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(54) REFRIGERATION APPARATUS

(57) A refrigeration apparatus includes a main compression mechanism, a gas cooler, a main throttle mechanism, and an evaporator, and allows circulation of a refrigerant containing carbon dioxide. The refrigeration apparatus includes a split heat exchanger including a first flow channel and a second flow channel, in which the first flow channel is disposed at a site downstream of the gas cooler and upstream of the main throttle mechanism, and part of a refrigerant flowing out of the first flow channel flows into the second flow channel; an auxiliary throttle mechanism that throttles a refrigerant that is to flow into the second flow channel; and an ejector including a nozzle and a suction part, in which the nozzle is disposed at a site downstream of the main compression mechanism and upstream of the first flow channel, and the suction part sucks in a refrigerant flowing out of the second flow channel.

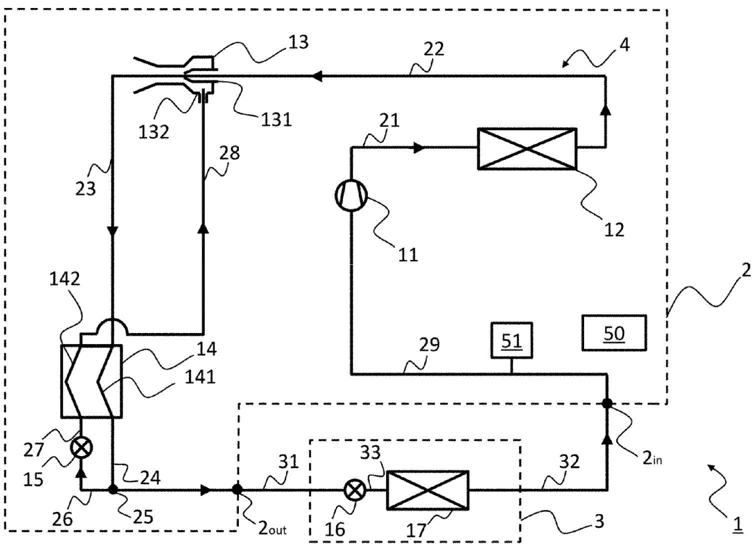

FIG. 1

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Description

Technical Field

[0001] The present disclosure relates to a refrigeration apparatus in which a refrigerant containing carbon dioxide circulates.

Background Art

[0002] Conventionally, a refrigeration apparatus includes a refrigeration cycle formed from a compression section, a gas cooler, a throttle section, an evaporator, and the like. A refrigerant compressed in the compression section radiates heat in the gas cooler, and is then decompressed in the throttle section and evaporates in the evaporator. As the refrigerant evaporates, the surrounding air is cooled.

[0003] In recent years, chlorofluorocarbon-based refrigerants have become unavailable for use in this type of refrigeration apparatuses due to, for example, natural environmental issues. For this reason, refrigeration apparatuses that use carbon dioxide, a natural refrigerant, as an alternative to chlorofluorocarbon-based refrigerants have been developed. The carbon dioxide refrigerant, which is a refrigerant having large difference between high and low pressures, is known to have a low critical pressure, so that when the carbon dioxide refrigerant is compressed, the refrigerant becomes in a supercritical state on the high pressure side of a refrigerant cycle (see, for example, Patent Literature (hereinafter abbreviated as "PTL") 1).

[0004] In view of this characteristics of the refrigerant, a refrigeration cycle utilizing an ejector has been developed to improve the coefficient of performance of the refrigeration cycle (see, for example, PTL 2).

Citation List

Patent Literature

[0005]

NPL 1
Japanese Examined Patent Application Publication No. H7-18602
NPL 2
Japanese Patent No. 3322263

Summary of Invention

Technical Problem

[0006] An object of the present disclosure is to improve the performance of a refrigeration apparatus which uses a refrigerant containing carbon dioxide and utilizes an ejector.

Solution to problem

[0007] A refrigeration apparatus according to the present disclosure includes a main compression mechanism, a gas cooler, a main throttle mechanism, and an evaporator, and allows circulation of a refrigerant containing carbon dioxide. The refrigeration apparatus includes a split heat exchanger including a first flow channel and a second flow channel, in which the first flow channel is disposed at a site downstream of the gas cooler and upstream of the main throttle mechanism, and part of a refrigerant flowing out of the first flow channel flows into the second flow channel; an auxiliary throttle mechanism that throttles a refrigerant that is to flow into the second flow channel; and an ejector including a nozzle and a suction part, in which the nozzle is disposed at a site downstream of the main compression mechanism and upstream of the first flow channel, and the suction part sucks in a refrigerant flowing out of the second flow channel.

Advantageous Effects of Invention

[0008] The present disclosure is capable of improving the performance of a refrigeration apparatus which uses a refrigerant containing carbon dioxide and uses an ejector.

Brief Description of Drawings

[0009]

FIG. 1 illustrates a refrigerant circuit of a refrigeration apparatus according to Embodiment 1;
FIG. 2 illustrates a refrigerant circuit of a refrigeration apparatus according to Embodiment 2;
FIG. 3 illustrates a refrigerant circuit of a refrigeration apparatus according to Embodiment 3; and
FIG. 4 is a graph showing the results of electric power simulation in the refrigeration apparatuses according to Embodiment 3 and a reference example.

Description of Embodiments

[0010] Hereinafter, the embodiments of the present disclosure will be described in detail with reference to the accompanying drawings.

(1) Embodiment 1

[0011] FIG. 1 illustrates a refrigerant circuit of refrigeration apparatus 1 according to Embodiment 1. Refrigeration apparatus 1 according to the present embodiment includes refrigerator unit 2 installed in, for example, an indoor machine room or an outdoor environment, and load device 3, for example, a showcase installed in a supermarket or the like. Refrigerator unit 2 and load device 3 are connected with each other by refrigerant pipe (liquid pipe) 31 and refrigerant pipe 32 via unit outlet 2_{out} and unit inlet 2in to form predetermined refrigerant circuit 4. Load device 3 may be a cooling coil of a food warehouse or the like, or a cooling device for cooling a refrigerant such as water.

[0012] Carbon dioxide (R744), whose pressure on the high pressure side may become equal to or higher than the critical pressure (supercritical), circulates as a refrigerant in refrigerant circuit 4. The refrigerant may consist only of carbon dioxide, or may be a mixed refrigerant containing carbon dioxide and other substances. The mixed refrigerant may contain carbon dioxide and, for example, one or more of R32, R41, R134a, R125, R152a, propane and dimethyl ether. Each arrow shown in FIG. 1 indicates the flow of a refrigerant.

[0013] The lubricating oil that circulates in refrigerant circuit 4 together with the refrigerant is, for example, mineral oil, alkylbenzene oil, ether oil, ester oil, or PAG (polyalkyl glycol).

[0014] Refrigerant circuit 4 includes main compression mechanism 11, gas cooler 12, ejector 13, split heat exchanger 14, and auxiliary throttle mechanism 15 in refrigerator unit 2. Refrigerant circuit 4 includes main throttle mechanism 16 and evaporator 17 in load device 3.

[0015] Main compression mechanism 11, which is a frequency-variable compressor, has one or more compression mechanism parts, sucks a refrigerant in a gas-phase (i.e., gas-phase refrigerant), and discharges the refrigerant having a high temperature and high pressure.

[0016] The refrigerant discharged from main compression mechanism 11 passes through pipe 21 to flow into gas cooler 12.

[0017] Gas cooler 12 lowers the temperature of the refrigerant by exchanging heat between the refrigerant and the outside air supplied by a blower for the gas cooler (not illustrated). Alternatively, gas cooler 12 may exchange heat between the refrigerant and water supplied by a water pump for the gas cooler.

[0018] The refrigerant flowing out of gas cooler 12 passes through pipe 22 to flow into nozzle 131 of ejector 13. Nozzle 131 is configured in such a way that the opening degree thereof can be adjusted. When the opening degree of nozzle 131 increases, the flow velocity of the refrigerant, which flows in from nozzle 131 and passes through ejector 13, decreases, and when the opening degree decreases, the flow velocity of the refrigerant increases.

[0019] The refrigerant flowing into nozzle 131 expands while mixing with a gas-phase refrigerant sucked in from suction part 132 (which will be described below) and flows out of ejector 13 in a gas-liquid mixed state. When the flow velocity of the refrigerant flowing in from nozzle 131 and passing through ejector 13 increases, the static pressure in ejector 13 decreases, so that the suction pressure in suction part 132 decreases (suction becomes easier). When the flow velocity of the refrigerant flowing in from nozzle 131 and passing through ejector 13 decreases, meanwhile, the static pressure in ejector 13 increases, so that the suction pressure in suction part 132 increases (suction becomes more difficult).

[0020] The refrigerant flowing out of ejector 13 passes through pipe 23 to flow into first flow channel 141 of split heat exchanger 14.

[0021] The refrigerant flowing into first flow channel 141 flows out of first flow channel 141 with the temperature of the refrigerant lowered by exchanging heat with a refrigerant that flows through second flow channel 142 (which will be described below).

[0022] The refrigerant flowing out of first flow channel 141 partly passes through pipe 24, unit outlet 2_{out}, and refrigerant pipe 31 to flow into main throttle mechanism 16. Main throttle mechanism 16 is, for example, an electric expansion valve whose opening degree can be adjusted.

[0023] In addition, there is branch part 25 at pipe 24 between the ends of the pipe. Branch pipe 26 branching off from pipe 24 is connected to branch part 25. The refrigerant flowing out of first flow channel 141 partly passes through branch pipe 26 to flow into auxiliary throttle mechanism 15. Auxiliary throttle mechanism 15 is, for example, an electric expansion valve whose opening degree can be adjusted.

[0024] Auxiliary throttle mechanism 15 expands and vaporizes the refrigerant flowing into auxiliary throttle mechanism 15. The temperature of the refrigerant is lowered during the procedure.

[0025] The refrigerant flowing out of auxiliary throttle mechanism 15 is in a gas-liquid mixed state, and passes through pipe 27 to flow into second flow channel 142 of split heat exchanger 14.

[0026] The refrigerant flowing into second flow channel 142 exchanges heat with a refrigerant passing through first flow channel 141 to lower the temperature of the refrigerant passing through first flow channel 141 as described above, and then flows out of second flow channel 142.

[0027] The refrigerant flowing out of second flow channel 142 passes through pipe 28 and is sucked into suction part 132 of ejector 13. The refrigerant sucked into ejector 13 from suction part 132 mixes with a refrigerant sucked from nozzle 131.

[0028] On the other hand, the refrigerant in a liquid-phase passing through branch part 25 to flow into main throttle mechanism 16 is expanded by main throttle mechanism 16 which is, for example, an electric expansion valve. The refrigerant flowing out of main throttle mechanism 16 flows into evaporator 17 via refrigerant pipe 33, and is completely evaporated in evaporator 17. The refrigerant flowing through evaporator 17 exchanges heat with a fluid in load device 3, for example, air, and cools the air. The fluid in load device 3 may be another refrigerant (for example, water), which is to be cooled by the refrigerant circulating in refrigerant circuit 4.

[0029] The refrigerant flowing out of evaporator 17 passes through refrigerant pipe 32, unit inlet 2in and pipe 29, and is sucked into main compression mechanism 11.

[0030] Refrigerator unit 2 includes control device 50 that controls the entire refrigeration apparatus 1. Low pressure sensor 51 (herein also referred to as "third pressure sensor"), which detects the pressure (low pressure) of the refrigerant to be sucked into main compression mechanism 11, is attached at a site downstream of main throttle mechanism 16 and upstream of main compression mechanism 11, for example, at pipe 29. A value detected by low pressure sensor 51 is transmitted to control device 50.

[0031] The value detected by low pressure sensor 51 indicates the evaporation pressure of a refrigerant in evaporator 17, that is, the temperature of the refrigerant in evaporator 17. Control device 50 can adjust the temperature of the refrigerant in evaporator 17 and thus the temperature of a fluid in load device 3 by adjusting the operating frequency of main compression mechanism 11 based on the detection result from low pressure sensor 51. In other words, control device 50 can cause main compression mechanism 11 to perform an operation according to the refrigeration capacity required in load device 3.

[0032] The carbon dioxide-containing refrigerant can generate a fluid of desired temperature and quantity in evaporator 17 by repeating the above described cycle.

[0033] The refrigeration apparatus 1 according to Embodiment 1 includes ejector 13, split heat exchanger 14, and auxiliary throttle mechanism 15 as described above. Ejector 13 can expand a refrigerant that has become in a high pressure state without requiring power. Split heat exchanger 14 and auxiliary throttle mechanism 15 can lower the temperature of a refrigerant that has flowed out of ejector 13 before the refrigerant flows into main throttle mechanism 16. Main throttle mechanism 16 can expand the refrigerant having passed through split heat exchanger 14 to lower its temperature. In other words, refrigeration apparatus 1 according to Embodiment 1 is capable of adjusting the pressure on the high-pressure side (discharge side of main compression mechanism 11) while obtaining a desired refrigeration capacity in load device 3 by virtue of the presence of ejector 13, split heat exchanger 14, and auxiliary throttle mechanism 15 in the refrigeration apparatus. That is, refrigeration apparatus 1 can appropriately operate main compression mechanism 11 according to the temperature of the outside air or water supplied to gas cooler 12.

[0034] In Embodiment 1, ejector 13 is disposed between gas cooler 12 and first flow channel 141 of split heat exchanger 14. However, ejector 13 may be disposed at any site downstream of main compression mechanism 11 and upstream of first flow channel 141. For example, ejector 13 may be disposed at a site downstream of main compression mechanism 11 and upstream of gas cooler 12. This disposition allows for efficient generation of cooled fluid (e.g., air or water) of desired temperature and quantity, in addition to the effects described above.

(2) Embodiment 2

[0035] FIG. 2 illustrates a refrigerant circuit of refrigeration apparatus 1 according to Embodiment 2. The description of matters common to Embodiment 1 may be omitted. Conversely, the description for the present embodiment may apply to Embodiment 1.

[0036] Refrigeration apparatus 1 according to the present embodiment includes gas-liquid separator 18, auxiliary compression mechanism 19, and a transfer pressure sensor 52 (herein also referred to as "first pressure sensor"). In the present embodiment, pipe 23 connecting ejector 13 with first flow channel 141 of split heat exchanger 14 is divided into pipe 231 on the upstream side and pipe 232 on the downstream side, and gas-liquid separator 18 is disposed between these pipes.

[0037] Gas-liquid separator 18 is a tank capable of storing a refrigerant. A refrigerant in a gas-liquid mixed state flows into gas-liquid separator 18 via the inlet connected to pipe 231. In gas-liquid separator 18, the refrigerant that has flowed into gas-liquid separator 18 is separated into a gas-phase refrigerant and a liquid-phase refrigerant.

[0038] The liquid-phase refrigerant separated in gas-liquid separator 18 flows out from the liquid-phase refrigerant outlet of gas-liquid separator 18 connected to pipe 232 and flows into first flow channel 141 of split heat exchanger 14.

[0039] The gas-phase refrigerant separated in gas-liquid separator 18 flows out from the gas-phase refrigerant outlet of gas-liquid separator 18 connected to pipe 41. The gas-phase refrigerant flowing out of the gas-phase refrigerant outlet passes through pipe 41 and is sucked into auxiliary compression mechanism 19. Transfer pressure sensor 52 is disposed at pipe 41. Transfer pressure sensor 52 detects the pressure of a refrigerant that is to flow into main throttle mechanism 16. A value detected by transfer pressure sensor 52 is transmitted to control device 50.

[0040] Transfer pressure sensor 52 may be disposed at any site other than pipe 41 when the transfer pressure sensor 52 can detect the pressure of the refrigerant that is to flow into main throttle mechanism 16. Transfer pressure sensor 52 may be disposed, for example, at pipe 231, gas-liquid separator 18, pipe 232, first flow channel 141, pipe 24, branch part 25, branch pipe 26, or refrigerant pipe 31.

[0041] Auxiliary compression mechanism 19 is, for example, a compressor including an airtight container, an electric element that serves as a drive element housed in internal space of the airtight container, and a rotary compression element driven by a rotating shaft of the electric element.

[0042] A refrigerant compressed by auxiliary compression mechanism 19 is discharged to merging pipe 42. Merging pipe 42 is connected to pipe 21 at merging part 43 that is provided between the ends of pipe 21, downstream of main compression mechanism 11 and upstream of gas cooler 12. The refrigerant discharged to merging pipe 42 from auxiliary compression mechanism 19 passes through merging pipe 42 and merging part 43 to join a refrigerant in pipe 21 discharged from main compression mechanism 11.

[0043] Refrigeration apparatus 1 according to the present embodiment includes high pressure sensor 53 (herein also referred to as "second pressure sensor") and outside air temperature sensor 54 (herein also referred to as "first temperature sensor"). Values detected by those sensors are transmitted to control device 50.

[0044] High pressure sensor 53 detects the pressure (high pressure) of a refrigerant discharged from main compression mechanism 11, and may be disposed anywhere, in so far as the high pressure sensor can detect this pressure. In the present embodiment, high pressure sensor 53 is disposed at pipe 22, but may be disposed at pipe 21 or at gas cooler 12.

[0045] Outside air temperature sensor 54 detects the outside air temperature, that is, the temperature of a fluid, for cooling the refrigerant, in gas cooler 12. Outside air temperature sensor 54 is disposed, for example, in the vicinity of gas cooler 12. Gas cooler 12 is not necessarily limited to a cooler that cools a refrigerant with outside air, and may be, for example, a cooler that cools the refrigerant with water. In this case, the first temperature sensor is a water temperature sensor in place of outside air temperature sensor 54.

[0046] Refrigeration apparatus 1 according to the present embodiment includes transfer temperature sensor 55 (herein also referred to as "second temperature sensor") and second flow channel inlet temperature sensor 56 (herein also referred to as "third temperature sensor"). Values detected by those sensors are transmitted to control device 50.

[0047] Transfer temperature sensor 55 detects the temperature of a refrigerant to be supplied to main throttle mechanism 16, and may be disposed anywhere, in so far as the transfer temperature sensor can detect this temperature. In the present embodiment, transfer temperature sensor 55 is disposed at pipe 24, but may be disposed at branch part 25 or branch pipe 26, or may be disposed at refrigerant pipe 31.

[0048] Second flow channel inlet temperature sensor 56 detects the temperature of a refrigerant that is to flow into second flow channel 142 of split heat exchanger 14, and is disposed at pipe 27.

[0049] In refrigeration apparatus 1 according to the present embodiment, a refrigerant circulates as follows.

[0050] Main compression mechanism 11 sucks a refrigerant in a gas-phase state and discharges the refrigerant in a high pressure state. The refrigerant discharged from main compression mechanism 11 passes through pipe 21 to flow into gas cooler 12. The refrigerant whose temperature is lowered in the gas cooler passes through pipe 22 to flow into nozzle 131 of ejector 13. The refrigerant flowing into nozzle 131 expands while mixing with a gas-phase refrigerant sucked in from suction part 132 and flows out of ejector 13 in a gas-liquid mixed state.

[0051] The refrigerant flowing out of ejector 13 passes through pipe 231 to flow into gas-liquid separator 18. In gas-liquid separator 18, the refrigerant is separated into a gas-phase refrigerant and a liquid-phase refrigerant. The liquid-phase refrigerant from the inside of gas-liquid separator 18 passes through pipe 232 and flows into first flow channel 141 of split heat exchanger 14. When the liquid-phase refrigerant passes through first flow channel 141, the liquid-phase refrigerant exchanges heat with a refrigerant passing through second flow channel 142 of split heat exchanger 14 and is cooled.

[0052] The liquid-phase refrigerant flowing out of first flow channel 141 passes through pipe 24, branch part 25, unit outlet 2_{out}, and refrigerant pipe 31 to flow into main throttle mechanism 16. The refrigerant that flows into main throttle mechanism 16 is throttled and expanded by main throttle mechanism 16. The refrigerant flowing out of main throttle mechanism 16 flows into evaporator 17 via refrigerant pipe 33, and is evaporated. At this time, the refrigerant exchanges heat with the surrounding air to generate cold air. Depending on the application of the load device 3, the fluid to be subjected to the heat exchange in evaporator 17 does not have to be air. For example, load device 3 may cool water to generate cold water. The gas-phase refrigerant flowing out of evaporator 17 passes through refrigerant pipe 32, unit inlet 2in and pipe 29, and is sucked into main compression mechanism 11 again.

[0053] Further, the liquid-phase refrigerant, which is branched off at branch part 25 and flows into branch pipe 26, flows into auxiliary throttle mechanism 15. The refrigerant that flows into auxiliary throttle mechanism 15 is throttled and expanded by auxiliary throttle mechanism 15. The refrigerant flowing out of auxiliary throttle mechanism 15 flows into second flow channel 142 of split heat exchanger 14 via pipe 27, and is evaporated. The refrigerant flowing into second flow channel 142 exchanges heat with a refrigerant passing through first flow channel 141 to lower the temperature of the refrigerant passing through first flow channel 141. The refrigerant flowing out of second flow channel 142 passes through pipe 28 and is sucked from suction part 132 of ejector 13. The refrigerant sucked from suction part 132 mixes with a refrigerant flowing into nozzle 131 in ejector 13, and then flows out of ejector 13 and flows into gas-liquid separator 18 again.

[0054] The gas-phase refrigerant from the inside of gas-liquid separator 18 passes through pipe 41 and is sucked into auxiliary compression mechanism 19. The refrigerant sucked into auxiliary compression mechanism 19 is compressed by auxiliary compression mechanism 19 until the refrigerant has a pressure equal to the pressure of a refrigerant at the outlet of main compression mechanism 11, and then discharged to merging pipe 42. The refrigerant discharged from auxiliary compression mechanism 19 to merging pipe 42 joins the refrigerant in pipe 21 discharged from main compression mechanism

11 via merging part 43.

[0055] In the present embodiment, auxiliary compression mechanism 19 can reduce the pressure in gas-liquid separator 18, that is, can lower the temperature of a refrigerant in gas-liquid separator 18. This configuration can lower the temperature of a refrigerant supplied to evaporator 17.

[0056] In addition, auxiliary compression mechanism 19 sucks a gas-phase refrigerant from the inside of gas-liquid separator 18 (the refrigerant whose pressure is relatively high), but not a gas-phase refrigerant flowing out of second flow channel 142 (the refrigerant whose pressure is reduced after passing through auxiliary throttle mechanism 15). The gas-phase refrigerant flowing out of second flow channel 142 is sucked by ejector 13. Therefore, the pressure of the refrigerant passing through second flow channel 142 can be reduced by the action of ejector 13 without increasing the power (that is, the input power) of auxiliary compression mechanism 19, and further, the temperature of the refrigerant passing through second flow channel 142 can be lowered. Lowering the temperature of the refrigerant passing through second flow channel 142 can lower the temperature of a refrigerant flowing out of first flow channel 141. This configuration can lower the temperature of a refrigerant supplied to evaporator 17. The refrigeration capacity of refrigeration apparatus 1 thus can be increased, and also the refrigeration efficiency can be improved.

[0057] In the present embodiment, control device 50 adjusts the operating frequency of auxiliary compression mechanism 19 based on the detection result from transfer pressure sensor 52. Accordingly, the transfer pressure, that is, the pressure of a refrigerant supplied to main throttle mechanism 16 can be set to a predetermined value. It becomes thus easier to set the pressure of a refrigerant after the refrigerant is throttled by main throttle mechanism 16 to a predetermined value, and as a result, setting the pressure and temperature of a refrigerant flowing into evaporator 17 to predetermined values becomes easier. This configuration allows evaporator 17 to stably generate cold air of desired temperature and quantity.

[0058] In addition, control device 50 adjusts the opening degree of nozzle 131 of ejector 13 based on the detection results from high pressure sensor 53 and from outside air temperature sensor 54 in the present embodiment. That is, control device 50 adjusts the discharge pressure of main compression mechanism 11, namely the pressure of a refrigerant in gas cooler 12, based on the temperature of a fluid for exchanging heat with the refrigerant in gas cooler 12.

[0059] Specifically, when the outside air temperature rises, i.e., the detection value from outside air temperature sensor 54 increases, control device 50 can increase the pressure of a refrigerant in gas cooler 12 by reducing the opening degree of nozzle 131 in such a way that the value detected by high pressure sensor 53 becomes a target value. The flow velocity of the refrigerant in ejector 13 then increases, and the pressure of a refrigerant sucked from suction part 132 decreases. As a result, the temperature of the refrigerant supplied from split heat exchanger 14 to main throttle mechanism 16 decreases. When the outside air temperature falls, i.e., the detection value from outside air temperature sensor 54 decreases, meanwhile, control device 50 can reduce the pressure of a refrigerant in gas cooler 12 by increasing the opening degree of nozzle 131 in such a way that the value detected by high pressure sensor 53 becomes a target value. The flow velocity of the refrigerant in ejector 13 then decreases, and the pressure of a refrigerant sucked from suction part 132 increases. As a result, the temperature of a refrigerant supplied from split heat exchanger 14 to main throttle mechanism 16 increases. The control as described above can optimize the operating state of main compression mechanism 11, namely the power consumption of main compression mechanism 11, thereby improving energy conservation of refrigeration apparatus 1.

[0060] In addition, control device 50 adjusts the opening degree of auxiliary throttle mechanism 15 based on the detection results from transfer temperature sensor 55 and from second flow channel inlet temperature sensor 56 in the present embodiment.

[0061] Specifically, the opening degree of auxiliary throttle mechanism 15 is adjusted in such a way that the value detected by transfer temperature sensor 55 approaches the value detected by second flow channel inlet temperature sensor 56. The control as described above can lower the temperature of a refrigerant supplied to evaporator 17 via main throttle mechanism 16. The refrigeration capacity of refrigeration apparatus 1 thus can be increased, and also the refrigeration efficiency can be improved.

[0062] The control to adjust the opening degree of auxiliary throttle mechanism 15 based on the detection results from transfer temperature sensor 55 and from second flow channel inlet temperature sensor 56 is particularly effective when the opening degree of nozzle 131 of ejector 13 changes due to changes in the outside temperature and/or the like. In other words, when the pressure of a refrigerant sucked from suction part 132 fluctuates due to a change in the opening degree of nozzle 131, the temperature of a refrigerant flowing into second flow channel 142 changes. As a result, the temperature of a refrigerant flowing out of first flow channel 141 and supplied to main throttle mechanism 16 may change. Even in such a case, adjusting the opening degree of auxiliary throttle mechanism 15 based on the detection results from transfer temperature sensor 55 and from second flow channel inlet temperature sensor 56 can still maintain the temperature of the refrigerant supplied to main throttle mechanism 16 at a desired value.

(3) Embodiment 3

[0063] FIG. 3 illustrates a refrigerant circuit of refrigeration apparatus 1 according to Embodiment 3. The description of matters common to Embodiments 1 and 2 may be omitted. Conversely, the description for the present embodiment may apply to Embodiments 1 and 2.

[0064] In refrigeration apparatus 1 according to the present embodiment, main compression mechanism 11 includes low-stage compression mechanism 111 and high-stage compression mechanism 112. Refrigeration apparatus 1 according to the present embodiment also include intercooler 121. Intercooler 121 is disposed between low-stage compression mechanism 111 and high-stage compression mechanism 112 in refrigerant circuit 4 via pipe 44 on the upstream side and pipe 45 on the downstream side.

[0065] Main compression mechanism 11 is, for example, an internal intermediate-pressure two-stage compression type rotary compressor. Main compression mechanism 11 includes an airtight container and a rotary compression mechanism part. The rotary compression mechanism part includes an electric element that serves as a drive element housed in an upper portion of the internal space of the airtight container, and a first rotary compression element (low-stage compression mechanism 111) and a second rotary compression element (high-stage compression mechanism 112) disposed below the electric element. Main compression mechanism 11 is a two-stage compressor including the first rotary compression element and the second rotary compression element driven by the same rotary shaft (rotary shaft of the electric element). In such a two-stage compressor, the excluded volume ratio between the low-stage side and the high-stage side is predetermined, and the intermediate pressure is determined according to the excluded volume ratio. Low-stage compression mechanism 111 and high-stage compression mechanism 112 may be single-stage compression compressors that are independent of each other.

[0066] Low-stage compression mechanism 111 compresses a refrigerant having a low pressure sucked into main compression mechanism 11 from the low-pressure side of refrigerant circuit 4 via pipe 29, increases the pressure of the refrigerant to an intermediate pressure, and discharges the refrigerant. High-stage compression mechanism 112 sucks in the refrigerant having an intermediate pressure discharged from low-stage compression mechanism 111, compresses the refrigerant until the refrigerant has a high pressure, and discharges the refrigerant to the high-pressure side of refrigerant circuit 4. Main compression mechanism 11 is a frequency-variable compressor. Control device 50 controls the rotation speeds of low-stage compression mechanism 111 and high-stage compression mechanism 112 by changing the operating frequency of the electric element.

[0067] Formed on the side surface of the airtight container of main compression mechanism 11 are a low-stage side suction port communicating with low-stage compression mechanism 111, a low-stage side discharge port communicating with the inside of the airtight container, a high-stage side suction port communicating with high-stage compression mechanism 112, and a high-stage side discharge port. One end of pipe 29 is connected to the low-stage side suction port of main compression mechanism 11, and the other end of pipe 29 is connected to refrigerant pipe 32 at unit inlet 2in.

[0068] A refrigerant gas having a low pressure sucked into the low-pressure part of low-stage compression mechanism 111 from the low-stage side suction port is subjected to the first-stage compression by low-stage compression mechanism 111 to have an intermediate pressure, and discharged into the airtight container. As a result, the pressure inside the airtight container becomes an intermediate pressure.

[0069] One end of pipe 44 is connected to the low-stage side discharge port of main compression mechanism 11 from which the refrigerant gas having the intermediate pressure in the airtight container is discharged, and the other end of pipe 44 is connected to the inlet of intercooler 121. Intercooler 121 cools the intermediate pressure refrigerant gas discharged from low-stage compression mechanism 111. One end of pipe 45 is connected to the outlet of intercooler 121. The other end of pipe 45 is connected to the high-stage side suction port of main compression mechanism 11.

[0070] The intermediate pressure refrigerant gas sucked into high-stage compression mechanism 112 from the high-stage side suction port of main compression mechanism 11 is subjected to the second-stage compression by high-stage compression mechanism 112 to become a refrigerant gas having high temperature and high pressure.

[0071] One end of pipe 21 is connected to the high-stage side discharge port provided on the high-pressure chamber side of high-stage compression mechanism 112 in main compression mechanism 11, and the other end of pipe 21 is connected to the inlet of gas cooler 12. An oil separator (not illustrated) may be provided at pipe 21 between the ends of the pipe. The oil separated from the refrigerant by the oil separator is returned to the airtight container of main compression mechanism 11 and the airtight container of auxiliary compression mechanism 19.

[0072] Gas cooler 12 cools the refrigerant having a high pressure discharged from main compression mechanism 11. A blower for the gas cooler (not illustrated) for air-cooling gas cooler 12 is provided in the vicinity of gas cooler 12. In the present embodiment, gas cooler 12 is provided in parallel with above described intercooler 121, and the coolers are provided in the same air passage. Gas cooler 12 and intercooler 121 may be water-cooled. In this case, a water pump for the gas cooler is provided in place of the blower for the gas cooler, and water is input to the gas cooler and the intercooler in parallel.

[0073] One end of pipe 22 is connected to the outlet of gas cooler 12, and the other end of pipe 22 is connected to the inlet of nozzle 131 of ejector 13.

[0074] In refrigeration apparatus 1 according to the present embodiment, main compression mechanism 11 includes low-stage compression mechanism 111 and high-stage compression mechanism 112. Intercooler 121 is disposed between low-stage compression mechanism 111 and high-stage compression mechanism 112. This configuration can lower the temperature of a refrigerant after the refrigerant is subjected to the compression as compared with the case of compression of a refrigerant until the refrigerant has the same pressure as in this configuration by using a single-stage compressor. Therefore, even with a refrigerant with a high compression ratio, such as a carbon dioxide-containing refrigerant, the temperature of the refrigerant discharged from the compressor can be kept relatively low, thereby preventing the denaturing of a lubricating oil in the refrigerant and the damage of piping and the sealing member of the piping.

[0075] In addition, refrigeration apparatus 1 according to the present embodiment includes ejector 13, gas-liquid separator 18, split heat exchanger 14, auxiliary throttle mechanism 15, and auxiliary compression mechanism 19 in the same manner as refrigeration apparatus 1 according to Embodiment 2. The refrigeration capacity of refrigeration apparatus 1 thus can be increased, and also the refrigeration efficiency can be improved. The advantages of Embodiments 2 and 3 will be further described with reference to FIG. 4.

[0076] FIG. 4 is a graph showing the results of electric power simulation in the refrigeration apparatuses according to Embodiment 3 and a reference example. The refrigeration apparatus according to the reference example differs from refrigeration apparatus 1 illustrated in FIG. 3 in the following points.
The refrigeration apparatus according to the reference example has the following features.

- No ejector 13 is present.
- A gas-phase refrigerant flowing out of gas-liquid separator 18 does not flow into auxiliary compression mechanism 19, but flows via a throttle mechanism into a site between auxiliary throttle mechanism 15 and second flow channel 142.
- A gas-phase refrigerant flowing out of second flow channel 142 does not flow into suction part 132 of ejector 13, but flows into auxiliary compression mechanism 19.

[0077] In the graph on the left side of FIG. 4, the abscissa represents the evaporation temperature (°C) in evaporator 17, and the ordinate represents the input power (kW) of auxiliary compression mechanism 19. In the graph on the right side of FIG. 4, the abscissa represents the evaporation temperature (°C) in evaporator 17, and the ordinate represents the total input power (kW) of auxiliary compression mechanism 19 and main compression mechanism 11. The simulation conditions are as follows.

- Volumetric efficiency = Compression efficiency = 1
- Refrigerant temperature at the outlet of gas cooler 12 = 35°C
- Refrigerant temperature at the outlet of intercooler 121 = 35°C
- Refrigerant pressure at the outlet of gas cooler 12 = 9 MPa
- Refrigerant pressure (transfer pressure) at the inlet of main throttle mechanism 16 = 6.5 MPa
- Refrigerant temperature at the inlet of main throttle mechanism 16 = 13.5°C
- Refrigerant temperature at the inlet of main compression mechanism 11 = 18°C
- Excluded volume ratio in main compression mechanism 11 = 70%
- Power recovery rate of ejector 13 = 70%

[0078] As shown in the graphs, refrigeration system 1 according to Embodiment 3 can reduce the input power as compared with the reference example over a wide range of evaporation temperatures in both cases of the input power to auxiliary compression mechanism 19 alone and the total input power to auxiliary compression mechanism 19 and main compression mechanism 11. Refrigeration apparatus 1, which includes ejector 13, gas-liquid separator 18, split heat exchanger 14, auxiliary throttle mechanism 15, and auxiliary compression mechanism 19 disposed in refrigerant circuit 4 as illustrated in FIG. 2 or 3, can efficiently obtain the required refrigeration capacity regardless of the temperature of a refrigerant in evaporator 17.

Industrial Applicability

[0079] The present disclosure can be widely used for showcases and other refrigeration apparatuses that use refrigeration circuits.

Reference Signs List

[0080]

1 Refrigeration apparatus
2 Refrigerator unit
2_{out} Unit outlet
2_{in} Unit inlet
3 Load device
4 Refrigerant circuit
11 Main compression mechanism
111 Low-stage compression mechanism
112 High-stage compression mechanism
12 Gas cooler
121 Intercooler
13 Ejector
131 Nozzle
132 Suction part
14 Split heat exchanger
141 First flow channel
142 Second flow channel
15 Auxiliary throttle mechanism

16 Main throttle mechanism
17 Evaporator
18 Gas-liquid separator
19 Auxiliary compression mechanism
21, 22, 23, 24, 27, 28, 29, 41, 44, 45 Pipe
25 Branch part
26 Branch pipe
31, 32, 33 Refrigerant pipe
42 Merging pipe
43 Merging part
50 Control device
51 Low pressure sensor
52 Transfer pressure sensor
53 High pressure sensor
54 Outside air temperature sensor
55 Transfer temperature sensor
56 Second flow channel inlet temperature sensor

Claims

1. A refrigeration apparatus that includes a main compression mechanism, a gas cooler, a main throttle mechanism, and an evaporator, and allows circulation of a refrigerant containing carbon dioxide, the refrigeration apparatus comprising:

a split heat exchanger including a first flow channel and a second flow channel, wherein the first flow channel is disposed at a site downstream of the gas cooler and upstream of the main throttle mechanism, and part of a refrigerant flowing out of the first flow channel flows into the second flow channel;
an auxiliary throttle mechanism that throttles a refrigerant that is to flow into the second flow channel; and
an ejector including a nozzle and a suction part, wherein the nozzle is disposed at a site downstream of the main compression mechanism and upstream of the first flow channel, and the suction part sucks a refrigerant flowing out of the second flow channel.

2. The refrigeration apparatus according to claim 1, wherein:

the nozzle is disposed at a site downstream of the gas cooler and upstream of the first flow channel.

3. The refrigeration apparatus according to claim 2, further comprising:

a gas-liquid separator into which a refrigerant flowing out of the ejector flows, and in which the refrigerant is subjected to gas-liquid separation; and
an auxiliary compression mechanism that sucks a gas-phase refrigerant flowing out of the gas-liquid separator and discharges the sucked gas-phase refrigerant to a site upstream of the gas cooler, wherein
a liquid-phase refrigerant flowing out of the gas-liquid separator flows into the first flow channel.

4. The refrigeration apparatus according to claim 3, further comprising:

an intercooler, wherein
the main compression mechanism includes a low-stage compression mechanism that discharges a refrigerant to a site upstream of the intercooler, and a high-stage compression mechanism that sucks a refrigerant flowing out of the intercooler.

5. The refrigeration apparatus according to claim 3 or 4, further comprising:

a first pressure sensor that detects pressure of a refrigerant that is to flow into the main throttle mechanism, wherein
operating frequency of the auxiliary compression mechanism is adjusted based on a detection result from the first pressure sensor.

6. The refrigeration apparatus according to any one of claims 3 to 5, further comprising:

a second pressure sensor that detects pressure of a refrigerant that is to flow into the nozzle; and a first temperature sensor that detects a temperature of a fluid that is to exchange heat with a refrigerant in the gas cooler, wherein
an opening degree of the nozzle is adjusted based on a detection result from the second pressure sensor and a detection result from the first temperature sensor.

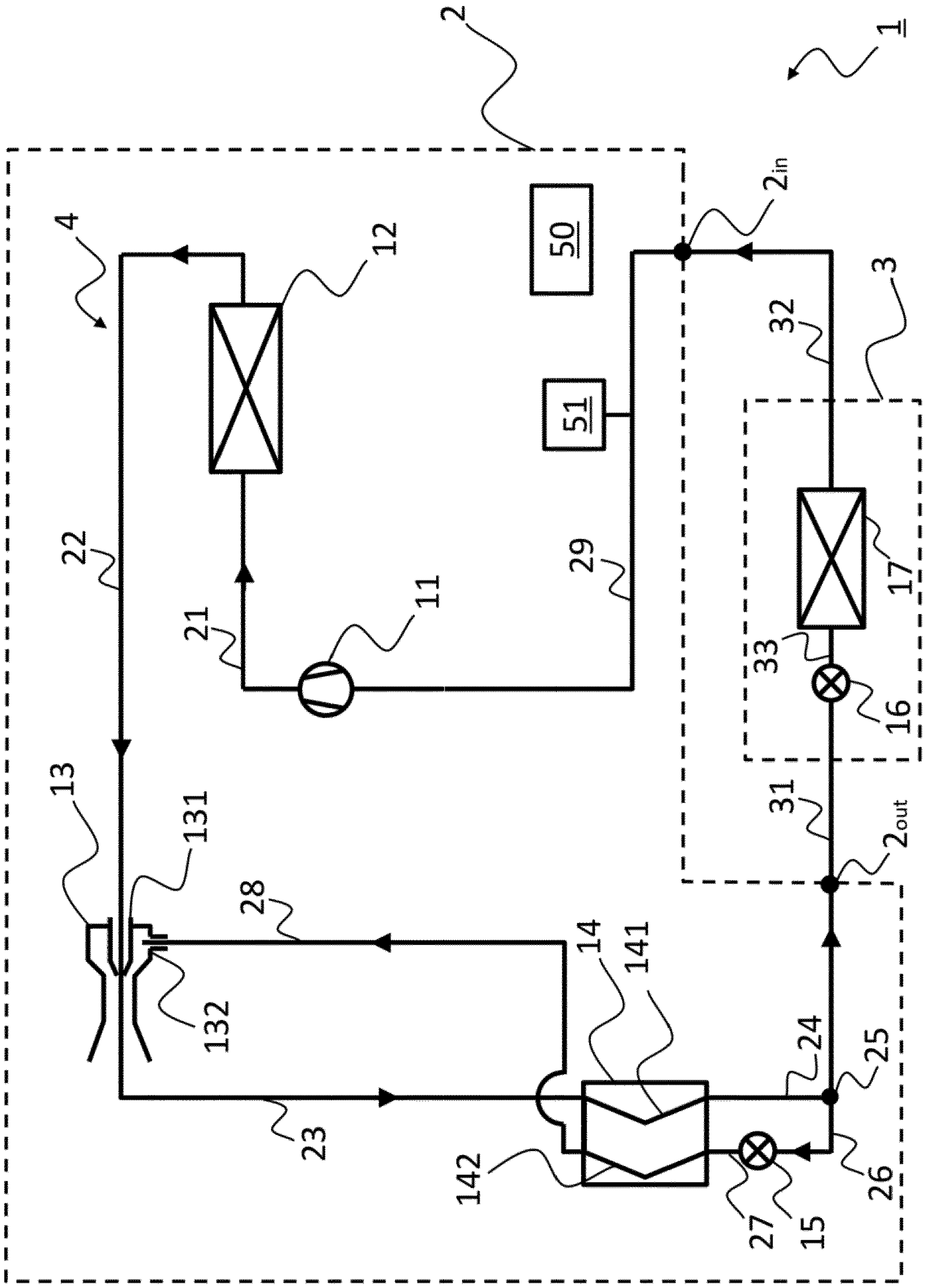
7. The refrigeration apparatus according to claim 6, further comprising:

a second temperature sensor that detects a temperature of a refrigerant flowing out of the first flow channel; and a third temperature sensor that detects a temperature of a refrigerant that is to flow into the second flow channel, wherein
an opening degree of the auxiliary throttle mechanism is adjusted based on a detection result from the second temperature sensor and a detection result from the third temperature sensor.

8. The refrigeration apparatus according to any one of claims 1 to 7, further comprising:

a third pressure sensor that detects pressure of a refrigerant that is to be sucked into the main compression mechanism, wherein

operating frequency of the main compression mechanism is adjusted based on a detection result from the third pressure sensor.


1
2
2_{in}
2_{out}
3
4
11
12
13
131
132
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141
142
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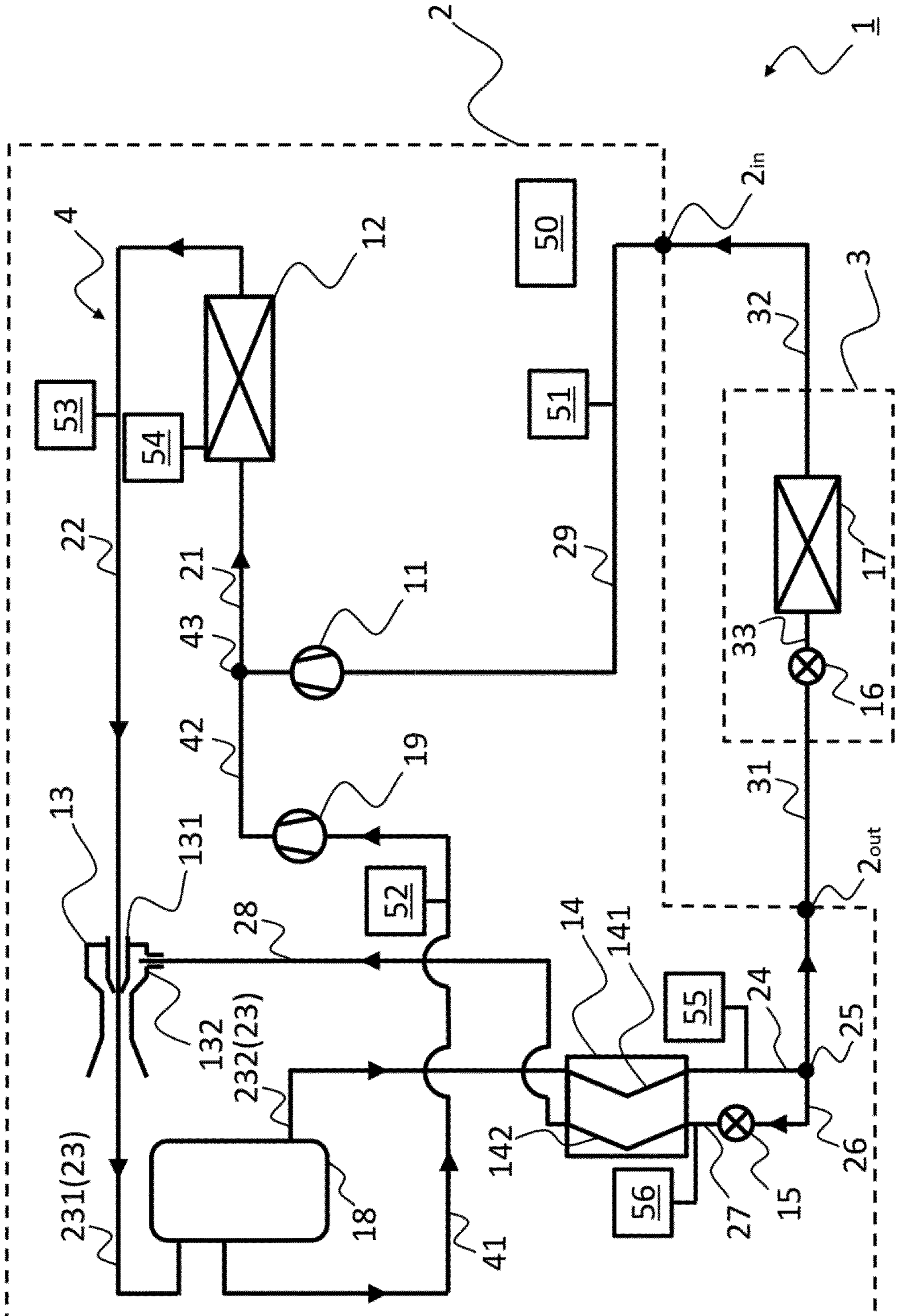
FIG. 1


1
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2in
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12
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131
132
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142
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231(23)
232(23)
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32
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41
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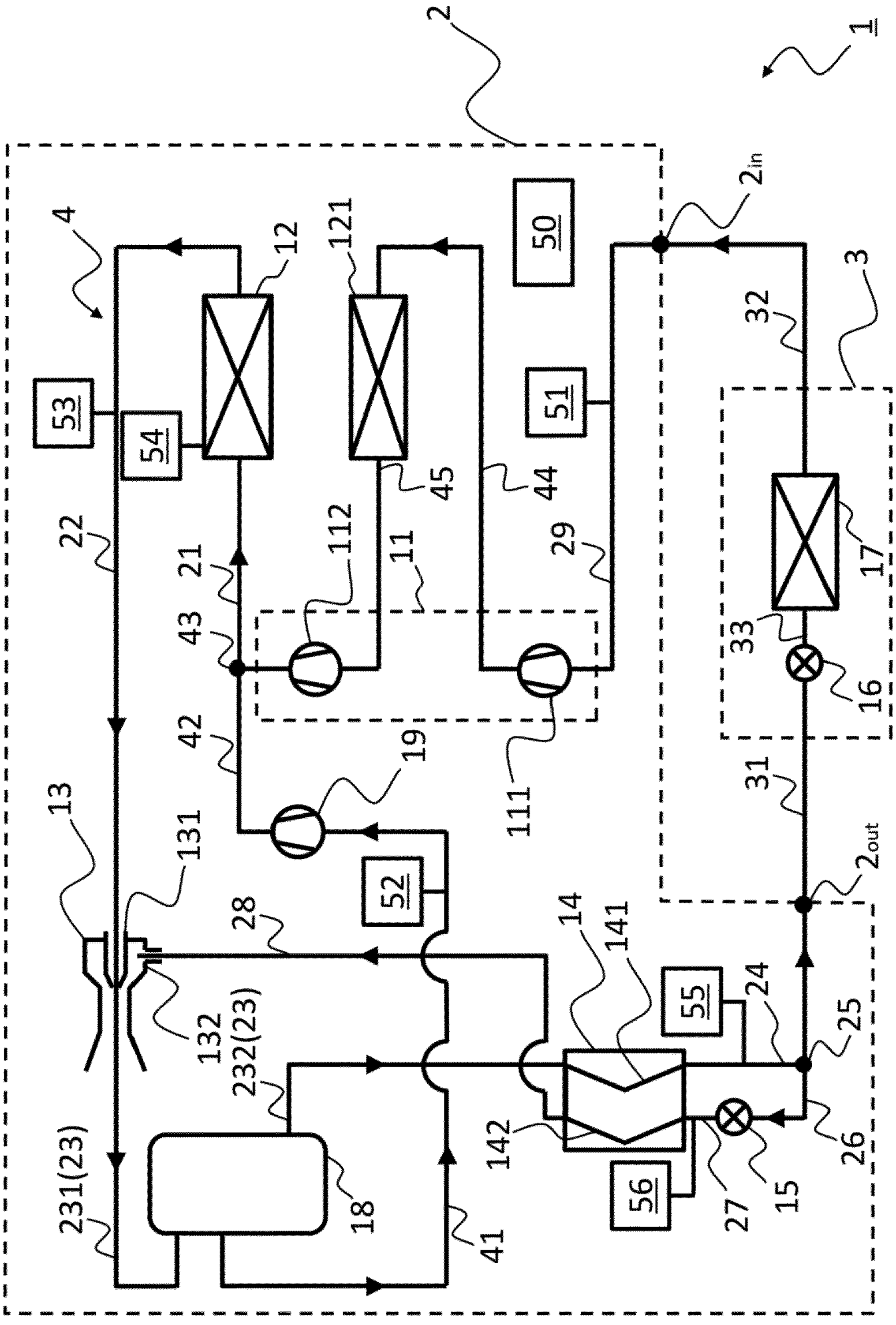
FIG. 2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2in
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12
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26
27
28
29
31
32
33
41
42
43
44
45
50
51
52
53
54
55
56
111
112
121
131
132
141
142
231(23)
232(23)

FIG. 3

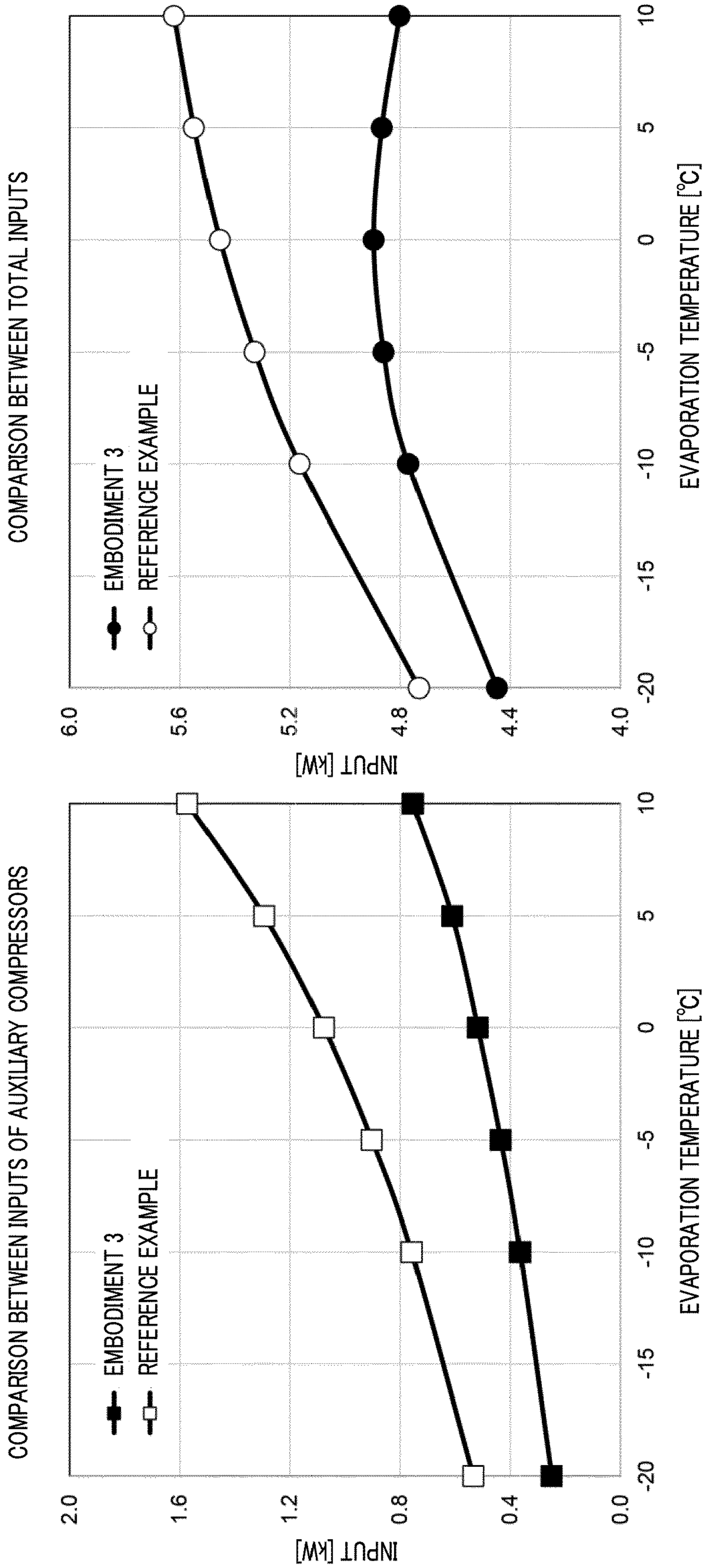
COMPARISON BETWEEN TOTAL INPUTS
EMBODIMENT 3
REFERENCE EXAMPLE
INPUT [kW]
6.0
5.6
5.2
4.8
4.4
4.0
-20
-15
-10
-5
0
5
10
EVAPORATION TEMPERATURE [°C]
COMPARISON BETWEEN INPUTS OF AUXILIARY COMPRESSORS
EMBODIMENT 3
REFERENCE EXAMPLE
INPUT [kW]
2.0
1.6
1.2
0.8
0.4
0.0
-20
-15
-10
-5
0
5
10
EVAPORATION TEMPERATURE [°C]

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 9825

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 10 2019 111309 A1 (UNIV DRESDEN TECH [DE]) 5 November 2020 (2020-11-05) * paragraph [0011] - paragraph [0143]; figures 1-4 * -----	1-8	INV. F25B1/10 F25B9/00 F25B41/00 F25B49/02
X	WO 2017/081157 A1 (DANFOSS AS [DK]) 18 May 2017 (2017-05-18) * page 12, line 7 - page 18, line 33; figures 1-5 * -----	1-8	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 March 2022	Szilagyi, Barnabas

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24-03-2022

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DE 102019111309 A1	05-11-2020	NONE	
WO 2017081157 A1	18-05-2017	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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