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(54) MULTI-STAGE COMPRESSION REFRIGERATION DEVICE

(57) Provided is a refrigeration device that is able to improve the efficiency of a refrigeration cycle by increasing the number of compression stages, while operating stably over a wide range of operating conditions. This refrigeration device is provided with: a compression unit containing a plurality of stages of compression mechanisms, the number of stages N being at least 3; a first heat exchange for releasing, to the outside air, heat from a refrigerant discharged from the compression unit; a decompression unit containing a plurality of decompression mechanisms provided to each of the plurality of stages; a second heat exchanger for causing the refrigerant that has passed through the decompression unit to absorb heat from a thermal load; a plurality of gas-liquid separators provided between the decompression mechanisms; a plurality of intermediate pressure injection flow passages corresponding respectively to the plurality of gas-liquid separators and supplying gas-phase refrigerant from the corresponding gas-liquid separator to between the compression mechanisms; and a valve provided to at least one of the plurality of intermediate pressure injection flow passages. When the valve is operated the number of effective stages circulating the refrigerant changes.

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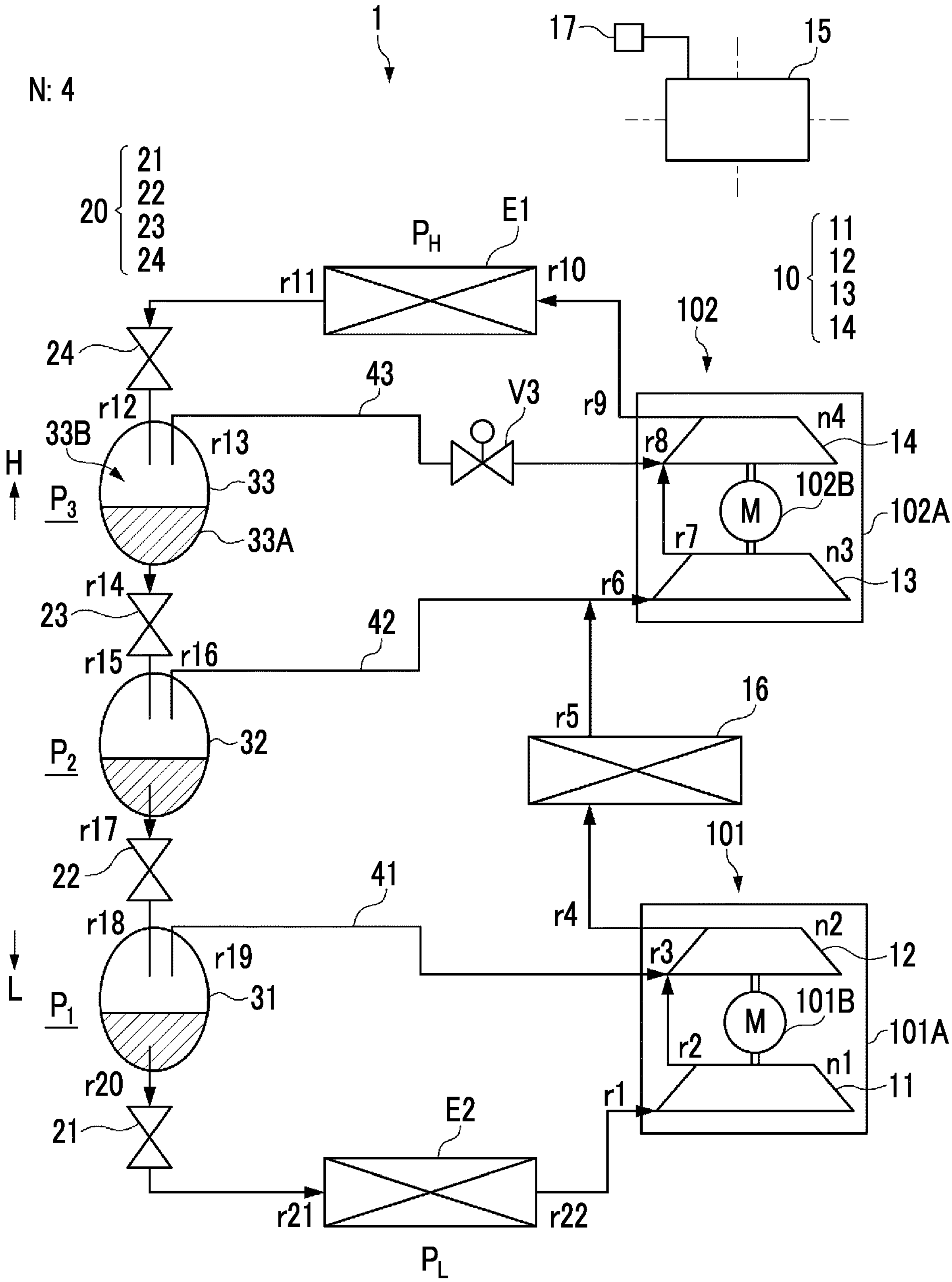
FIG. 1


1
N: 4
17
15
20
21
22
23
24
P_H
E1
r11
r10
10
11
12
13
14
102
24
43
V3
r9
r12
n4
33B
r13
r8
14
H
33
102B
P_3
M
102A
33A
r7
n3
r14
r6
13
23
42
r15
r16
16
P_2
32
r5
r17
101
22
41
r4
n2
r18
r3
12
L
r19
P_1
31
101B
M
101A
r2
n1
r20
11
E2
r1
21
r21
r22
P_L

Description

Technical Field

[0001] The present disclosure relates to a refrigeration device that compresses a refrigerant in multiple stages.

Background Art

[0002] PTL 1 discloses a refrigeration device including a two-stage compression mechanism. Such a refrigeration device includes an electric compressor including a low-stage compression mechanism and a high-stage compression mechanism in a sealed housing, a condenser (gas cooler), a high-pressure expansion valve, a gas-liquid separator, a low-pressure expansion valve, an evaporator, and a gas injection pipe. A gas refrigerant introduced from the gas-liquid separator into the housing of the electric compressor by the gas injection pipe is sucked into the high-stage compression mechanism together with a refrigerant discharged into the housing from the low-stage compression mechanism.

Citation List

Patent Literature

[0003] [PTL 1] Japanese Unexamined Patent Publication No. 2017-44420

Summary of Invention

Technical Problem

[0004] For the purpose of reducing the global warming potential (GWP) and improving the coefficient of performance (COP), development and commercialization of a refrigeration device that employs a refrigerant having a low GWP and includes a two-stage compression mechanism are in progress.

[0005] In a case where a refrigerant including CO_2 is employed as the refrigerant, in order to suppress the high refrigerant discharge temperature caused by the high-pressure operation to an allowable limit, it is effective to introduce a gas refrigerant, which has an intermediate pressure between the high pressure which is set in the condenser (gas cooler) and the low pressure which is set in the evaporator, from the gas-liquid separator into a spacing between the low-stage compression mechanism and the high-stage compression mechanism (intermediate-pressure gas injection). According to such a configuration, the discharge temperature can be suppressed by the injection of the gas refrigerant having a temperature which is lower than the temperature of the refrigerant discharged from the low-stage compression mechanism. In addition, since the liquid refrigerant is supplied from the gas-liquid separator to the low-pressure expansion valve, an enthalpy obtained by the evaporator is increased as compared with the case of single-stage compression. Therefore, the cooling capacity can be increased, and the COP can be improved.

[0006] In the refrigeration device that employs the refrigerant having a low GWP, it is desired to implement a refrigeration device having an increased COP while suppressing the discharge temperature thereof in discharge from the compressor by further increasing the number of stages of the compression mechanism. However, according to a test study by the inventor of the present disclosure, the refrigeration device, in which the number of stages of the compression mechanism is increased to for example "4", does not operate stably depending on operating conditions such as an outside air temperature. Such a refrigeration device includes N compression mechanisms, N expansion valves, N-1 gas-liquid separators, and N-1 gas injection pipes.

[0007] Based on the above description, an object of the present disclosure is to provide a refrigeration device capable of stably operating in a wide range of operating conditions while improving the efficiency of the refrigerating cycle by increasing the number of compression stages.

Solution to Problem

[0008] According to the present disclosure, there is provided a refrigeration device that circulates a refrigerant in accordance with a refrigerating cycle, the refrigeration device including: a compression portion that includes compression mechanisms which have a plurality of stages and are connected in series, each of which compress the refrigerant, and of which the number of stages is three or more; a first heat exchanger that dissipates heat of the refrigerant compressed by the compression portion from a low stage to a high stage through a plurality of steps and discharged from the compression portion to outside air; a decompression portion that includes a plurality of decompression mechanisms applied to each of the plurality of stages and that reduces a pressure of the refrigerant which passes through the first heat exchanger through a plurality of steps; a second heat exchanger that absorbs heat from a thermal load of the refrigerant which passes through the decompression portion; a plurality of gas-liquid separators that each are provided in a spacing between decompression mechanisms of the plurality of decompression mechanisms; a plurality of intermediate-pressure injection flow paths that respectively correspond to the plurality of gas-liquid separators and each supply the gas phase refrigerant to a spacing between compression mechanisms of the plurality of compression mechanisms from the corresponding gas-liquid separator; and a valve that is provided in at least one of the plurality of intermediate-pressure injection flow paths. In such a refrigeration device, the number of effective stages through which the refrigerant circulates is configured to be variable by operating the valve.

[0009] In the present invention, the valve provided in the intermediate-pressure injection flow path can be opened and closed during the operation of the refrigeration device according to operating conditions for the purpose of stably operating the refrigeration device. In addition to this, the valve can not be prevented from being closed for other purposes such as a purpose of preventing the refrigerant from being moved in a case where the refrigeration device is stopped.

Advantageous Effects of Invention

[0010] According to the refrigeration device of the present disclosure, the number of effective stages through which the refrigerant circulates is configured to be variable by switching the valve provided in at least one of the plurality of intermediate-pressure injection flow paths to open or closed. Therefore, in a case where the operating state becomes unstable in a case where the COP is improved by the refrigerating cycle with the maximum number of stages and the operation is performed with the maximum number of stages, the valve is closed during the operation to reduce the number of effective stages with respect to the maximum number of stages. Thereby, the refrigeration device can be stably operated.

[0011] According to the present disclosure, a cycle appropriate for each of the states of the refrigerant under various operating conditions can be easily implemented by changing the number of effective stages through opening and closing of the valve. Therefore, it is possible to provide a multi-stage compression refrigeration device which can be stably operated in a wide range of operating conditions.

Brief Description of Drawings

[0012]

Fig. 1 is a diagram showing a circuit configuration of a refrigeration device according to a first embodiment.
Fig. 2 is a Mollier diagram in a normal operating mode of the refrigeration device shown in Fig. 1.
Fig. 3 is a Mollier diagram in a high outside air temperature mode of the refrigeration device shown in Fig. 1.
Fig. 4 is a diagram showing a circuit configuration of a refrigeration device according to a modification example of the first embodiment.
Fig. 5 is a diagram showing a circuit configuration of a refrigeration device according to a second embodiment.
Fig. 6 is a Mollier diagram in a low outside air temperature mode of the refrigeration device shown in Fig. 5.
Fig. 7 is a diagram showing a circuit configuration of a refrigeration device according to a modification example.

Description of Embodiments

[0013] Hereinafter, embodiments of the present disclosure will be described with reference to the accompanying drawings.

[First Embodiment]

(Basic Elements of Refrigerating Cycle)

[0014] In the multi-stage compression type refrigeration device 1 shown in Fig. 1, thermal loads (for example, air in a device housing and articles housed therein), which are appropriate in a case where the outside air is used as a heat source, are cooled by circulating a refrigerant in accordance with a refrigerating cycle.

[0015] The refrigeration device 1 has, as basic elements forming a refrigerating cycle, a compression portion 10 that compresses the refrigerant, a condenser (gas cooler) E1 (first heat exchanger) that dissipates heat of the refrigerant to the outside air, a decompression portion 20 that reduces a pressure of the refrigerant, and a evaporator E2 (second heat exchanger) that absorbs heat from the thermal loads to the refrigerant. The refrigerant, which is compressed by the compression portion 10, flows through the condenser (gas cooler) E1, the decompression portion 20, and the evaporator E2 in this order, and is sucked into the compression portion 10.

[0016] A refrigerant including carbon dioxide (CO_2) in at least a part thereof is sealed in the refrigerant circuit of the refrigeration device 1 of the present embodiment. Such a refrigerant corresponds to a single refrigerant of CO_2 or a mixed refrigerant obtained by mixing CO_2 with, for example, an R32 refrigerant at a ratio of about 10 to 20%. A GWP of carbon dioxide is "1". A critical temperature of carbon dioxide is lower than a critical temperature of another refrigerant (for example, hydro fluoro carbon (HFC)). Therefore, in the normal operating mode of the refrigeration device 1, the refrigerant of the present embodiment is compressed to a pressure greater than the critical pressure P_C by the compression portion 10 that compresses the refrigerant through a plurality of stages. Therefore, as compared with a case of using another refrigerant, the operation is performed in a state where the set pressure on the high pressure side H is high.

(Compression Mechanisms and Decompression Mechanisms Having Plurality of Stages)

[0017] The compression portion 10 includes a plurality of compression mechanisms 11 to 14 connected in series. The first stage compression mechanism 11, the second stage compression mechanism 12, the third stage compression mechanism 13, and the fourth stage compression mechanism 14 sequentially compress the refrigerant from the low pressure side L to the high pressure side H through a plurality of steps. The number of stages N of the compression portion 10 is equal to or greater than 3, and for example, the number of stages N is "4". The reference numerals of n1, n2, n3, and n4 represent first to fourth stages.

[0018] As will be described later, the number of stages N is changed in accordance with the operating mode of the refrigeration device 1. Fig. 2 is a Mollier diagram showing a relationship between the specific enthalpy and the pressure of the refrigerant assumed in the normal operating mode. Symbols such as r1 and r2 shown in Fig. 2 correspond to the same symbols shown in Fig. 1.

[0019] The refrigeration device 1 of the present embodiment includes two electric compressors 101 and 102, a control unit 15 capable of controlling operations of the electric motor, the expansion valve, and the like of each of the electric compressors 101 and 102, and an intermediate cooling heat exchanger 16 which is provided between the electric compressors 101 and 102.

[0020] The first electric compressor 101 includes the first stage compression mechanism 11 and the second stage compression mechanism 12 connected in series, a housing 101A that houses the compression mechanisms 11 and 12, and an electric motor 101B that rotationally drives the compression mechanisms 11 and 12.

[0021] The second electric compressor 102 includes the third stage compression mechanism 13 and the fourth stage compression mechanism 14 connected in series, a housing 102A that houses the compression mechanisms 13 and 14, and an electric motor 102B that rotationally drives the compression mechanisms 13 and 14.

[0022] The multi-stage compression refrigeration device 1 having the number of stages N is implemented by combining the two electric compressors 101 and 102 each of which is driven by the same electric motor and includes compression mechanisms having a plurality of stages. Therefore, the control unit 15 may control rotation speeds of the two electric motors 101B and 102B, respectively. Therefore, the control of the refrigeration device 1 is easier than that in a case where the corresponding electric motors individually drive the compression mechanisms 11 to 14 of the respective stages. Further, as compared with a case where the compression portion 10 includes four compressors each including a compression mechanism, an electric motor, and a housing, it is possible to achieve reduction in size and weight of the refrigeration device 1.

[0023] The intermediate cooling heat exchanger 16 cools the refrigerant discharged from the second stage compression mechanism 12 by dissipating heat to the outside air and supplies the refrigerant to a suction portion of the third stage compression mechanism 13 (operational points r4 and r5 in Fig. 2).

[0024] The first stage compression mechanism 11 corresponds to, for example, a rotary compression mechanism which includes a piston rotor and a cylinder. It is the same for the third stage compression mechanism 13. The second stage compression mechanism 12 corresponds to, for example, a scroll-type compression mechanism which includes a pair of scroll members. It is the same for the fourth stage compression mechanism 14.

[0025] Corresponding to the case where the compression portion 10 is formed of the compression mechanisms 11 to 14 having a plurality of stages, the decompression portion 20 includes decompression mechanisms 21 to 24 each of which is provided to each stage (n1, n2, n3, n4) and has the same number as the number of stages N for compression. Each of the decompression mechanisms 21 to 24 may be an expansion valve, a capillary tube, or the like. The fourth stage decompression mechanism 24, the third stage decompression mechanism 23, the second stage decompression mechanism 22, and the first stage decompression mechanism 21 sequentially reduce the pressure of the refrigerant, which passes through the condenser (gas cooler) E1, through a plurality of steps in this order.

[0026] As shown in Fig. 2, the compression mechanisms 11 to 14 of the plurality of stages n1, n2, n3, and n4 compress the refrigerant, and thereby the pressure of the refrigerant is increased stepwise. Thereby, the discharge temperature of the refrigerant rises.

[0027] By lowering the temperature of the refrigerant due to the action of the intermediate cooling heat exchanger 16 that dissipates heat of the refrigerant to the outside air (refer to an arrow A1 in Fig. 2), it is possible to contribute to suppression of the discharge temperature of the entire compression portion 10 as a whole.

[0028] A pressure between a pressure of suction to the first stage n1 and a pressure of discharge from the second stage n2 is referred to as a first intermediate pressure P_1. Similarly, a pressure between a pressure of suction to the second stage n2 and a pressure of discharge from the third stage n3 is referred to as a second intermediate pressure P_2, and a pressure between a pressure of suction to the third stage n3 and a pressure of discharge from the fourth stage n4 is referred to as a third intermediate pressure P_3. A relationship of $P_1 < P_2 < P_3$ is established.

[0029] The refrigerant circulates in the refrigerant circuit of the refrigeration device 1 while changing the pressure and the enthalpy with the phase change on the basis of pressure ratios of the respective stages n1, n2, n3, and n4 determined by a set pressure P_H of the condenser (gas cooler) E1 on the high pressure side H, a set pressure P_L of the evaporator E2 on the low pressure side L, and the intermediate pressures (P_1, P_2, P_3).

(Intermediate-Pressure Gas Injection)

[0030] The refrigeration device 1 performs gas injection for supplying the gas refrigerant having an intermediate pressure to each spacing between the first to fourth stage compression mechanisms 11 to 14. The gas refrigerant is obtained by gas-liquid separation of the refrigerant in each spacing between the stages of the first to fourth stage decompression mechanisms 21 to 24. Therefore, the refrigeration device 1 includes N-1 gas-liquid separators 31 to 33, each of which is provided to each spacing between the first to fourth stage decompression mechanisms 21 to 24, and N-1 intermediate-pressure injection flow paths 41 to 43 respectively corresponding to the gas-liquid separators 31 to 33.

[0031] In the normal operating mode, the pressure (r12, r13, r14) of the refrigerant, which is discharged from the fourth stage compression mechanism 14 and passes through the condenser (gas cooler) E1 and the fourth stage decompression mechanism 24, that is, the third intermediate pressure P_3 is kept equal to or less than a critical pressure P_C.

[0032] The third intermediate-pressure gas-liquid separator 33 (liquid receiver) receives the refrigerant from the fourth stage decompression mechanism 24 into a storage tank 33A and separates the refrigerant into the gas phase and the liquid phase. As shown in Fig. 2, this corresponds to a status change from r12 to r13 and r14.

[0033] The refrigerant inside the storage tank 33A is separated into a gas phase and a liquid phase on the basis of a density difference. A third intermediate-pressure injection flow path 43 is connected to a gas phase region 33B above the liquid level.

the third intermediate-pressure injection flow path 43 supplies the gas refrigerant, which has the third intermediate pressure P_3, from the gas phase region 33B to the suction portion of the fourth stage compression mechanism 14 (from r13 to r8). A temperature of the gas refrigerant, which is supplied to the fourth stage compression mechanism 14 through the third intermediate-pressure injection flow path 43, is lower than a temperature of the refrigerant which is discharged from the third stage compression mechanism 13. Therefore, the temperature of the refrigerant to be sucked into the fourth stage compression mechanism 14, as the entirety of the refrigerant supplied through the third intermediate-pressure injection flow path 43 and the refrigerant discharged from the third stage compression mechanism 13, is lowered (from r7 to r8). Then, the temperature of the refrigerant discharged from the fourth stage compression mechanism 14 is also lowered. Therefore, the intermediate-pressure gas injection contributes to the reduction in discharge temperature.

[0034] On the other hand, the liquid refrigerant of the third intermediate pressure P_3, which is stored in the storage tank 33A, flows out from the storage tank 33A and is decompressed by the third stage decompression mechanism 23 (from r14 to r15). According to a configuration in which the liquid refrigerant is supplied to the decompression mechanisms 21 to 23 including the decompression mechanism 23, the enthalpy corresponding to the evaporation process in the evaporator E2 is increased (refer to the arrow A2 in Fig. 2 in the third stage decompression mechanism 23). As a result, it is possible to improve the COP.

[0035] The reduction in discharge temperature and the improvement in efficiency obtained by increasing the enthalpy described above can be said in each of the third intermediate pressure P_3, the second intermediate pressure P_2, and the first intermediate pressure P_1. The present invention is not limited to the four stages of the present embodiment. By increasing the number of stages N to five or six stages, it is possible to enhance the effect of reducing the discharge temperature and improving the efficiency.

[0036] The gas injection of each of the second intermediate pressure P_2 and the first intermediate pressure P_1 is similar to the gas injection of the third intermediate pressure P_3 described above.

[0037] The refrigerant, which passes through the third stage decompression mechanism 23, is received by the second intermediate-pressure gas-liquid separator 32 and is separated into the gas phase and the liquid phase, in a similar manner to the third intermediate-pressure gas-liquid separator 33. This corresponds to a status change from r15 to r16 and r17.

[0038] A second intermediate-pressure injection flow path 42 is connected to a gas phase region of the second intermediate-pressure gas-liquid separator 32. In a case where the gas refrigerant of the second intermediate pressure P_2 is supplied to the suction portion of the third stage compression mechanism 13 (from r16 to r6) through the second intermediate-pressure injection flow path 42, the gas refrigerant of the second intermediate pressure P_2 flows out from the intermediate cooling heat exchanger 16. Thereby, the temperature of the refrigerant sucked into the third stage compression mechanism 13 is lowered (from r5 to r6). Between the second stage compression mechanism 12 and the third stage compression mechanism 13, in addition to the injection action of the intermediate pressure P_2, the action of the intermediate cooling heat exchanger 16 (from r4 to r5) also lowers a suction temperature in suction into the third stage compression mechanism 13 is lowered. Thus, it is possible to further suppress the discharge temperature.

[0039] The second stage decompression mechanism 22 decompress the liquid refrigerant of the second intermediate pressure P_2 flowing out from the second intermediate-pressure gas-liquid separator 32 (from r17 to r18) .

[0040] The refrigerant, which passes through the second stage decompression mechanism 22, is received by the first intermediate-pressure gas-liquid separator 31 and is separated into the gas phase and the liquid phase. This corresponds to a status change from r18 to r19 and r20.

[0041] In a case where the gas refrigerant of the first intermediate pressure P_1 is supplied to the suction portion of the second stage compression mechanism 12 through the first intermediate-pressure injection flow path 41 connected to the gas phase region of the first intermediate-pressure gas-liquid separator 31 (from r18 to r3), the temperature of the refrigerant sucked into the second stage compression mechanism 12 is lowered (from r2 to r3).

[0042] The first stage decompression mechanism 21 decompress the liquid refrigerant of the first intermediate pressure P_1 flowing out of the first intermediate-pressure gas-liquid separator 31 (from r20 to r21). The refrigerant, which passes through the first stage decompression mechanism 21, evaporates by absorbing heat from the thermal load by the evaporator E2 and is sucked into the first stage compression mechanism 11 (from r21 to r22 and r1).

[0043] In a case where the refrigeration device 1 is operated in a state of being set to the normal operating mode by the control unit 15, compression, expansion, and intermediate-pressure injection corresponding to the number of stages N provided in the refrigeration device 1 are performed. In such a manner, it is possible to improve the COP while using a refrigerant having a low GWP. In addition, it is possible to stably operate the refrigeration device 1 while keeping the discharge temperature equal to or less than the allowable limit.

[0044] However, for example, in a case where the outside air temperature is excessively high with respect to the range of the outside air temperature assumed in the normal operating mode, when the refrigeration device 1 is operated with the maximum number of stages N, the operating state may become unstable and the refrigerant may not be circulated.

[0045] Even though it is permissible for a temperature of the CO_2 refrigerant discharged from the compression portion 10 through the multi-stage compression to be greater than the critical pressure P_C, the amount of heat dissipated by the refrigerant by the condenser (gas cooler) E1 decreases as the outside air temperature rises. Thereby, in a case where the third intermediate pressure P_3 (r12, r13, r14) is greater than the critical pressure P_C, the gas-liquid separation cannot be performed since the refrigerant does not condense in the third intermediate-pressure gas-liquid separator 33, and it is difficult to perform stable control since the behavior of the refrigerant in the supercritical state is not stable. It is difficult to stabilize the operating state by estimating the pressure, temperature, flow rate, and the like of the supercritical fluid.

[0046] Therefore, in order to stably operate the refrigeration device 1 in a wide range including an operating condition in which the outside air temperature is excessively high or other operating conditions, the refrigeration device 1 includes a valve (V3) provided in at least one arbitrarily selected from the intermediate-pressure injection flow paths 41 to 43.

[0047] The refrigeration device 1 of the present embodiment includes the third intermediate-pressure valve V3 provided in the third intermediate-pressure injection flow path 43 on the highest pressure side H.

[0048] The third intermediate-pressure valve V3 is an electromagnetic valve, and is switched to be open or closed on the basis of a command issued from the control unit 15.

[0049] In the normal operating mode, the refrigeration device 1 is operated while performing the injection of first to third intermediate pressures P_1, P_2, and P_3 through the first to third intermediate-pressure injection flow paths 41 to 43 in a state where the third intermediate-pressure valve V3 is open and while changing the pressure and enthalpy of the refrigerant as shown in Fig. 2. In such a case, the number of effective stages N_A as the number of stages, in which the refrigerant is circulated, is "4" corresponding to the total number of stages N provided in the refrigeration device 1.

(High Outside Air Temperature Mode)

[0050] In a case where the outside air temperature becomes excessively higher as the pressure of the refrigerant becomes greater than the critical pressure, the control unit 15 closes the third intermediate-pressure valve V3 and switches the operating mode of the refrigeration device 1 to the high outside air temperature mode for performing the intermediate-pressure injection through only the first intermediate-pressure injection flow path 41 and the second intermediate-pressure injection flow path 42. In the high outside air temperature mode, the refrigerant in the supercritical state even after passing through the fourth stage decompression mechanism 24 passes through the inside of the storage tank 33A of the third intermediate-pressure gas-liquid separator 33, is decompressed by the third stage decompression mechanism 23, and thereafter flows into the second intermediate-pressure gas-liquid separator 32 (from r12, r13, and r14 to r15). In such a case, the liquid refrigerant is not stored in the storage tank 33A (corresponding to the internal state of the storage tank 33A shown in Fig. 4).

[0051] In a case where the third intermediate-pressure valve V3 is closed, the refrigerant does not flow through the third intermediate-pressure injection flow path 43. Thus, as a result of combining the third stage n3 and the fourth stage n4 in the normal operating mode into one stage in the compression expansion process, the number of effective stages N decreases to "3". As shown in the state of the refrigerant in the high outside air temperature mode in Fig. 3, the refrigeration device 1 is operated by a cycle of three-stage compression and three-stage expansion of n1 to n3. Since the pressure of the refrigerant in the supercritical state is reduced by the third stage decompression mechanism 23 (from r12, r13, and r14 to r15), the second intermediate pressure P_2 is kept equal to or less than the critical pressure P_C. Therefore, the refrigeration device 1 is stably operated.

[0052] In the normal operating mode, the control unit 15 determines whether or not the pressure on the high pressure side H on the map data corresponding to the detection result of the outside air temperature is greater than the first threshold pressure T_1 (Fig. 3) which is set lower than the critical pressure P_C on the basis of estimation of a margin, by using, for example, map data or the like indicating correspondence between the outside air temperature and the set pressure on the high pressure side H and the outside air temperature detected by the temperature sensor 17. In a case where the pressure on the high pressure side H on the map data corresponding to the detection result of the outside air temperature is greater than the first threshold pressure T_1, the control unit 15 shifts to the high outside air temperature mode from the normal operating mode by closing the third intermediate-pressure valve V3.

[0053] The outside air temperature is continuously monitored even in the high outside air temperature mode. For example, in a case where the pressure on the high pressure side H on the map data corresponding to the detection result of the outside air temperature is smaller than the second threshold pressure T_2 lower than the first threshold pressure T_1, the control unit 15 returns from the high outside air temperature mode to the normal operating mode by opening the third intermediate-pressure valve V3.

[0054] According to the refrigeration device 1 of the first embodiment described above, the number of effective stages N_A through which the refrigerant circulates is configured to be variable by switching the valve V3 provided in at least one of the intermediate-pressure injection flow paths 41 to 43 to open or closed. Therefore, in the normal operating mode, the refrigeration device 1 can be stably operated by closing the valve V3 provided in the intermediate-pressure injection flow path 43 on the high pressure side H to reduce the number of effective stages N_A, in a case where the outside air temperature becomes higher as the intermediate pressure on the high pressure side H becomes greater than the critical pressure P_C, while improving the COP by the refrigerating cycle with the maximum number of stages N.

[0055] Consequently, according to the present embodiment, while handling the refrigerant compressed to the supercritical state, difficult control based on the estimation of the behavior of the refrigerant in the supercritical state is not necessary. In addition, by changing the number of effective stages N_A through opening and closing of the valve V3, a cycle appropriate for each of the states of the refrigerant under various operating conditions can be easily implemented. Therefore, it is possible to provide the refrigeration device 1 with multi-stage compression that can be stably operated in a wide range of operating conditions.

[0056] The refrigeration device 1 may include a valve provided in another intermediate-pressure injection flow path 42 or 41 in addition to the valve V3 provided in the third intermediate-pressure injection flow path 43. For example, as shown in Fig. 4, the valve V2, which can be opened and closed by the control unit 15, is not prevented from being also provided in the second intermediate-pressure injection flow path 42. In the high outside air temperature mode shown in Fig. 4, in the intermediate-pressure valves V2 and V3, only the third intermediate-pressure valve V3 shown in black is closed.

[Second Embodiment]

[0057] Next, a second embodiment will be described with reference to Figs. 5 and 6. The following description will be given focusing on items that differ from those of the first embodiment. The same reference numerals will be assigned to the same components as those in the first embodiment.

[0058] The refrigeration device 1-2 shown in Fig. 5 includes a first intermediate-pressure valve V1 provided in the first intermediate-pressure injection flow path 41 in order to cope with operating conditions different from those of the refrigeration device 1 of the first embodiment. The refrigeration device 1-2 also includes the third intermediate-pressure valve V3 provided in the third intermediate-pressure injection flow path 43, in a similar manner to the refrigeration device 1 of the first embodiment. The refrigeration device 1-2 of the second embodiment is configured in a similar manner to the refrigeration device 1 of the first embodiment except that the first intermediate-pressure valve V1 is provided.

[0059] The refrigeration device 1-2 includes the third intermediate-pressure valve V1 as in the refrigeration device 1. Therefore, by closing only the third intermediate-pressure valve V3 of the intermediate-pressure valves V1 and V3 to reduce the number of effective stages N_A to "3", the above-mentioned high outside air temperature mode can be performed.

[0060] Contrary to the high outside air temperature mode, in a case where the outside air temperature is low, a pressure ratio between the set pressure P_H on the high pressure side H and the set pressure P_L on the low pressure side L decreases. The pressure ratio is proportionally distributed into each stage. Therefore, in a case where the operation is performed with the maximum number of stages N as in the normal operating mode, the pressure ratios of the respective stages n1, n2, n3, and n4 decrease. In a case where the outside air temperature becomes lower as the pressure ratio of each stage becomes more insufficient relative to the pressure ratios necessary for respectively transporting the refrigerant from the gas-liquid separators 31 to 33 to the compression mechanisms 12 to 14, the refrigerant cannot be circulated in each stage.

[0061] In such a case, the control unit 15 switches the operating mode of the refrigeration device 1-2 from the normal operating mode to the low outside air temperature mode (low pressure ratio operating mode) by closing both the first intermediate-pressure valve V1 and the third intermediate-pressure valve V3. In the low outside air temperature mode, the intermediate-pressure injection is performed only through the second intermediate-pressure injection flow path 42.

[0062] Fig. 6 shows a state of the refrigerant in the low outside air temperature mode. By closing the first intermediate-pressure valve V1 and the third intermediate-pressure valve V3, the number of effective stages N_A decreases to "2", and at this time, the refrigeration device 1-2 is operated by a cycle of two-stage compression and two-stage expansion. As the number of effective stages N_A decreases with respect to the total number of stages N, a sufficient pressure for transporting the refrigerant from each of the gas-liquid separators 31 to 33 to the compression mechanisms 12 to 14 is ensured in each stage. Therefore, the refrigeration device 1 is stably operated.

[0063] In the normal operating mode, the control unit 15 determines whether the pressure ratio of each stage on the map data corresponding to the detection result of the outside air temperature is larger or smaller than the first pressure ratio R_1 of each stage in consideration of the pressure ratio of each stage necessary for the intermediate-pressure injection, by using, for example, the map data indicating correspondence between the outside air temperature and the pressure ratio of each stage and the outside air temperature detected by the temperature sensor 17. In a case where the pressure ratio of each stage on the map data corresponding to the detection result of the outside air temperature is smaller than the first pressure ratio R_1 of each stage, the control unit 15 closes the first intermediate-pressure valve V1 and the third intermediate-pressure valve V3 to shift from the normal operating mode to the low outside air temperature mode.

[0064] The outside air temperature is continuously monitored. For example, the pressure ratio of each stage on the map data corresponding to the detection result of the outside air temperature is greater than a second pressure ratio R_2 ($R_1 < R_2$) of each stage. In such a case, the control unit 15 opens the intermediate-pressure valves V1 and V3 to return from the low outside air temperature mode to the normal operating mode.

[0065] According to the refrigeration device 1-2 of the second embodiment described above, by closing at least the third intermediate-pressure valve V3 of the intermediate-pressure valves V1 and V3 provided, one on each of the high pressure side H and the low pressure side L, the number of effective stages N_A can be changed to three stages and two stages with respect to four stages as the total number of stages. Then, the refrigeration device 1-2 can be stably operated in a wider range of operating conditions with respect to the refrigeration device 1 of the first embodiment.

[0066] From the viewpoint of reducing the number of effective stages N_A, only one of the intermediate-pressure valves V1 and V3 of the second embodiment can be closed in the low outside air temperature mode. For example, only the third intermediate-pressure valve V3 may be closed, and a pressure ratio sufficient for performing intermediate-pressure injection through the first intermediate-pressure injection flow path 41 and the second intermediate-pressure injection flow path 42 may be ensured in each of the stages n1, n2, and n3. While detecting the outside air temperature, for example, the refrigeration device 1-2 can be operated in the number of stages which are most stable in a state where all of the intermediate-pressure valves V1 to V3 are open (four stages), a state where only the intermediate-pressure valve V3 is closed (three stages), and a state where both the intermediate-pressure valves V1 and V3 are closed (two stages), among the intermediate-pressure valves V1 to V3.

[0067] Alternatively, only the first intermediate-pressure valve V1 may be closed, and a pressure ratio sufficient for performing intermediate-pressure injection through the third intermediate-pressure injection flow path 43 and the second intermediate-pressure injection flow path 42 may be ensured in each of the stages n2, n3, and n4. In the latter case, in a case where the refrigeration device 1-2 is not used in an environment where the outside air temperature becomes higher as the third intermediate pressure P_3 becomes greater than the critical pressure P_C, installation of the intermediate-pressure valve V3 for the third intermediate-pressure injection flow path 43 can be omitted.

[0068] In the second embodiment, an on/off valve is not prevented from being also provided in the second intermediate-pressure injection flow path 42. However, in the second embodiment, the two-stage compression or two-stage expansion cycle is maintained by constantly performing the intermediate-pressure injection through the second intermediate-pressure injection flow path 42 in all the operating modes including the low outside air temperature mode. Therefore, the intermediate-pressure valve is not installed in the second intermediate-pressure injection flow path 42, and thus the device cost can be suppressed.

[0069] Even in a case where the total number of stages N is more than "4", for example, the total number of stages N is "5" or "6", the refrigeration device can be operated by reducing the number of stages N, in a similar manner to the second embodiment.

[0070] For example, in a case where the number of stages N is "5", the refrigeration device includes an intermediate-pressure valve provided in at least one of the fourth intermediate-pressure injection flow path and the third intermediate-pressure injection flow path on the high pressure side H, and an intermediate-pressure valve provided in at least one of a second intermediate-pressure injection flow path and a first intermediate-pressure injection flow path on the low pressure side L.

[0071] In such a case, it is assumed that the refrigeration device includes the fourth intermediate-pressure valve V4, the third intermediate-pressure valve V3, the second intermediate-pressure valve V2, and the first intermediate-pressure valve V1. Then, in the low outside air temperature mode, for example, the first intermediate-pressure valve V1, the third intermediate-pressure valve V3, and the fourth intermediate-pressure valve V4 can be closed and operated in a two-stage cycle, or the first intermediate-pressure valve V1 and the fourth intermediate-pressure valve V4 can be closed and operated in a three-stage cycle. Consequently, the number of effective stages N_A can be changed to "2" or "3".

[Modification Example]

[0072] Although not shown, it is also possible to provide intermediate-pressure valves respectively in the first to third intermediate-pressure injection flow paths 41 to 43, that is, in all of the intermediate-pressure injection flow paths 41 to 43. In such a case, the number of effective stages N_A can be reduced to "1" by closing any of the three intermediate-pressure valves V1, V2, and V3 provided in the refrigeration device.

[0073] In addition, one or two of the three intermediate-pressure valves V1, V2, and V3 provided in the refrigeration device are constantly open, and only the remaining intermediate-pressure valves are open and closed. Thereby, the refrigeration device can be made to meet various required operating conditions. Even the valve that is constantly open at this time can be closed in accordance with the operating mode depending on operating conditions such as a refrigerant used in the refrigeration device and an outside air temperature range appropriate for the area where the refrigeration device is used. Consequently, the same refrigerant circuit can be applied to a plurality of products having different refrigerants, operating environment temperatures, use applications or the like.

[0074] The refrigeration device 1-3 shown in Fig. 7 does not include a plurality of stages of electric compressors (101 and 102 in Fig. 1). Each of the compression mechanisms 11 to 13 provided in the refrigeration device 1-3 is configured as a single stage compressor together with an electric motor 10M and a housing 10H.

[0075] The refrigeration device 1-3 includes the second intermediate-pressure valve V2 provided in the second intermediate-pressure injection flow path 42 on the high pressure side H, and the first intermediate-pressure valve V1 provided in the first intermediate-pressure injection flow path 41 on the low pressure side L, in the first and second intermediate-pressure injection flow paths 41 and 42.

[0076] Since the outside air temperature is high, if the second intermediate pressure P_2 is greater than the critical pressure P_C in a case where the intermediate-pressure injection is performed using any of the first and second intermediate-pressure injection flow paths 41 and 42, the second intermediate-pressure valve V2 on the highest pressure side H is closed. Thereby, the refrigeration device 1-3 may be operated in the two-stage compression and two-stage expansion cycle.

[0077] Further, since the outside air temperature is low, if the pressure ratio of each of the stages is insufficient in a case where intermediate-pressure injection is performed using both the first and second intermediate-pressure injection flow paths 41 and 42, or for another reason, one or both of the intermediate-pressure valves V1 and V2 are closed. Thereby, the refrigeration device 1-3 may be operated in the two-stage compression and two-stage expansion cycle or the one-stage compression and one-stage expansion cycle.

[0078] The refrigeration device 1-3 includes the intermediate cooling heat exchanger 16, but may not include the intermediate cooling heat exchanger 16. In order to reduce the discharge temperature, the intermediate cooling heat exchanger 16 can be provided in at least any of a spacing between the compression mechanisms 11 and 12 and a spacing between the compression mechanisms 12 and 13.

[0079] Also in the refrigeration devices 1 and 1-2 described above, it is sufficient that the intermediate cooling heat exchanger 16 is provided as necessary.

[0080] In addition to the above, it is possible to select the configurations described in the above-mentioned embodiments or change the configurations to other configurations as appropriate.

[0081] For example, in each of the above-mentioned embodiments, liquid level sensors can be provided in the gas-liquid separators 31 to 33 in order to protect the compression mechanisms 11 to 14. In a case where the liquid level sensor detects that an excessive amount of liquid refrigerant is stored in the storage tank, the control unit 15 may close the intermediate-pressure valve of the corresponding intermediate-pressure injection flow path. In such a manner, it is possible to prevent damage to the compression mechanism due to inflow of the liquid refrigerant.

[Additional Notes]

[0082] The refrigeration device described above is understood as follows.

[1] A refrigeration device 1, 1-2, or 1-3 that circulates a refrigerant in accordance with a refrigerating cycle, the refrigeration device 1, 1-2, or 1-3 includes: a compression portion 10 that includes compression mechanisms 11 to 14 which have a plurality of stages and are connected in series, each of which compress the refrigerant, and of which the number of stages N is three or more; a first heat exchanger (E1) that dissipates heat of the refrigerant compressed by the compression portion 10 from a low stage to a high stage through a plurality of steps and discharged from the compression portion 10 to outside air; a decompression portion 20 that includes a plurality of decompression mechanisms 21 to 24 applied to each of the plurality of stages and that reduces a pressure of the refrigerant which passes through the first heat exchanger (E1) through a plurality of steps; a second heat exchanger (E2) that absorbs heat from a thermal load of the refrigerant which passes through the decompression portion 20; a plurality of gas-liquid separators 31 to 33 that are respectively provided in spacings between the decompression mechanisms among the decompression mechanisms 21 to 24; a plurality of intermediate-pressure injection flow paths 41 to 43 that respectively correspond to the plurality of gas-liquid separators 31 to 33 and respectively supply the gas phase refrigerant to spacings between the compression mechanisms among the compression mechanisms 11 to 14 from

the corresponding gas-liquid separators 31 to 33; and valves V1, V2, and V3 that are provided in at least one of the plurality of intermediate-pressure injection flow paths 41 to 43. The number of effective stages N_A through which the refrigerant circulates is configured to be variable by operating the valves V1, V2, and V3.

[2] The valve V3 is provided in the intermediate-pressure injection flow path 41 to 43 having a highest pressure among the plurality of intermediate-pressure injection flow paths 41 to 43.

[3] The refrigerant includes at least carbon dioxide in at least a part thereof.

[4] The number of stages N is four or more. In addition, the valves V1, V2, and V3 are provided in at least one of the intermediate-pressure injection flow paths 41 to 43 on a high pressure side and at least one of the intermediate-pressure injection flow paths 41 to 43 on a low pressure side among the plurality of intermediate-pressure injection flow paths 41 to 43.

[5] The refrigeration device 1, 1-2, or 1-3 further includes an intermediate cooling heat exchanger 16 that exchanges the heat of the refrigerant, which is discharged from the compression mechanism on a low pressure side as any one of the compression mechanisms 11 to 14, with heat of the outside air, and that allows the refrigerant to flow into the compression mechanism on a high pressure side as the compression mechanism connected in series with the compression mechanism on the low pressure side.

[6] The compression portion 10 includes multi-stage electric compressors 101 and 102 including a plurality of compression mechanisms 11, 12 (or 13, 14) that are connected in series, a housing (101A, or the like) that houses the plurality of compression mechanisms 11 and 12 (or 13 and 14), and an electric motor (101B, or the like) that drives the plurality of compression mechanisms 11 and 12 (or 13 and 14).

[7] The refrigeration devices 1, 1-2, and 1-3 include a control unit 15 that generates a command to operate the valves V1, V2, and V3, and the control unit 15 changes the number of effective stages N_A by generating the command in accordance with a temperature of the outside air.

Reference Signs List

[0083]

1, 1-2, 1-3: refrigeration device
10: compression portion
10H: housing
10M: electric motor
11: first stage compression mechanism
12: second stage compression mechanism
13: third stage compression mechanism
14: fourth stage compression mechanism
15: control unit
16: intermediate cooling heat exchanger (intermediate heat exchanger)
17: temperature sensor
20: decompression portion
21: first stage decompression mechanism
22: second stage decompression mechanism
23: third stage decompression mechanism
24: fourth stage decompression mechanism
31: first intermediate-pressure gas-liquid separator
32: second intermediate-pressure gas-liquid separator
33: third intermediate-pressure gas-liquid separator
33A: storage tank
33B: gas phase region
41: first intermediate-pressure injection flow path
42: second intermediate-pressure injection flow path
43: third intermediate-pressure injection flow path
101: first electric compressor (multi-stage electric compressor)
101A: housing
101B: electric motor
102: second electric compressor (multi-stage electric compressor)
102A: housing
102B: electric motor
E1: condenser (gas cooler) (first heat exchanger)
E2: evaporator (second heat exchanger)
H: high pressure side
L: low pressure side
N: number of stages
N_A: number of effective stages
P_1: first intermediate pressure
P_2: second intermediate pressure
P_3: third intermediate pressure
P_C: critical pressure
P_H, P_L: set pressure
R_1, R_2: pressure ratio
T_1: first threshold pressure
T_2: second threshold pressure
V1: first intermediate-pressure valve
V2: second intermediate-pressure valve
V3: third intermediate-pressure valve
n1 to n4: stages
r1 to r22: operational points

Claims

1. A refrigeration device that circulates a refrigerant in accordance with a refrigerating cycle, the refrigeration device comprising:

a compression portion that includes compression mechanisms which have a plurality of stages and are connected in series, each of which compress the refrigerant, and of which the

number of stages is three or more;
a first heat exchanger that dissipates heat of the refrigerant compressed by the compression portion from a low stage to a high stage through a plurality of steps and discharged from the compression portion to outside air;
a decompression portion that includes a plurality of decompression mechanisms applied to each of the plurality of stages and that reduces a pressure of the refrigerant which passes through the first heat exchanger through a plurality of steps;
a second heat exchanger that absorbs heat from a thermal load of the refrigerant which passes through the decompression portion;
a plurality of gas-liquid separators that each are provided in a spacing between decompression mechanisms of the plurality of decompression mechanisms;
a plurality of intermediate-pressure injection flow paths that respectively correspond to the plurality of gas-liquid separators and each supply the gas phase refrigerant to a spacing between the compression mechanism and the compression mechanism from the corresponding gas-liquid separator; and
a valve that is provided in at least one of the plurality of intermediate-pressure injection flow paths,
wherein the number of effective stages through which the refrigerant circulates is configured to be variable by operating the valve.

2. The refrigeration device according to claim 1, wherein the valve is provided in the intermediate-pressure injection flow path having a highest pressure among the plurality of intermediate-pressure injection flow paths.

3. The refrigeration device according to claim 1 or 2, wherein the refrigerant includes carbon dioxide in at least a part thereof.

4. The refrigeration device according to any one of claims 1 to 3,

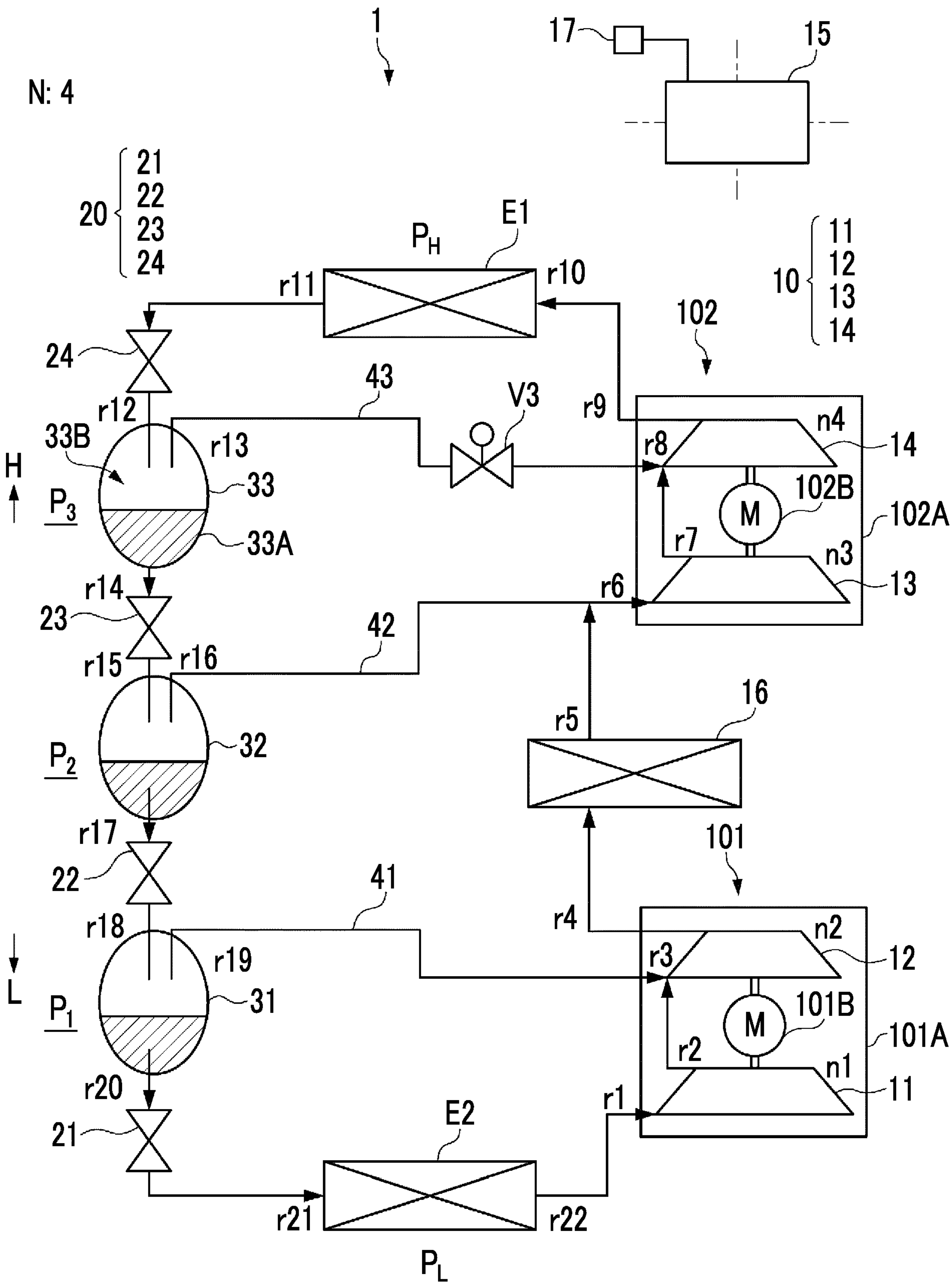
wherein the number of stages is four or more, and
the valve is provided in at least one of the intermediate-pressure injection flow paths on a high pressure side and at least one of the intermediate-pressure injection flow paths on a low pressure side among the plurality of intermediate-pressure injection flow paths.

5. The refrigeration device according to any one of claims 1 to 4, further comprising an intermediate heat exchanger that exchanges the heat of the refrigerant, which is discharged from the compression mechanism on a low stage side as any one of the compression mechanisms, with heat of the outside air, and that allows the refrigerant to flow into the compression mechanism on a high stage side as the compression mechanism connected in series with the compression mechanism on the low stage side.

6. The refrigeration device according to any one of claims 1 to 5,
wherein the compression portion includes
multi-stage electric compressors including a plurality of the compression mechanisms that are connected in series, a housing that houses the plurality of compression mechanisms, and an electric motor that drives the plurality of compression mechanisms.

7. The refrigeration device according to any one of claims 1 to 6, further comprising a control unit that generates a command to operate the valve,
wherein the control unit changes the number of effective stages by generating the command in accordance with a temperature of the outside air.

FIG. 1


1
N: 4
17
15
20
21
22
23
24
E1
P_H
r11
r10
10
11
12
13
14
102
24
43
V3
r9
r12
n4
33B
r13
r8
14
H
P_3
33
102B
33A
r7
102A
r14
n3
23
r6
13
42
r15
r16
16
r5
P_2
32
101
r17
22
41
r4
n2
r18
r3
12
L
r19
P_1
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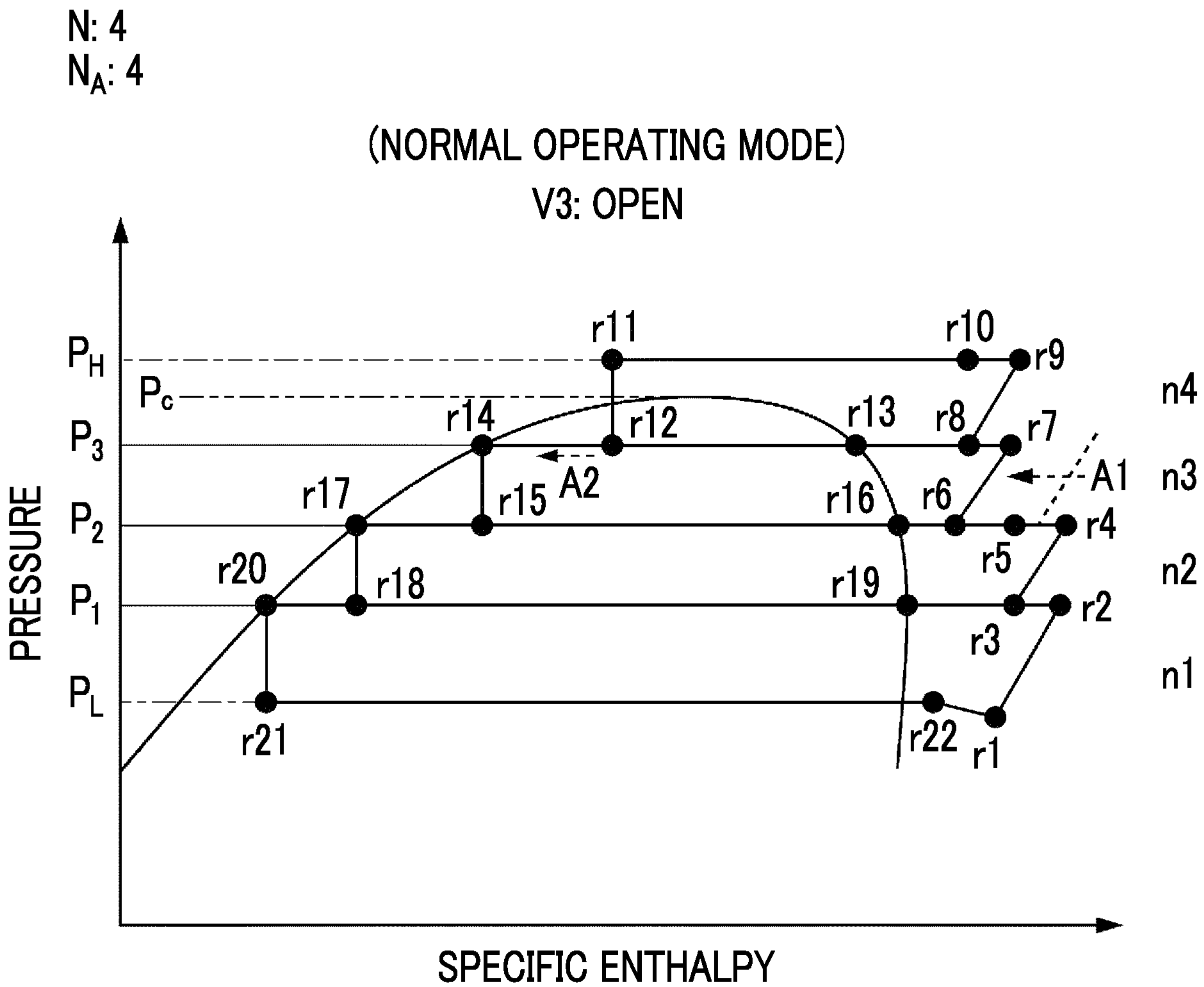
r2
n1
r20
r1
11
21
E2
r21
r22
P_L

FIG. 2


N: 4
N_A: 4
(NORMAL OPERATING MODE)
V3: OPEN
PRESSURE
P_H
P_c
P_3
P_2
P_1
P_L
r11
r10
r9
r14
r12
r13
r8
r7
n4
A2
A1
n3
r17
r15
r16
r6
r4
r5
n2
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r18
r19
r2
r3
n1
r21
r22
r1
SPECIFIC ENTHALPY

FIG. 3

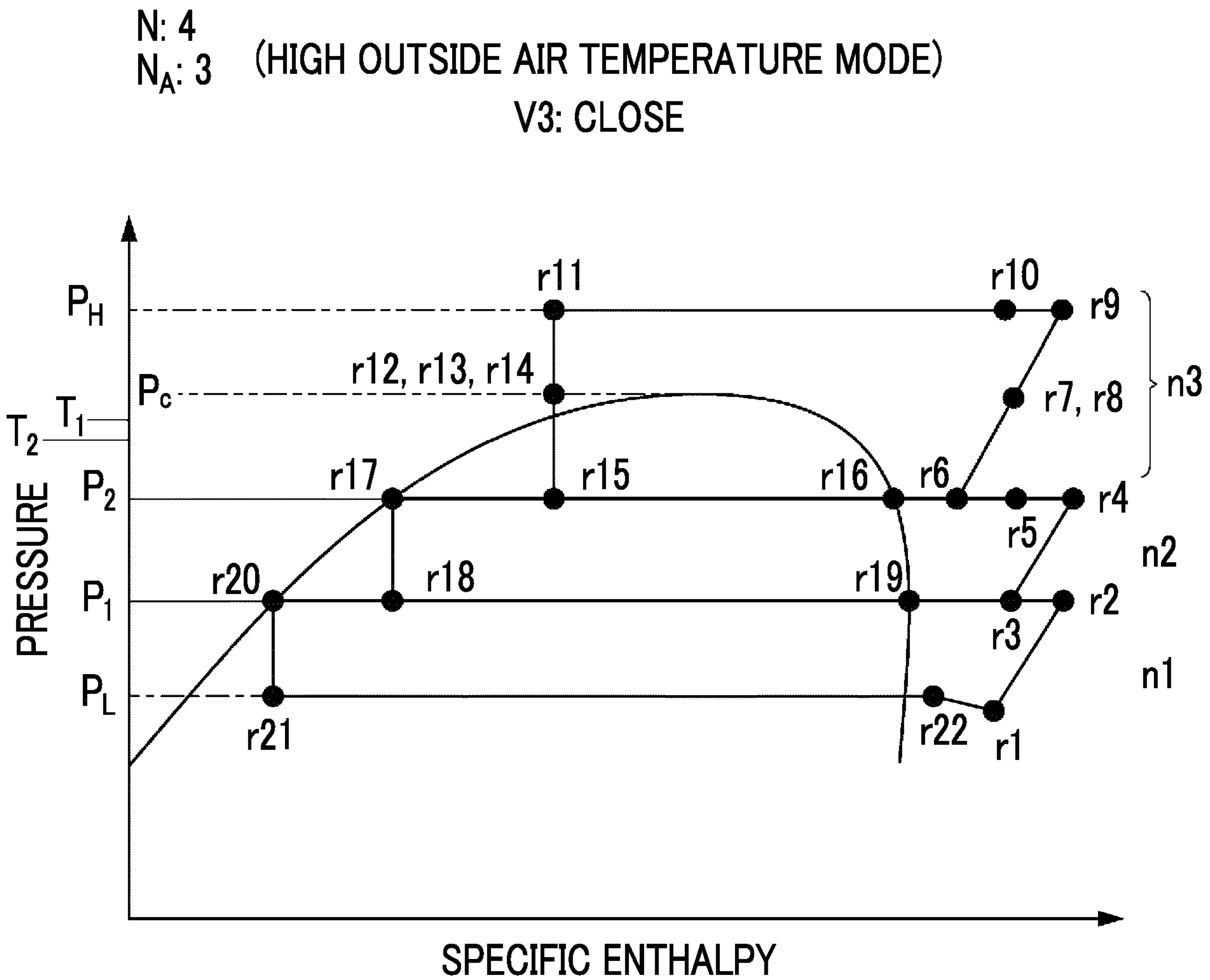

N: 4
NA: 3
(HIGH OUTSIDE AIR TEMPERATURE MODE)
V3: CLOSE
PH
Pc
T1
T2
P2
P1
PL
PRESSURE
SPECIFIC ENTHALPY
r11
r10
r9
r12, r13, r14
r7, r8
n3
r17
r15
r16
r6
r4
r5
n2
r20
r18
r19
r3
r2
n1
r21
r22
r1

FIG. 4

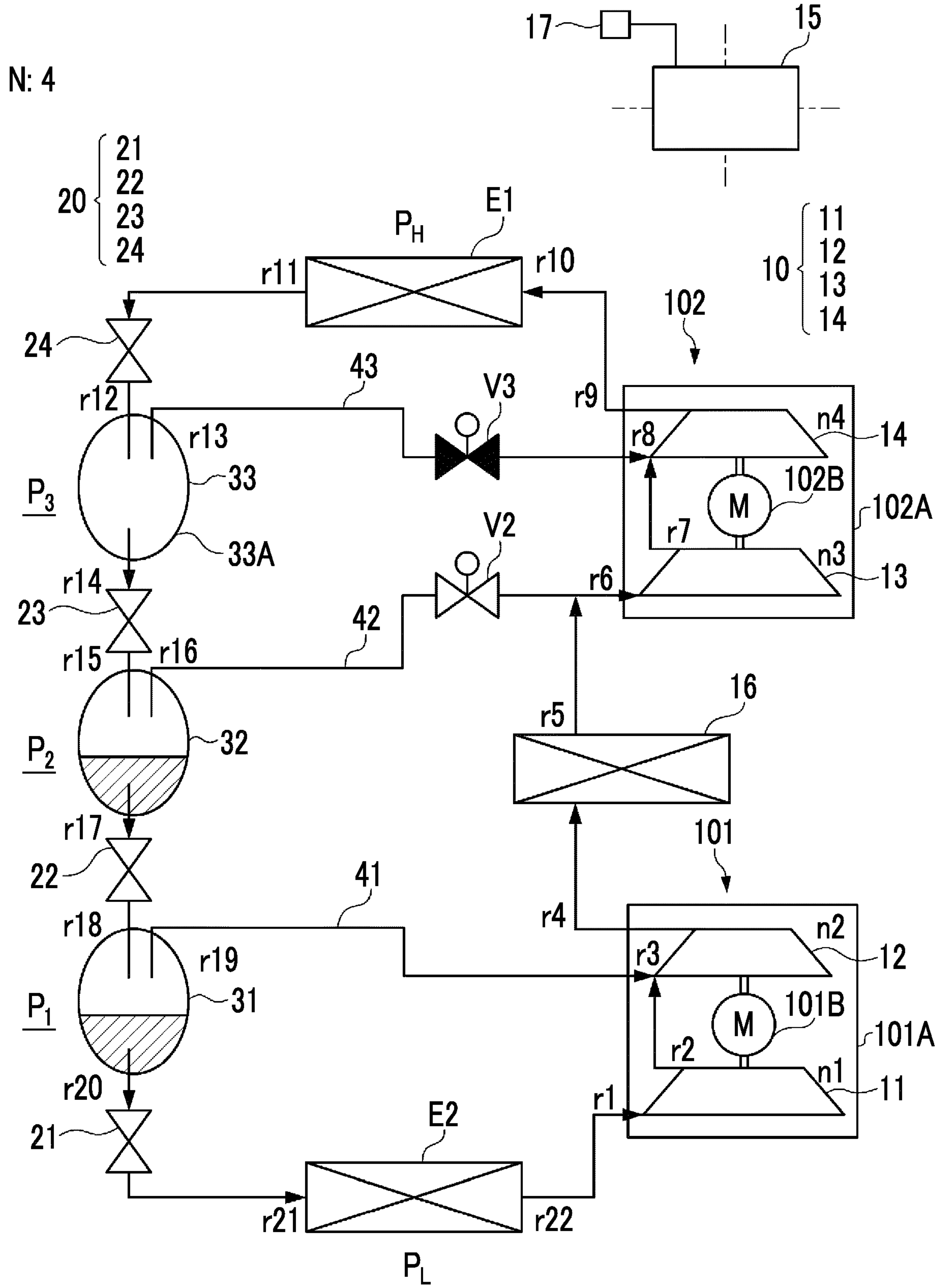
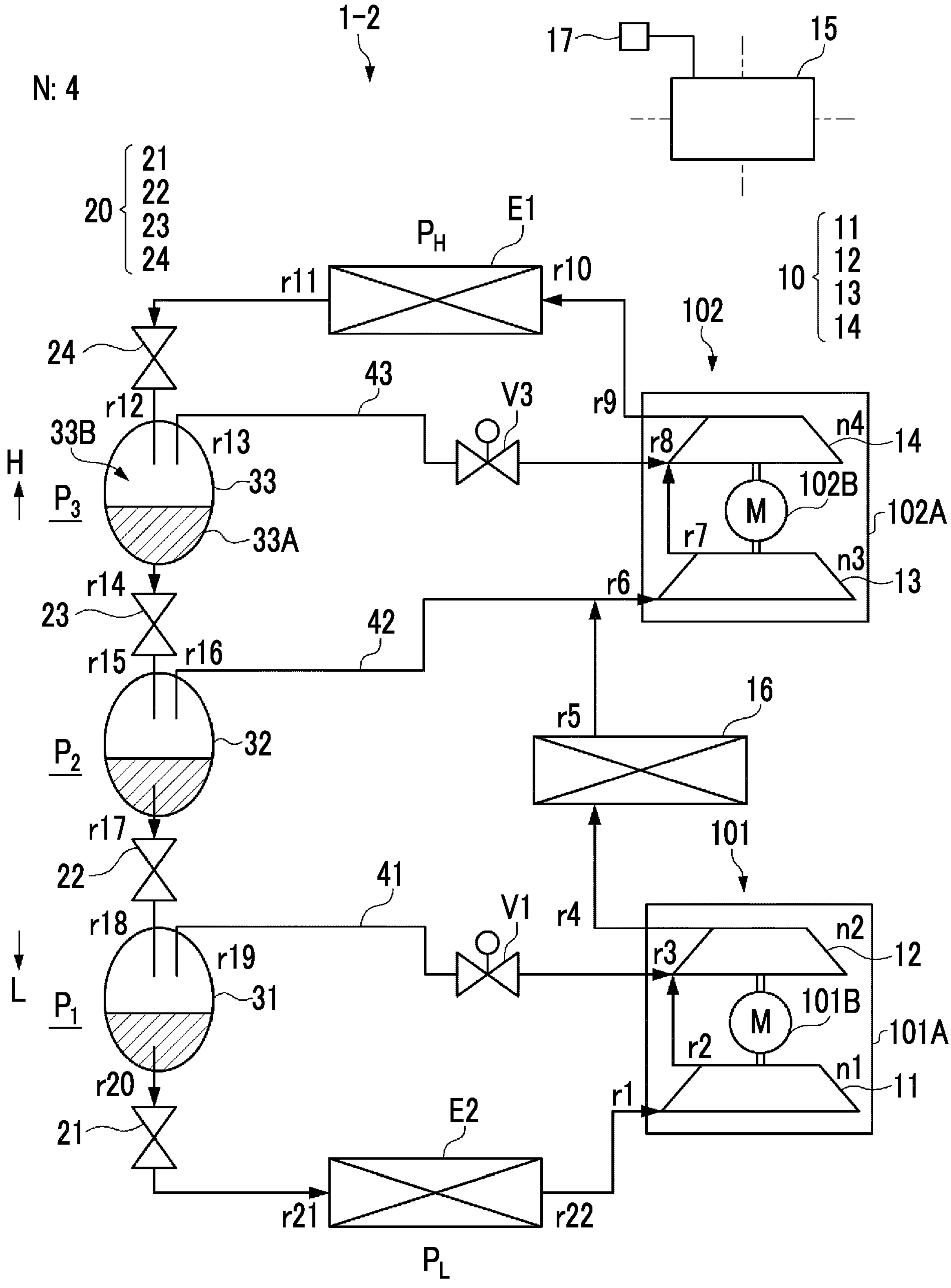

N: 4
20
21
22
23
24
10
11
12
13
14
17
15
E1
P_H
r11
r10
102
24
43
V3
r9
r12
r13
r8
n4
14
H
P_3
33
102B
102A
33A
V2
r7
n3
r14
r6
13
23
42
r15
r16
16
r5
P_2
32
r17
101
22
41
r4
n2
r18
r3
12
r19
L
P_1
31
101B
M
101A
r2
n1
r20
r1
11
21
E2
r21
r22
P_L

FIG. 5


1-2
N: 4
17
15
20
21
22
23
24
E1
P_H
r11
r10
10
11
12
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14
102
24
43
V3
r9
r12
33B
r13
r8
n4
14
H
33
102B
P_3
M
102A
33A
r7
n3
r14
r6
13
23
42
r16
r15
16
r5
32
P_2
r17
101
22
41
V1
r4
n2
r18
r3
12
r19
L
P_1
31
101B
M
101A
r2
n1
r20
11
r1
E2
21
r21
r22
P_L

FIG. 6

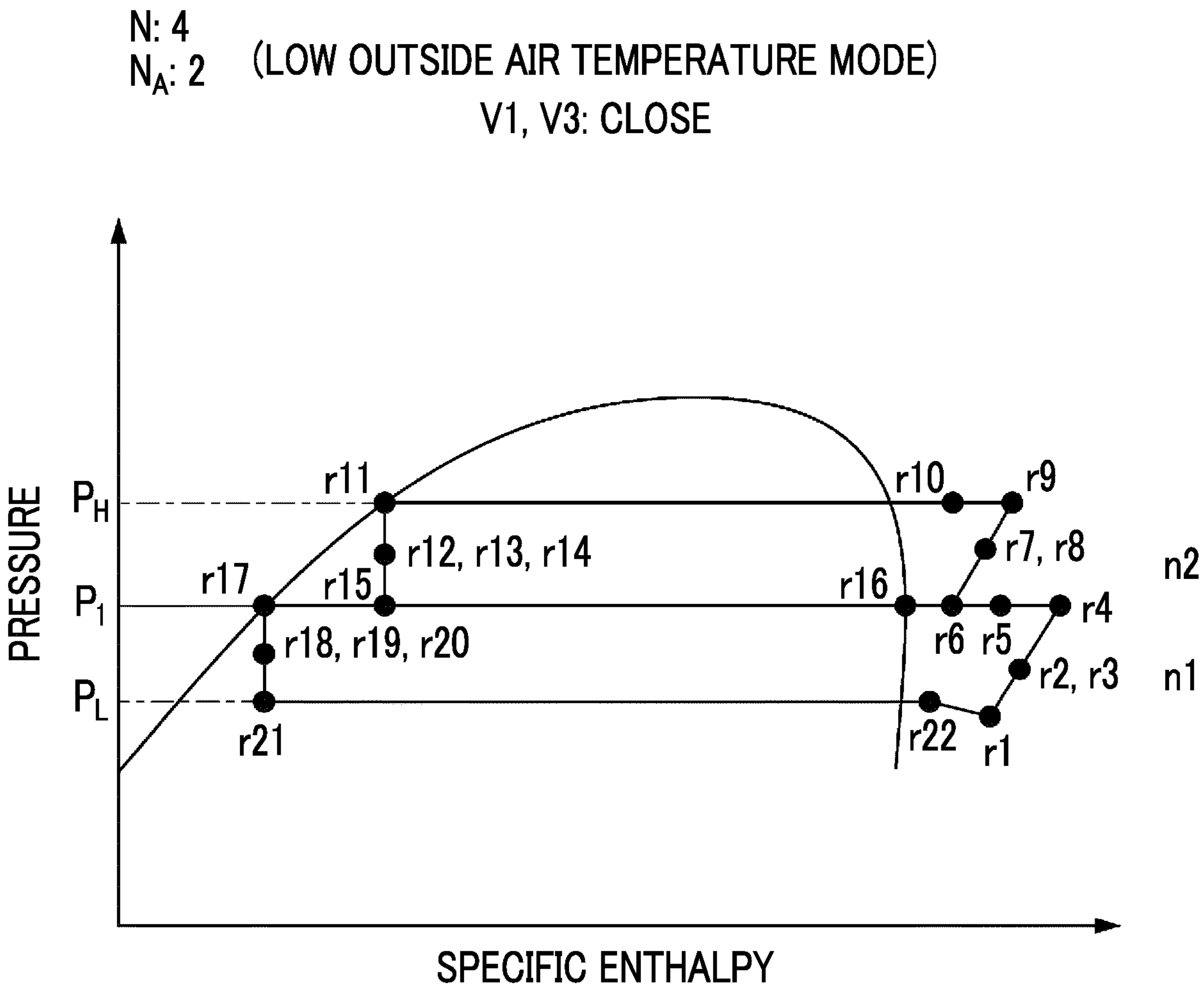
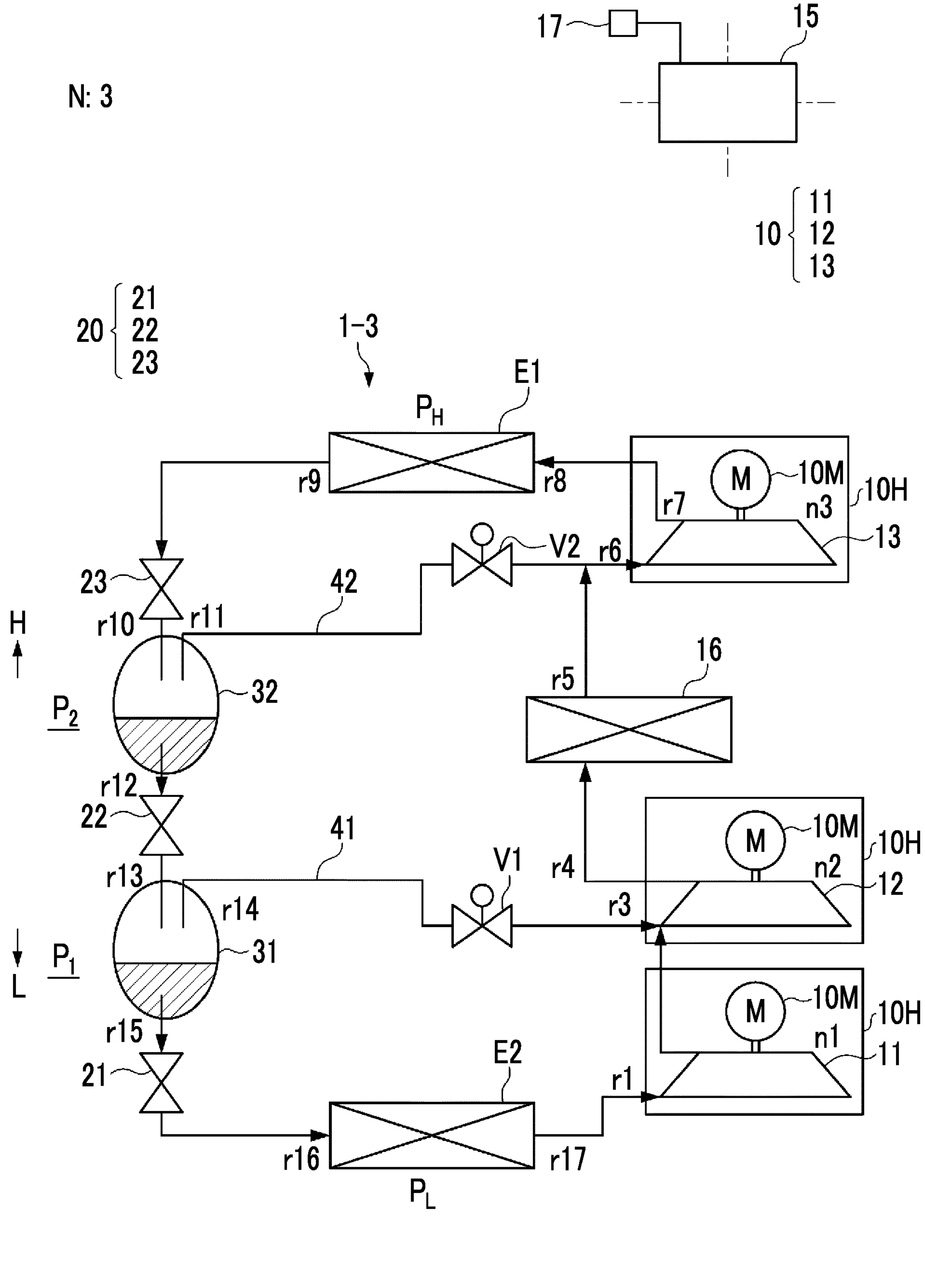

N: 4
N_A: 2
(LOW OUTSIDE AIR TEMPERATURE MODE)
V1, V3: CLOSE
PRESSURE
P_H
P_1
P_L
r11
r12, r13, r14
r15
r17
r18, r19, r20
r21
r10
r9
r7, r8
r16
r6
r5
r4
r2, r3
r22
r1
n2
n1
SPECIFIC ENTHALPY

FIG. 7



N: 3
17
15
10
11
12
13
20
21
22
23
1-3
E1
P_H
r9
r8
10M
10H
r7
n3
13
V2
r6
23
42
r10
r11
H
32
P_2
r5
16
r12
22
10M
10H
41
V1
r4
n2
12
r13
r14
r3
P_1
31
L
10M
10H
r15
n1
11
E2
21
r1
r16
r17
P_L
M

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/004824

A. CLASSIFICATION OF SUBJECT MATTER

F25B 43/00(2006.01)i; ***F25B 1/00***(2006.01)i; ***F25B 1/10***(2006.01)i
FI: F25B1/10 E; F25B1/00 396D; F25B1/00 311B; F25B43/00 R

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B43/00; F25B1/00; F25B1/10

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2020-204454 A (PANASONIC CORP) 24 December 2020 (2020-12-24) paragraphs [0017]-[0047], fig. 2, 4	1-7
Y	JP 2015-161499 A (EBARA REFRIGERATION EQUIPMENT AND SYSTEMS CO., LTD.) 07 September 2015 (2015-09-07) paragraphs [0022]-[0023], [0029], fig. 1	1-7
Y	US 2011/0113804 A1 (CHIN, Simwon) 19 May 2011 (2011-05-19) paragraphs [0068]-[0069], [0082]-[0083], fig. 1	1-7
Y	JP 2002-188865 A (MITSUBISHI HEAVY IND LTD) 05 July 2002 (2002-07-05) paragraphs [0018]-[0019], fig. 2	4
Y	JP 2006-183950 A (SANYO ELECTRIC CO LTD) 13 July 2006 (2006-07-13) paragraph [0021], fig. 1	5
Y	JP 2006-242557 A (THERMAL ANALYSIS PARTNERS LLC) 14 September 2006 (2006-09-14) paragraph [0029], fig. 1	5

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

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March 2022	**22 March 2022**

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

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/004824

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-153455 A (SANYO ELECTRIC CO LTD) 15 June 2006 (2006-06-15) paragraph [0013], fig. 1	6
Y	JP 2017-044420 A (MITSUBISHI HEAVY IND LTD) 02 March 2017 (2017-03-02) paragraph [0022], fig. 1-2	6
A	JP 2018-009565 A (DENSO CORP) 18 January 2018 (2018-01-18) fig. 1	1-7

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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