	56	SIXTH PIPE (FIRST CHANNEL)
25	57	SEVENTH PIPE (FOURTH CHANNEL)
	58	OIL RETURN PIPE (FIFTH CHANNEL)
	59	BYPASS PIPE (THIRD CHANNEL)
	60	OIL SEPARATOR

- 70 CONTROL UNIT
- 100 REFRIGERATION APPARATUS
- 127 COOLER (THIRD HEAT EXCHANGER)
- 141 DECOMPRESSION MECHANISM (DECOMPRESSION VALVE)
- 5 200 REFRIGERATION APPARATUS
- 300 REFRIGERATION APPARATUS

CITATION LIST

PATENT LITERATURE

PTL 1: Japanese Unexamined Patent Application Publication No. 2016-128734

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CLAIMS

[Claim 1]

A refrigeration apparatus (100) comprising a refrigerant circuit (10) in which a first compressor (21), a second compressor (22), a first heat exchanger (23), an expansion mechanism (25a, 25b), and a second heat exchanger (31) are sequentially connected, wherein
5 the first heat exchanger functions as a radiator of a refrigerant compressed by the first compressor or the second compressor,

the second heat exchanger functions as a heat absorber of a refrigerant decompressed by the expansion mechanism,

10 the refrigerant circuit includes

a gas-liquid separator (26) or a third heat exchanger (127),

a first channel (56) that connects the gas-liquid separator or the third heat exchanger to a suction side of the second compressor,

a second channel (52) that connects a discharge side of the first compressor to the
15 suction side of the second compressor, and

a third channel (59) that connects the discharge side of the first compressor to a discharge side of the second compressor,

the gas-liquid separator separates a refrigerant in a gas-liquid two-phase state decompressed by the expansion mechanism into a liquid refrigerant and a gas refrigerant,

20 the third heat exchanger exchanges heat between a refrigerant decompressed by a decompression mechanism (141) after radiating heat in the first heat exchanger and a refrigerant after radiating heat in the first heat exchanger and before being decompressed by the expansion mechanism,

the first channel guides the gas refrigerant in the gas-liquid separator or the refrigerant
25 decompressed by the decompression mechanism and heat-exchanged in the third heat exchanger to the suction side of the second compressor,

the second channel guides a refrigerant discharged from the first compressor to the suction side of the second compressor, and

the third channel guides the refrigerant discharged from the first compressor to the discharge side of the second compressor in a state where the refrigerant discharged from the first compressor does not flow through the second channel.

[Claim 2]

5 The refrigeration apparatus according to claim 1, further comprising a control unit (70) that switches the refrigerant circuit between a first state and a second state, wherein

in the first state, the refrigerant discharged from the first compressor flows through the second channel, merges with the gas refrigerant flowing through the first channel, and is suctioned into the second compressor,

10 in the second state, the refrigerant discharged from the first compressor flows through the third channel without flowing through the second channel and merges with a refrigerant discharged from the second compressor,

the refrigerant circuit further includes a first valve (43) provided in the second channel and a second valve (44) which is a check valve provided in the third channel, and

15 the control unit opens the first valve in the first state and closes the first valve in the second state.

[Claim 3]

 The refrigeration apparatus according to claim 2, wherein when the refrigerant circuit is in the second state, the control unit switches the refrigerant circuit from the second state to
20 the first state in a case where a temperature of the refrigerant suctioned into the first compressor decreases to a first value and a temperature of the refrigerant discharged from the first compressor increases to a second value.

[Claim 4]

 The refrigeration apparatus according to claim 2 or 3, wherein when the refrigerant
25 circuit is in the first state, the control unit switches the refrigerant circuit from the first state to the second state in a case where a temperature of the refrigerant suctioned into the first compressor increases to a third value, or in a case where a number of rotations of the first compressor falls below a number of rotations of the second compressor.

[Claim 5]

The refrigeration apparatus according to any one of claims 2 to 4, wherein
the control unit switches the refrigerant circuit among the first state, the second state,
and a third state,

5 in the third state, the refrigerant is not suctioned into the second compressor, and the
refrigerant discharged from the first compressor flows through the third channel without
flowing through the second channel,

the refrigerant circuit further includes a third valve (41) provided in the first channel,
and

10 the control unit opens the third valve in the first state or the second state and closes the
third valve in the third state.

[Claim 6]

The refrigeration apparatus according to claim 5, wherein the control unit switches the
refrigerant circuit to the third state, the second state, and the first state in this order when the
15 first compressor and the second compressor are activated.

[Claim 7]

The refrigeration apparatus according to any one of claims 1 to 6, wherein
the refrigerant circuit includes the gas-liquid separator and further includes a fourth
channel (57) that connects the gas-liquid separator to the first channel, and

20 the fourth channel guides refrigerating machine oil in the gas-liquid separator to the
suction side of the second compressor via the first channel together with the liquid refrigerant
in the gas-liquid separator.

[Claim 8]

The refrigeration apparatus according to any one of claims 1 to 7, wherein
25 the refrigerant circuit further includes a fifth channel (58) that connects the discharge
side of the second compressor to the suction side of the second compressor, and
the fifth channel guides refrigerating machine oil discharged from the second
compressor to the suction side of the second compressor, and

the fifth channel is provided with an oil separator (60) that separates the refrigerating machine oil from a mixture of the refrigerant and the refrigerating machine oil.

[Claim 9]

5 The refrigeration apparatus according to any one of claims 1 to 8, wherein the refrigerant circuit includes the gas-liquid separator and further includes a fourth heat exchanger (27) that heats the gas refrigerant in the gas-liquid separator by exchanging heat with a refrigerant after radiating heat in the first heat exchanger and before being decompressed by the expansion mechanism.