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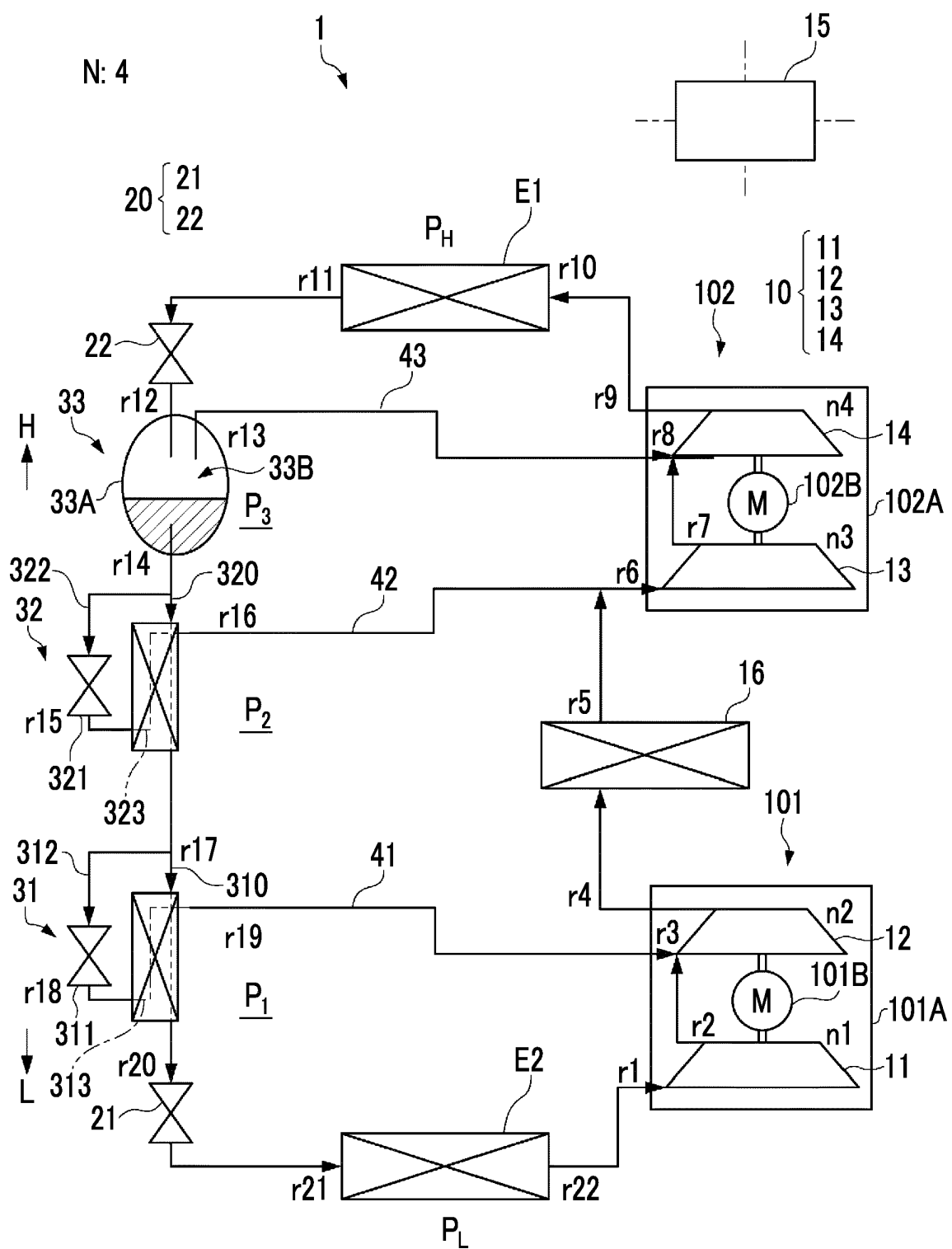
(54) **MULTI-STAGE COMPRESSION REFRIGERATION APPARATUS**

(57) Provided is a refrigeration apparatus capable of stably operating while improving the efficiency of a refrigeration cycle. The refrigeration apparatus is provided with a compression section including three or more stages of compression mechanisms, a first heat exchanger, a pressure reduction section, a second heat exchanger, a plurality of intermediate-pressure injection flow paths that are provided between a high-pressure pressure reduction mechanism and a low-pressure pressure reduction mechanism and supply a refrigerant at an intermediate pressure, which is between a high pressure and a low pressure, between the compression mechanisms, a gas-liquid separator that supplies a gas-phase refriger-

ant to a high-pressure intermediate-pressure injection flow path on a relatively high-pressure side among the plurality of intermediate-pressure injection flow paths, and an internal heat exchanger that supplies a refrigerant that has absorbed heat from a liquid refrigerant, which is a liquid-phase refrigerant supplied from the gas-liquid separator, by heat exchange between the liquid refrigerant and a two-phase refrigerant obtained by reducing pressure of a part of the liquid refrigerant to the intermediate-pressure injection flow path on a low-pressure side relative to the high-pressure intermediate-pressure injection flow path.

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FIG. 1



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, 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 CO₂ 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 refrigerant, which has an intermediate pressure between the high pressure which is set in the condenser 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 injection). According to such a configuration, the discharge temperature can be suppressed by the injection of the 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 com-

pared 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, it has been found that the liquid levels of the plurality of gas-liquid separators are not determined in a case where the number of stages is increased to three or more. In general, in order to avoid a flash (generation of air bubbles in a refrigerant), the liquid refrigerant is stored in the gas-liquid separator, and the refrigerant is supercooled by a supercooling heat exchanger.

[0007] For example, in a case where the number of stages of the compression mechanism and expansion valve is increased to, for example, "4", in the refrigeration device operated by the four-stage compression four-expansion cycle, liquid levels of the liquid refrigerants respectively stored in three gas-liquid separators are uneven due to local fluctuations in the refrigerant pressure or the like. The liquid may not be ensured in the gas-liquid separator on the low pressure side that allows the refrigerant to flow into the evaporator due to uneven distribution of the liquid refrigerant and the refrigerant flows into the low-pressure decompression mechanism and the evaporator in a two-phase state. In such a case, the efficiency deteriorates, and the operation of the refrigeration device may be likely to become unstable. In order to avoid this, it is conceivable to detect the liquid level in each of the three gas-liquid separators and control the operation of the compressor on the basis of the liquid level, but such control is difficult.

[0008] Based on the above description, an object of the present disclosure is to provide a refrigeration device capable of stably operating while improving the efficiency of the refrigerating cycle.

Solution to Problem

[0009] 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 are connected in series, each of which compresses the refrigerant, and which have three or more stages; a first heat exchanger that dissipates heat of the refrigerant discharged from the compression portion to outside air; a decompression portion that includes a high-pressure decompression mechanism on a relatively high pressure side and a low-pressure decompression mechanism on a relatively low pressure side, and causes the high-pressure decompression mechanism and the low-pressure decompression mechanism to reduce a pressure of the refrigerant

which passes through the first heat exchanger; a second heat exchanger that absorbs heat from a thermal load to the refrigerant which passes through the decompression portion; a plurality of intermediate-pressure injection flow paths that supply a spacing between the compression mechanism and the compression mechanism with the refrigerant having an intermediate pressure which is applied to a spacing between the high-pressure decompression mechanism and the low-pressure decompression mechanism and which is between a high pressure that is set in the first heat exchanger and a low pressure that is set in the second heat exchanger; a gas-liquid separator that supplies the gas phase refrigerant to a high-pressure intermediate-pressure injection flow path on the relatively high pressure side among the plurality of intermediate-pressure injection flow paths; and an internal heat exchanger that supplies the refrigerant, which absorbs heat from a liquid refrigerant as the refrigerant in the liquid phase supplied from the gas-liquid separator by exchanging heat between the liquid refrigerant and a two-phase refrigerant obtained by reducing a pressure of a part of the liquid refrigerant, to the intermediate-pressure injection flow path on the low pressure side relative to the high-pressure intermediate-pressure injection flow path. Advantageous Effects of Invention

[0010] In the present disclosure, by combining one or more gas-liquid separators and one or more internal heat exchangers as two types of intermediate-pressure injection units, the necessary number of stages (N-1) for intermediate-pressure injection corresponding to the number of stages N for compression (three or more) is satisfied, and the gas-liquid separator is disposed on the high pressure side relative to the internal heat exchanger. Then, the number of gas-liquid separators is smaller than that in the case where the gas-liquid separators are disposed at the respective stages of the intermediate-pressure injection. Therefore, it is possible to suppress the efficiency decrease and the instability of the operating state due to the uneven distribution of the liquid refrigerants.

[0011] In addition, the gas-liquid separators are disposed on the high pressure side relative to the internal heat exchanger. Therefore, it is possible to supercool the refrigerant by flowing the saturated liquid from the gas-liquid separator into the internal heat exchanger. Stable and efficient operation can be achieved through supercooling. Thereby, it is not necessary to provide a supercooling heat exchanger that allows the refrigerant to flow through the internal heat exchanger. Therefore, it is possible to contribute to reduction in costs and reduction in size and weight of the device.

Brief Description of Drawings

[0012]

Fig. 1 is a diagram showing a circuit configuration of a refrigeration device according to an embodiment

of the present disclosure.

Fig. 2 is a Mollier diagram of the refrigeration device shown in Fig. 1.

Fig. 3 is a Mollier diagram of a refrigeration device according to a comparative example.

Fig. 4 is a diagram showing a circuit configuration of a refrigeration device according to a modification example of the present disclosure.

Fig. 5 is a Mollier diagram of the refrigeration device shown in Fig. 4.

Description of Embodiments

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

[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 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 heat absorber 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 E1, the decompression portion 20, and the heat absorber E2 in this order, and is sucked into the compression portion 10.

[0016] A single refrigerant or a mixed refrigerant is sealed into a refrigerant circuit of the refrigeration device 1 of the present embodiment. The refrigerant is arbitrarily selected from, for example, a hydro fluoro carbon (HFC) refrigerant, a hydro fluoro olefin (HFO) refrigerant, a carbon dioxide (CO₂) refrigerant, a hydrocarbon-based refrigerant, and the like. From the viewpoint of reducing a GWP, in the present embodiment, a refrigerant including carbon dioxide (CO₂) in at least a part thereof is employed.

[Compression Mechanisms and Decompression Mechanisms Having Plurality of Stages]

[0017] The compression portion 10 includes compression mechanisms 11 to 14 that have a plurality of stages and are 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] Fig. 2 is a Mollier diagram showing a relationship between a pressure of the refrigerant in the refrigeration device 1 and a specific enthalpy. Symbols such as r1 and r2 shown in Fig. 2 correspond to the same symbols shown in Fig. 1.

[0019] As shown in Fig. 2, the refrigeration device 1 is operated by a refrigerating cycle of four-stage compression and two-stage expansion.

[0020] 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.

[0021] 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.

[0022] 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.

[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] The decompression portion 20 includes a low-pressure decompression mechanism 21 on a relatively low pressure side L and a high-pressure decompression mechanism 22 on a relatively high pressure side H. The decompression mechanisms 21 and 22 each may be an expansion valve, a capillary tube, or the like. In particular, it is preferable that the decompression mechanisms 21 and 22 each are an expansion valve capable of adjusting an opening degree of a throttle.

[0026] The high-pressure decompression mechanism 22 and the low-pressure decompression mechanism 21 sequentially reduce the pressure of the refrigerant which

passes through the condenser E1 in this order.

[0027] 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.

[0028] 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 (from r4 to r5), it is possible to contribute to suppression of the discharge temperature of the entire compression portion 10 as a whole.

[0029] A pressure between a pressure of suction to the first stage n1 of compression 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.

[0030] A critical temperature of CO_2 is lower than a critical temperature of another refrigerant (for example, hydro fluoro carbon (HFC)). Therefore, in a steady operation of the refrigeration device 1, the CO_2 refrigerant 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. However, the pressure (r12, r13, r14) of the refrigerant which passes through the condenser E1 and the high-pressure decompression mechanism 22, that is, the third intermediate pressure P_3 is kept equal to or less than the critical pressure P_C .

(Intermediate-Pressure Injection)

[0031] The refrigeration device 1 performs intermediate-pressure injection for supplying the refrigerant having an intermediate pressure to each spacing between the first to fourth stage compression mechanisms 11 to 14. The refrigerant is obtained by gas-liquid separation of the refrigerant in each spacing between the low-pressure decompression mechanism 21 and the high-pressure decompression mechanism 22. Therefore, the refrigeration device 1 includes N-1 intermediate-pressure injection units (31 to 33) provided between the low-pressure decompression mechanism 21 and the high-pressure decompression mechanism 22 and N-1 intermediate-pressure injection flow paths 41 to 43 that respectively correspond to the intermediate-pressure injection units (31 to 33).

[0032] By supplying the refrigerants having intermediate pressures P_1 , P_2 , and P_3 to the respective spacings between the compression mechanisms 11 to 14 connected in series through the intermediate-pressure injection flow paths 41 to 43, it is possible to reduce the discharge

temperature of each of the second to fourth stage compression mechanisms 12 to 14.

[0033] As necessary, valves can be respectively provided in the intermediate-pressure injection flow paths 41 to 43. The valve may be switched to open or closed depending on operating conditions.

[0034] As shown in Fig. 1, the intermediate-pressure injection units (31 to 33) includes a single gas-liquid separator 33 (liquid receiver) and internal heat exchangers 32 and 31. The gas-liquid separator 33 is disposed on the high pressure side H relative to the internal heat exchangers 32 and 31. The high-pressure internal heat exchanger 32 is disposed on the high pressure side H relative to the low-pressure internal heat exchanger 31.

[0035] The gas-liquid separator 33, the internal heat exchanger 32, and the internal heat exchanger 31 respectively supply the refrigerants having intermediate pressures to the second to fourth stage compression mechanisms 12 to 14 through the corresponding intermediate-pressure injection flow paths 41 to 43.

[0036] The refrigerant, which is discharged from the fourth stage compression mechanism 14, is decompressed by the high-pressure decompression mechanism 22 and flows into the gas-liquid separator 33. The refrigerant, which has flowed into the gas-liquid separator 33, is separated into a gas phase and a liquid phase on the basis of a density difference inside the storage tank 33A. As shown in Fig. 2, this corresponds to a status change from r12 to r13 and r14. A third intermediate-pressure injection flow path 43 is connected to a gas phase region 33B above the liquid level in the storage tank 33A.

[0037] The gas phase refrigerant having the third intermediate pressure P_3 separated from the liquid phase in the gas-liquid separator 33 is supplied to the intermediate-pressure injection on the high pressure side H through the third intermediate-pressure injection flow path 43 (from r13 to r8).

[0038] A temperature of the refrigerant, which has the third intermediate pressure P_3 and 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.

[0039] On the other hand, the liquid phase refrigerant (liquid refrigerant) stored in the storage tank 33A is supplied to the high-pressure internal heat exchanger 32 and the low-pressure internal heat exchanger 31. The sup-

plied refrigerants are respectively supercooled by the high-pressure internal heat exchanger 32 and the low-pressure internal heat exchanger 31. Concurrently, a part thereof is supplied to the intermediate-pressure injection on the low pressure side L relative to the third intermediate pressure injection through each of the second intermediate-pressure injection flow path 42 and the first intermediate-pressure injection flow path 41. In accordance with the performing of the injection of the intermediate pressures P_1 , P_2 , and P_3 , flow rates of the refrigerant are sequentially reduced. Therefore, a capacity of the high-pressure internal heat exchanger 32 upstream of the flow of the refrigerant from the high-pressure decompression mechanism 22 to the low-pressure decompression mechanism 21 is greater than a capacity of the low-pressure internal heat exchanger 31 downstream. Under the rated conditions of the refrigeration device 1, the capacity of the high-pressure internal heat exchanger 32 is, for example, about 2.5 times greater than the capacity of the low-pressure internal heat exchanger 31.

[0040] Both the high-pressure internal heat exchanger 32 and the low-pressure internal heat exchanger 31 exchange heat between the liquid refrigerant supplied from the gas-liquid separator 33 and the two-phase refrigerant that is obtained by decompressing a part of the liquid refrigerant supplied from the gas-liquid separator 33 through decompression mechanisms (321, 311).

[0041] The high-pressure internal heat exchanger 32 includes a main flow path 320 into which the liquid refrigerant supplied from the inside of the saturated gas-liquid separator 33 flows, the decompression mechanism 321, a branch flow path 322 through which a part of the liquid refrigerant supplied from the gas-liquid separator 33 flows into the decompression mechanism 321, and a heat absorption flow path 323 into which the two-phase refrigerant decompressed from the third intermediate pressure P_3 to the second intermediate pressure P_2 (from r14 to r15 in Fig. 2) by the decompression mechanism 321 flows.

[0042] The refrigerant, which flows through the heat absorption flow path 323, is gasified (from r15 to r16) by absorbing heat from the refrigerant which flows through the main flow path 320, and is sucked into the third stage compression mechanism 13 through the second intermediate-pressure injection flow path 42.

[0043] On the other hand, the refrigerant, which flows through the main flow path 320, is supercooled (from r14 to r17) by dissipating heat to the refrigerant which flows through the heat absorption flow path 323, and flows into the low-pressure internal heat exchanger 31.

[0044] In a case where the 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 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.

[0045] The low-pressure internal heat exchanger 31 includes a main flow path 310 into which a supercooled-state liquid refrigerant (supercooled liquid) flowing out of the high-pressure internal heat exchanger 32 flows, a decompression mechanism 311, a branch flow path 312 through which the supercooled liquid partially flows into a decompression mechanism 311, and a heat absorption flow path 313 into which the two-phase refrigerant decompressed from the second intermediate pressure P_2 to the first intermediate pressure P_1 (from r17 to r18) by the decompression mechanism 311 flows. The refrigerant, which flows through the heat absorption flow path 313, is gasified (from r18 to r19) by absorbing heat from the refrigerant which flows through the main flow path 310, and is sucked into the second stage compression mechanism 12 through the first intermediate-pressure injection flow path 41 (from r19 to r3). Thereby, the temperature of the refrigerant sucked into the second stage compression mechanism 12 is lowered (from r2 to r3).

[0046] On the other hand, the refrigerant, which flows through the main flow path 310, dissipates heat to the refrigerant which flows through the heat absorption flow path 313. Thereby, a degree of supercooling is increased (from r17 to r20). Then the refrigerant flows into the low-pressure decompression mechanism 21.

[0047] The liquid refrigerant, which has the first intermediate pressure P_1 and flows out of the low-pressure internal heat exchanger 31, is sufficiently supercooled. Therefore, the liquid refrigerant flows directly to the low-pressure decompression mechanism 21 without passing through the supercooling heat exchanger, and is decompressed by the low-pressure decompression mechanism 21 (from r20 to r21). The refrigerant, which passes through the low-pressure decompression mechanism 21, evaporates by absorbing heat from the thermal load by the heat absorber E2 and is sucked into the first stage compression mechanism 11 (from r21 to r22).

[0048] Each pressure of the liquid refrigerant which flows from the gas-liquid separator 33 to the internal heat exchanger 32, the liquid refrigerant which flows from the high-pressure internal heat exchanger 32 to the low-pressure internal heat exchanger 31, and the refrigerant which flows from the low-pressure internal heat exchanger 31 into the low-pressure decompression mechanism 21 corresponds to a third intermediate pressure P_3 (r14, r17, and r20). Therefore, an expansion process in the refrigerating cycle is integrated into two stages of decompression from the high pressure P_H to the third intermediate pressure P_3 and decompression from the third in-

termediate pressure P_3 to the low pressure P_L through the high-pressure decompression mechanism 22. That is, the refrigeration device 1 is operated in a state where the number of expansion stages is smaller than the number of stages N for compression, that is, through a four-stage compression two-stage expansion cycle.

[Main Actions and Effects]

[0049] In order to improve the COP while using a refrigerant having a low GWP, it is effective to increase the number of stages N , for example, from single-stage compression to two-stage compression and further three-stage compression and four-stage compression.

[0050] The action and effect of the refrigeration device 1 of the present embodiment will be described below with reference to a comparative example.

[0051] In a case where multi-stage compression of three or more stages is employed, on the basis of an example of two-stage compression (for example, PTL 1 described above), it is conceivable that the same number of decompression mechanisms as the number of stages N for compression and $N-1$ gas-liquid separators are provided in the refrigeration device. For example, in the case of a four-stage refrigeration device, a decompression mechanism, a gas-liquid separator, a decompression mechanism, a gas-liquid separator, a decompression mechanism, a gas-liquid separator, a decompression mechanism, a gas-liquid separator, and a decompression mechanism are disposed in this order, from the high pressure side H to the low pressure side L . Accordingly, a gas phase refrigerant having an intermediate pressure is supplied from each gas-liquid separator to the suction portion of the compression mechanism through the intermediate-pressure injection flow path.

[0052] As shown by the solid line in Fig. 3, the refrigeration device of the comparative example operates by a cycle of N -stage compression and N -stage expansion. N is, for example, "4".

[0053] The refrigeration device of the comparative example may include a supercooling heat exchanger that exchanges heat between the outside air and the liquid refrigerant which flows out from the gas-liquid separator on the lowest pressure side L . In such a case, supercooling is applied to the refrigerant as indicated by the arrow of the dashed-dotted line in Fig. 3.

[0054] The refrigeration device of the comparative example includes $N-1$ gas-liquid separators. Therefore, in a case where the number of stages N is three or more, the refrigeration device includes two or more gas-liquid separators. In such a case, it is difficult to ensure the liquid refrigerant in a predetermined gas-liquid separator among the plurality of gas-liquid separators. Even in a case where the supercooling heat exchanger is provided on the lowest pressure side L , in order to prevent the refrigerant in a two-phase state from flowing into the low-pressure decompression mechanism 21 and the heat absorber E2, it is desired that the liquid refrigerant is ensured in at least the gas-liquid separator located on the

lowest pressure side L and that the liquid refrigerant is supplied from the gas-liquid separator to the low-pressure decompression mechanism 21. For that purpose, it is necessary to control rotation speeds of the compression mechanisms 11 to 14 on the basis of the respective liquid levels of the N-1 gas-liquid separators. At least two liquid level sensors are necessary in order to grasp the liquid level of each of the N-1 gas-liquid separators.

[0055] Unlike the comparative example, in increasing the number of stages N, the refrigeration device 1 of the present embodiment does not include a number of decompression mechanisms and a number of gas-liquid separators each corresponding to the number of stages N, or does not include a number of internal heat exchangers corresponding to the number of stages N. In addition, the refrigeration device 1 includes the single gas-liquid separator 33 on the high pressure side H, and includes the internal heat exchangers 32 and 31 on the low pressure side L. That is, the refrigeration device 1 of the present embodiment does not include the same number of gas-liquid separators as the necessary number of stages (N-1) for intermediate-pressure injection. The refrigeration device 1 includes a smaller number of the gas-liquid separators 33 than the necessary number of stages (N-1) for intermediate-pressure injection.

[0056] The number of gas-liquid separators 33 included in the refrigeration device 1 is smaller than the necessary number of stages (N-1) for intermediate-pressure injection. Therefore, a degree of uneven distribution of the refrigerant between the gas-liquid separators, which may occur in a case where a plurality of gas-liquid separators are provided, is reduced. As a result, it is possible to ensure the effect of improving efficiency by increasing the number of stages N for compression while suppressing the decrease in efficiency and the instability of the operating state due to the uneven distribution of the liquid refrigerant. In addition, it is possible to contribute to the stability of the operating state of the refrigeration device 1.

[0057] In particular, the refrigeration device 1 of the present embodiment includes only a single gas-liquid separator 33 as the gas-liquid separator. Therefore, it is possible to ensure that the liquid refrigerant is stored in the specific gas-liquid separator 33 without running out of the amount of liquid in some gas-liquid separators among the plurality of gas-liquid separators. Then, the control based on the liquid level of the gas-liquid separator is unnecessary, and the liquid level sensor is also unnecessary. Even in a case where a liquid level sensor is provided, it is possible to reduce the number of the liquid level sensors.

[0058] From the above description, according to the refrigeration device 1 of the present embodiment, the following effects can be obtained. (1) Only the single gas-liquid separator 33 is provided as the gas-liquid separator. Therefore, unlike a case where the plurality of gas-liquid separators are provided, it is possible to ensure that the liquid refrigerant is stored in the specific gas-liquid separator 33 without moving the liquid refrigerant

between the gas-liquid separators. Therefore, it is not necessary to perform control based on the liquid level in the gas-liquid separator. The cost of the refrigeration device 1 can be reduced by simplifying the control.

[0059] (2) The gas-liquid separator 33 is disposed on the high pressure side H relative to the internal heat exchangers 32 and 31. Therefore, the saturated liquid flows from the gas-liquid separator 33 to the internal heat exchangers 32 and 31. Therefore, supercooling can be provided to the refrigerant. Then, not only the COP can be improved, occurrence of a flash can be suppressed, and the refrigeration device 1 can be operated stably and efficiently, but also supercooling can be reliably provided. Therefore, it is not necessary for the refrigerant, which passes through the internal heat exchangers 32 and 31, to flow into the supercooling heat exchanger. That is, the refrigerant, which passes through the internal heat exchangers 32 and 31, may be directly flowed into the low-pressure decompression mechanism 21.

[0060] In such a case, the supercooling heat exchanger becomes unnecessary as compared with the comparative example, and the refrigerant circuit configuration can be simplified. Therefore, it is possible to contribute to reduction in costs and reduction in size and weight of the device.

[0061] In the present embodiment, the degree of supercooling can be sufficiently obtained by sequentially flowing the liquid refrigerant from the gas-liquid separator 33 into the two internal heat exchangers 32 and 31. Therefore, in addition to the great effects of improving the efficiency and stabilizing the operation, it is not necessary to add a supercooling heat exchanger having a large capacity in order to increase the degree of supercooling. Therefore, the effects of reduction in costs and reduction in size and weight of the device are also great.

[0062] (3) According to the high-pressure internal heat exchanger 32 and/or the low-pressure internal heat exchanger 31 each including an expansion valve as the decompression mechanism, as shown in Fig. 2, by adjusting the opening degree of the expansion valve, it is possible to perform intermediate-pressure injection using the two-phase refrigerant. For example, in a case where the high-pressure internal heat exchanger 32 includes an expansion valve as the decompression mechanism 321, it is possible to perform injection (from r16 to r6) of the second intermediate pressure P_2 using the two-phase refrigerant into the third stage compression mechanism 13 through the second intermediate-pressure injection flow path 42 by adjusting the opening degree of the expansion valve.

[0063] Alternatively, in a case where the low-pressure internal heat exchanger 31 includes an expansion valve as the decompression mechanism 311, it is possible to perform injection (from r19 to r3) of the first intermediate pressure P_1 using the two-phase refrigerant into the second stage compression mechanism 12 by adjusting the opening degree of the expansion valve.

[0064] The suction temperature of the refrigerant to the

compression mechanism is lowered by the injection of the two-phase refrigerant. As a result, the discharge temperature can be suppressed to an allowable limit.

[0065] (4) Generally, a heat insulating material is provided in the gas-liquid separator in order to keep the refrigerant at a low temperature. According to the fact that the gas-liquid separator 33 is disposed on the high pressure side H relative to the internal heat exchangers 31 and 32, as compared with a case where the gas-liquid separator is disposed on the low pressure side L, the pressure saturation temperature in the gas-liquid separator is high. Therefore, the temperature difference between the gas-liquid separator 33 and the outside air temperature is small. Therefore, it is possible to reduce the thickness of the heat insulating material provided in the gas-liquid separator 33. As a result, it is possible to contribute to reduction in costs and reduction in size and weight of the device.

[0066] For example, under the rated conditions of the refrigeration device 1, as shown in Fig. 1, the single gas-liquid separator 33 corresponding to the third intermediate pressure P_3 is provided, and the two internal heat exchangers 32 and 31 respectively corresponding to the second intermediate pressure P_2 and the first intermediate pressure P_1 are provided. In such a case, the temperature at the liquid outlet of the gas-liquid separator 33 is 20°C. In such a case, the temperature difference from the outside air temperature is the smallest. A temperature at the liquid outlet is obtained by cycle calculation. It is the same for the following description.

[0067] Although not shown, the single gas-liquid separator corresponding to the second intermediate pressure P_2 is provided, and the two internal heat exchangers corresponding to the third intermediate pressure P_3 and the first intermediate pressure P_1 are provided. In such a case, the temperature at the liquid outlet of the gas-liquid separator is 2°C.

[0068] Further, in a case where the single gas-liquid separator corresponding to the first intermediate pressure P_1 is provided and the two internal heat exchangers corresponding to the third intermediate pressure P_3 and the second intermediate pressure P_2 are provided. In such a case, the temperature of the liquid outlet of the gas-liquid separator is -12°C.

[0069] The pressure saturation temperature is higher as the position of the gas-liquid separator is closer to the high pressure side. Therefore, it is also possible to explain a fact that the temperature difference between the gas-liquid separator and the outside air is small with reference to the Mollier diagram of Fig. 3 according to the comparative example. As can be understood from Fig. 3, assuming that the pressure saturation temperature of the gas-liquid separator (r12) having a high pressure is T_1 , the pressure saturation temperature of the gas-liquid separator (r15) having a medium pressure is T_2 , and the pressure saturation temperature of the gas-liquid separator (r18) having a low pressure is T_3 , it is clear that $T_1 > T_2 > T_3$. The higher the pressure saturation tempera-

ture, the smaller the temperature difference between the gas-liquid separator and the outside air.

[0070] As described above, according to the refrigeration device 1 of the present embodiment, one or more gas-liquid separators 33 and one or more internal heat exchangers 31 and 32 as two types of intermediate-pressure injection units are combined. Then, the necessary number of stages (N-1) for intermediate-pressure injection corresponding to the number of stages N for compression (three or more) is satisfied, and the gas-liquid separator 33 is disposed on the high pressure side H relative to the internal heat exchangers 31 and 32. In such a manner, it is possible to stably operate the refrigeration device 1 by improving the COP while using a refrigerant having a low GWP such as CO_2 and keeping the discharge temperature equal to or less than the allowable limit.

[Modification Example]

[0071] The refrigeration device 1 does not necessarily have to include the high-pressure internal heat exchanger 32 and the low-pressure internal heat exchanger 31. The refrigeration device 1 may include only a single internal heat exchanger or three or more internal heat exchangers, depending on the number of stages N. Even in such a case, the same action and effect as those obtained by the above-mentioned embodiment can be obtained.

[0072] The refrigeration device 1-2 shown in Fig. 4 includes N-stage (four-stage) compression mechanisms 11 to 14, and includes the two gas-liquid separators 33 and 32-2 and the single internal heat exchanger 31, as N-1 (three) intermediate-pressure injection units. Fig. 5 is a Mollier diagram of the refrigeration device 1-2.

[0073] The refrigeration device 1-2 includes three decompression mechanisms 21 to 23 which include the decompression mechanism 22 located between the two gas-liquid separators 33 and 32-2 and which constitute the decompression portion 20. Therefore, the operation is performed by a cycle of four-stage compression and three-stage expansion.

[0074] In a similar manner to the refrigeration device 1 of the above-mentioned embodiment, the refrigeration device 1-2 also includes two gas-liquid separators 33 and 32-2, which are a small number relative to the necessary number of stages (N-1) for intermediate-pressure injection. Thereby, the degree of uneven distribution of the liquid refrigerant between the gas-liquid separators 33 and 32-2 is reduced. As a result, it is possible to ensure the effect of improving efficiency by increasing the number of stages N for compression while suppressing a decrease in cycle efficiency and instability of the operating state, and it is also possible to contribute to the stability of the operating state of the refrigeration device 1-2.

[0075] In addition, since the gas-liquid separators 33 and 32-2 are disposed on the high pressure side H rel-

ative to the internal heat exchanger 31, the saturated liquid flows from the gas-liquid separator 32-2 into the internal heat exchanger 31. Therefore, supercooling can be provided to the refrigerant (from r17 to r20 in Fig. 5). Stable and efficient operation can be achieved through supercooling. Thereby, it is not necessary to add a supercooling heat exchanger in order to obtain supercooling. Therefore, it is possible to contribute to reduction in costs and reduction in size and weight of the device.

[0076] In addition, the injection of the first intermediate pressure P_1 using the two-phase refrigerant can be performed by adjusting the opening degree of the expansion valve provided in the internal heat exchanger 31 as the decompression mechanism 311 (from r19 to r3). Then, the suction temperature of the refrigerant to the second stage compression mechanism 12 is lowered. Therefore, the discharge temperature of the refrigerant from the compression portion 10 can be suppressed to the allowable limit.

[0077] Further, according to the configuration in which the gas-liquid separators 33 and 32-2 are disposed on the high pressure side H relative to the internal heat exchanger 31, as compared with the case where the gas-liquid separators 33 and 32-2 are disposed on the low pressure side L relative to the internal heat exchanger 31, the thickness of the heat insulating material can be reduced. As a result, it is possible to contribute to the reduction in size and weight of the device.

[0078] 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.

(Additional Notes)

[0079] The refrigeration device described above is understood as follows.

[1] A refrigeration device 1 or 1-2 that circulates a refrigerant in accordance with a refrigerating cycle, the refrigeration device 1 or 1-2 includes: a compression portion 10 that includes compression mechanisms 11 to 14 which are connected in series, each of which compresses the refrigerant, and which have three or more stages; a first heat exchanger (E1) that dissipates heat of the refrigerant discharged from the compression portion 10 to outside air; a decompression portion 20 that includes a high-pressure decompression mechanism 22 on a relatively high pressure side and a low-pressure decompression mechanism 21 on a relatively low pressure side, and causes the high-pressure decompression mechanism 22 and the low-pressure decompression mechanism 21 to reduce a pressure of the refrigerant which passes through the first heat exchanger (E1); a second heat exchanger (E2) that absorbs heat from a thermal load to the refrigerant which passes through the decompression portion 20; a plurality of

intermediate-pressure injection flow paths 41 to 43 that supply a spacing between the compression mechanism and the compression mechanism with the refrigerant having an intermediate pressure P_1 , P_2 , or P_3 which is applied to a spacing between the high-pressure decompression mechanism 22 and the low-pressure decompression mechanism 21 and which is between a high pressure P_H that is set in the first heat exchanger (E1) and a low pressure P_L that is set in the second heat exchanger (E2); a gas-liquid separator 33 (or 33 and 32-2) that supplies the gas phase refrigerant to a high-pressure intermediate-pressure injection flow path (43, or 43 and 42) on the relatively high pressure side H among the plurality of intermediate-pressure injection flow paths 41 to 43; and internal heat exchangers 32 and 31 (or 31) each of which supplies the refrigerant, which absorbs heat from a liquid refrigerant as the refrigerant in the liquid phase supplied from the gas-liquid separator 33 by exchanging heat between the liquid refrigerant and a two-phase refrigerant obtained by reducing a pressure of a part of the liquid refrigerant, to the intermediate-pressure injection flow paths 42 and 41 (or 41) on the low pressure side L relative to the high-pressure intermediate-pressure injection flow path (43, or 43 and 42).

[2] In the refrigeration device 1, as the gas-liquid separator 33, only one gas-liquid separator 33 is provided, and as the internal heat exchangers 32 and 31, one or more internal heat exchangers 32 and 31 are provided between the gas-liquid separator 33 and the low-pressure decompression mechanism 21.

[3] In the refrigeration device 1, as the gas-liquid separator 33 located on a highest pressure side H, a highest-pressure gas-liquid separator (33), to which the refrigerant is directly supplied from the high-pressure decompression mechanism 22, is provided.

[4] In the refrigeration device 1 or 1-2, as the internal heat exchanger 31 located on a lowest pressure side L, a lowest-pressure internal heat exchanger (31), which allows the refrigerant to directly flow into the low-pressure decompression mechanism 21, is provided.

[5] The internal heat exchangers 31 and 32 include expansion valves (311 and 321) which reduce a pressure of a part of the liquid refrigerant to expand the part.

[6] In the refrigeration device 1, as the internal heat exchangers 31 and 32, two or more internal heat exchangers 31 and 32 are provided, and a capacity of the internal heat exchanger 32 located on the relatively high pressure side H is greater than a capacity of the internal heat exchanger 31 located on the relatively low pressure side L.

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

Reference Signs List

[0080]

1, 1-2: refrigeration device	5
10: compression portion	
11: first stage compression mechanism	
12: second stage compression mechanism	
13: third stage compression mechanism	
14: fourth stage compression mechanism	10
15: control unit	
16: intermediate cooling heat exchanger	
20: decompression portion	
21: low-pressure decompression mechanism	
22: high-pressure decompression mechanism	15
21 to 23: decompression mechanism	
31: low-pressure internal heat exchanger (lowest-pressure internal heat exchanger)	
32: high-pressure internal heat exchanger	
32-2: gas-liquid separator	20
33: gas-liquid separator (highest-pressure gas-liquid separator)	
33A: storage tank	
33B: gas phase region	
41: first intermediate-pressure injection flow path	25
42: second intermediate-pressure injection flow path	
43: third intermediate-pressure injection flow path (high-pressure intermediate-pressure injection flow path)	
101: first electric compressor	30
101A: housing	
101B: electric motor	
102: second electric compressor	
102A: housing	
102B: electric motor	35
310: main flow path	
311: decompression mechanism	
312: branch flow path	
313: heat absorption flow path	
320: main flow path	40
321: decompression mechanism	
322: branch flow path	
323: heat absorption flow path	
E1: condenser (first heat exchanger)	
E2: heat absorber (second heat exchanger)	45
H: high pressure side	
L: low pressure side	
N: number of stages	
P_1, P_2, P_3 : intermediate pressure	
P_C : critical pressure	50
P_H : high pressure	
P_L : low pressure	
n1, n2, n3, n4: stage	

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 are connected in series, each of which compresses the refrigerant, and which have three or more stages;
a first heat exchanger that dissipates heat of the refrigerant discharged from the compression portion to outside air;
a decompression portion that includes a high-pressure decompression mechanism on a relatively high pressure side and a low-pressure decompression mechanism on a relatively low pressure side, and causes the high-pressure decompression mechanism and the low-pressure decompression mechanism to reduce a pressure of the refrigerant which passes through the first heat exchanger;
a second heat exchanger that absorbs heat from a thermal load to the refrigerant which passes through the decompression portion;
a plurality of intermediate-pressure injection flow paths that supply a spacing between the compression mechanism and the compression mechanism with the refrigerant having an intermediate pressure which is applied to a spacing between the high-pressure decompression mechanism and the low-pressure decompression mechanism and which is between a high pressure that is set in the first heat exchanger and a low pressure that is set in the second heat exchanger;
a gas-liquid separator that supplies the gas phase refrigerant to a high-pressure intermediate-pressure injection flow path on the relatively high pressure side among the plurality of intermediate-pressure injection flow paths; and
an internal heat exchanger that supplies the refrigerant, which absorbs heat from a liquid refrigerant as the refrigerant in the liquid phase supplied from the gas-liquid separator by exchanging heat between the liquid refrigerant and a two-phase refrigerant obtained by reducing a pressure of a part of the liquid refrigerant, to the intermediate-pressure injection flow path on the low pressure side relative to the high-pressure intermediate-pressure injection flow path.

2. The refrigeration device according to claim 1,

wherein as the gas-liquid separator, only one gas-liquid separator is provided, and
as the internal heat exchanger, one or more internal heat exchangers are provided between the gas-liquid separator and the low-pressure decompression mechanism.

3. The refrigeration device according to claim 1 or 2,
wherein as the gas-liquid separator located on a
highest pressure side, a highest-pressure gas-liquid
separator, to which the refrigerant is directly supplied
from the high-pressure decompression mechanism, 5
is provided.
4. The refrigeration device according to claim 1 or 2,
wherein as the internal heat exchanger located on a
lowest pressure side, a lowest-pressure internal heat 10
exchanger, which allows the refrigerant to directly
flow into the low-pressure decompression mechanism, is provided.
5. The refrigeration device according to any one of 15
claims 1 to 4, wherein the internal heat exchanger
includes an expansion valve which reduces a pressure
of a part of the liquid refrigerant to expand the
part. 20
6. The refrigeration device according to any one of
claims 1 to 5,
- wherein as the internal heat exchanger, two or
more internal heat exchangers are provided, 25
and
a capacity of the internal heat exchanger located
on the relatively high pressure side is greater
than a capacity of the internal heat exchanger
located on the relatively low pressure side. 30
7. The refrigeration device according to any one of
claims 1 to 6, wherein the refrigerant includes carbon
dioxide in at least a part thereof. 35

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FIG. 1

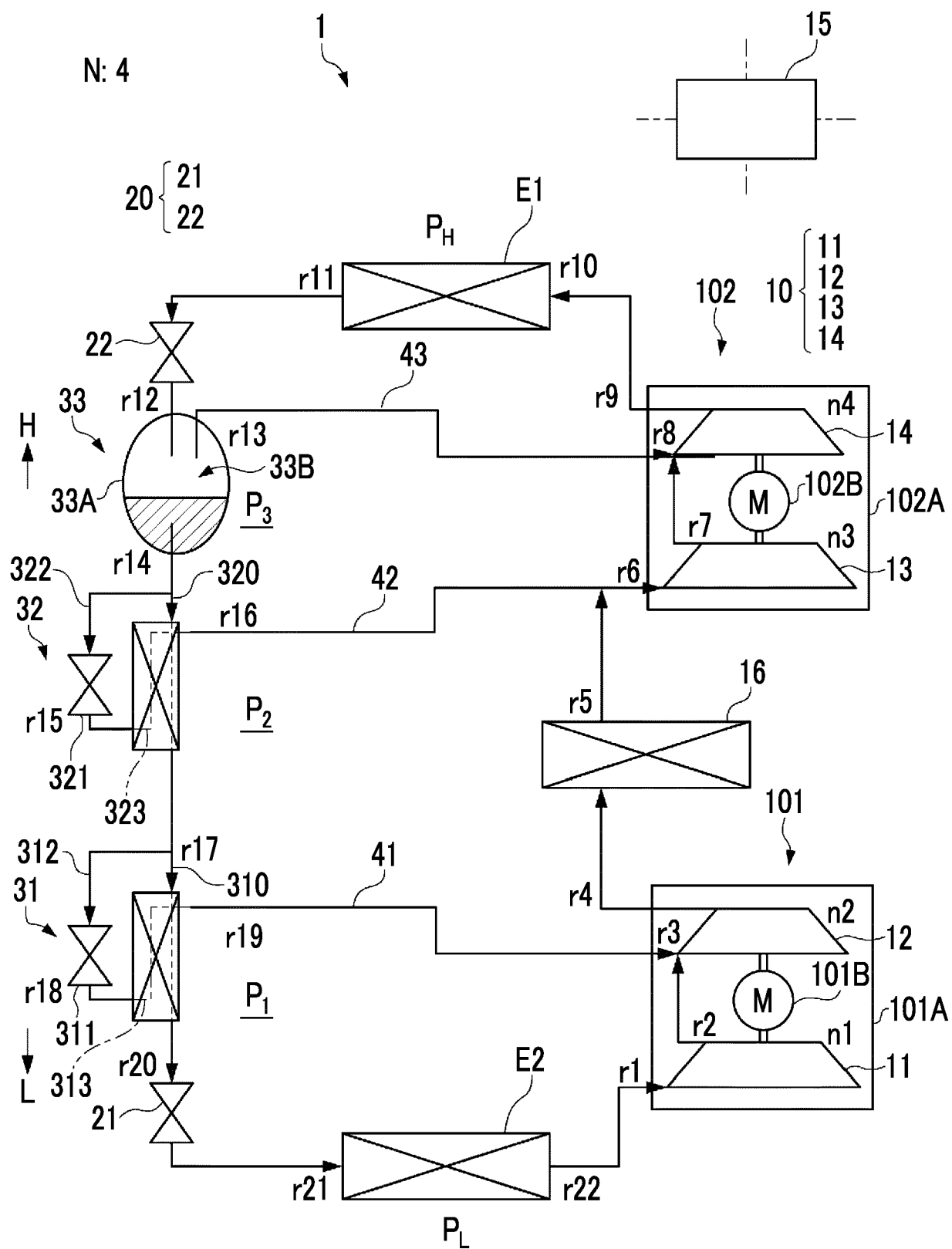


FIG. 2

N: 4

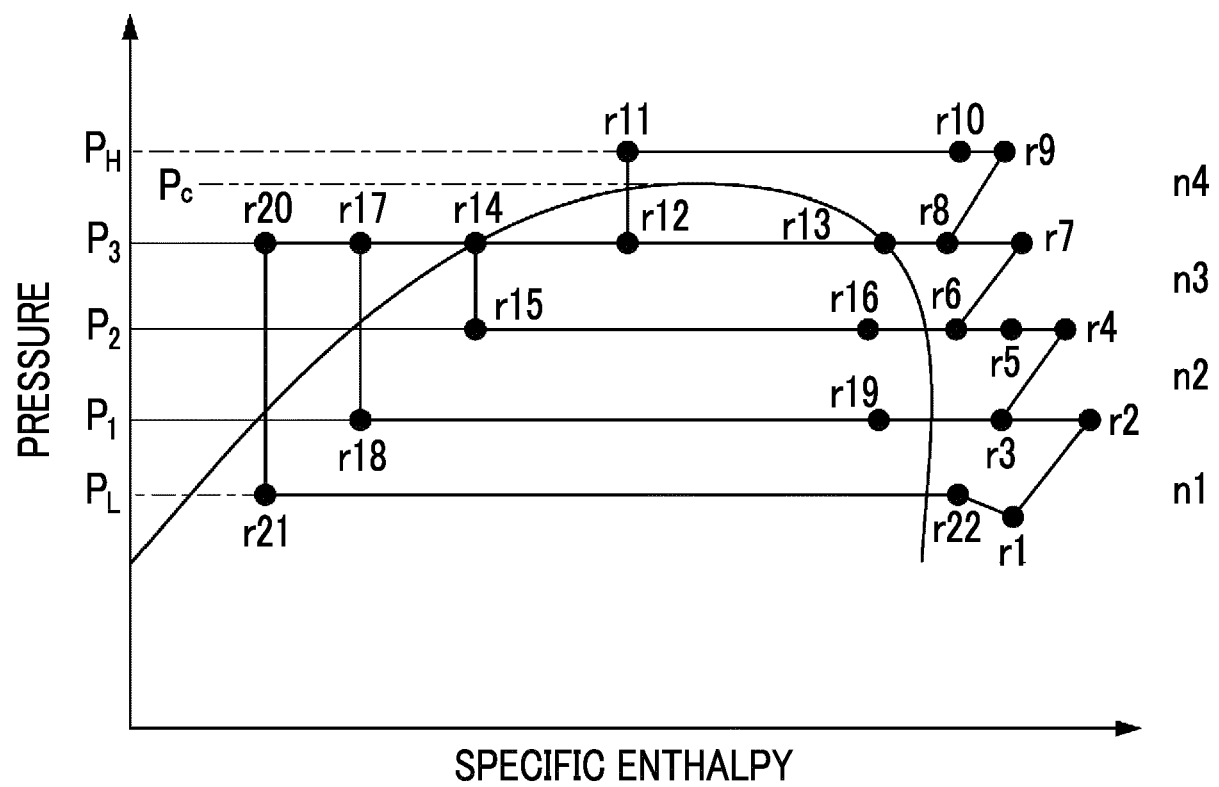


FIG. 3

N: 4

(COMPARATIVE EXAMPLE)

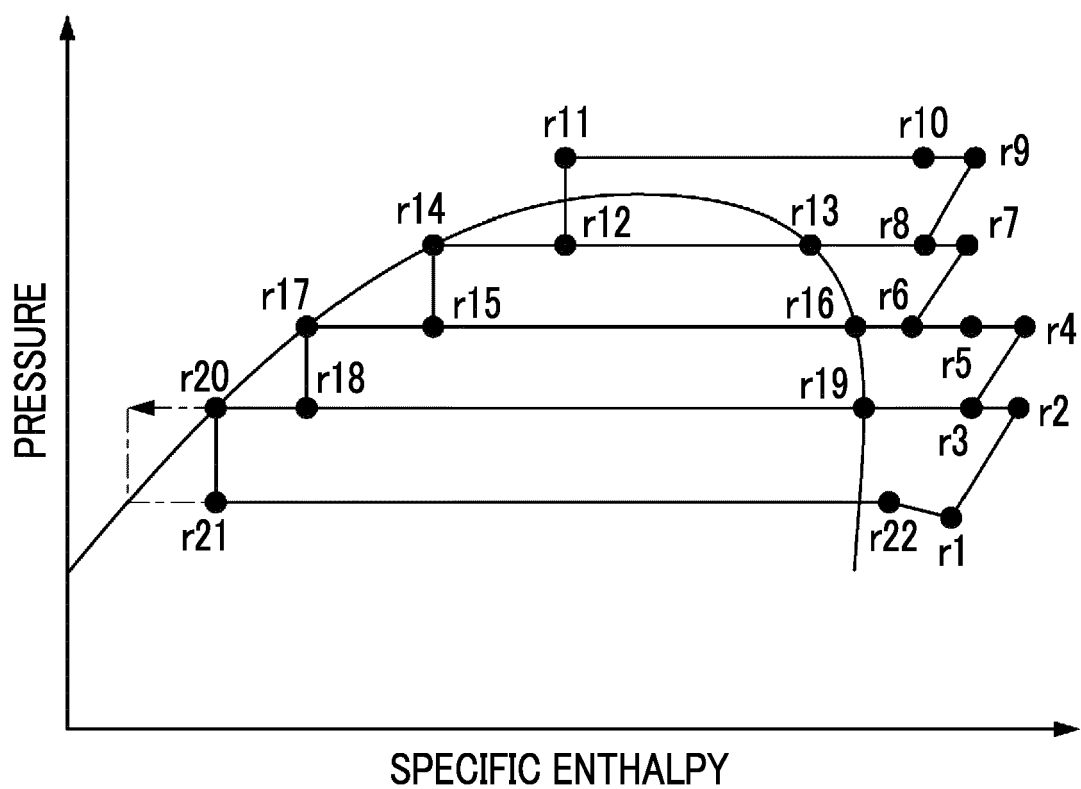


FIG. 4

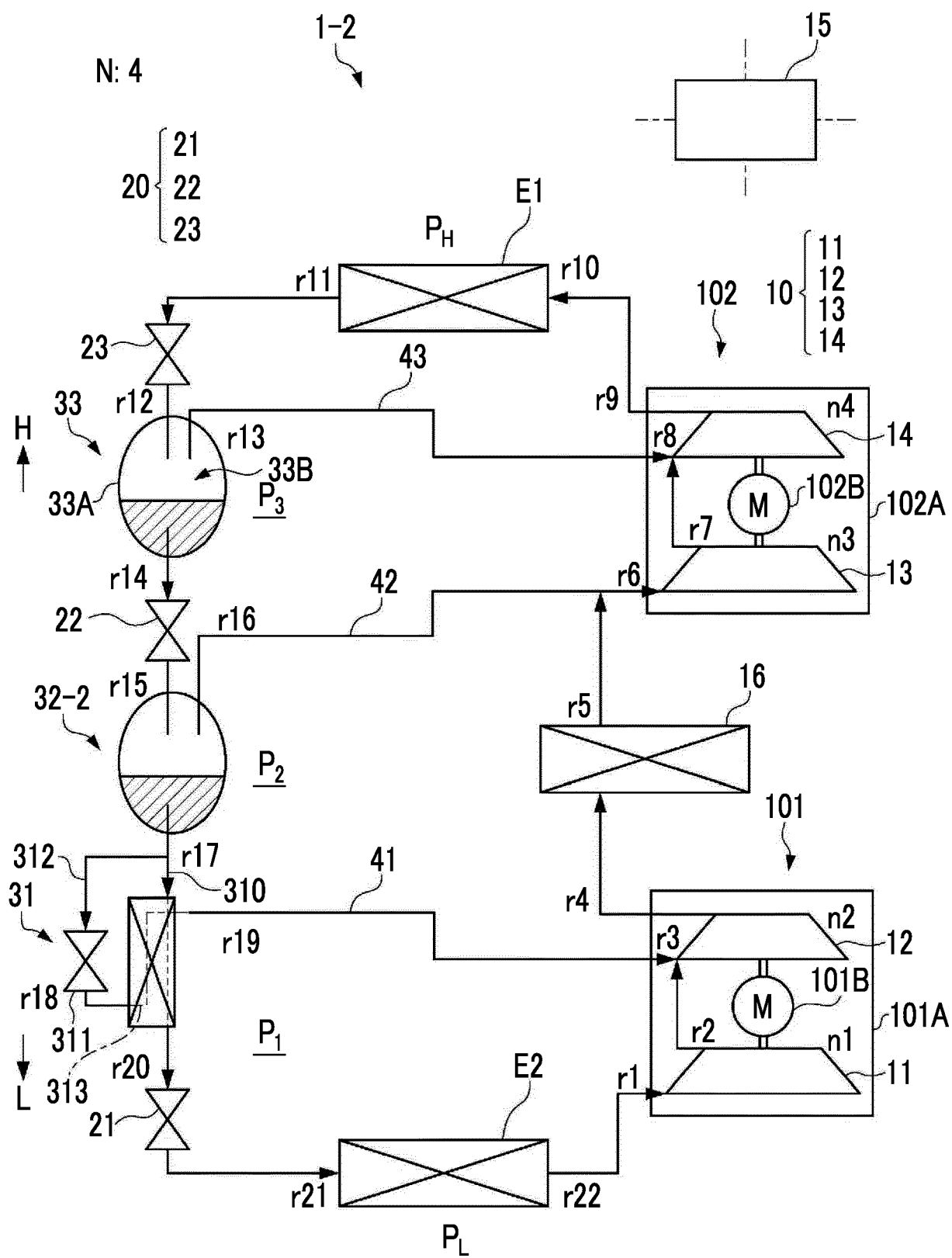
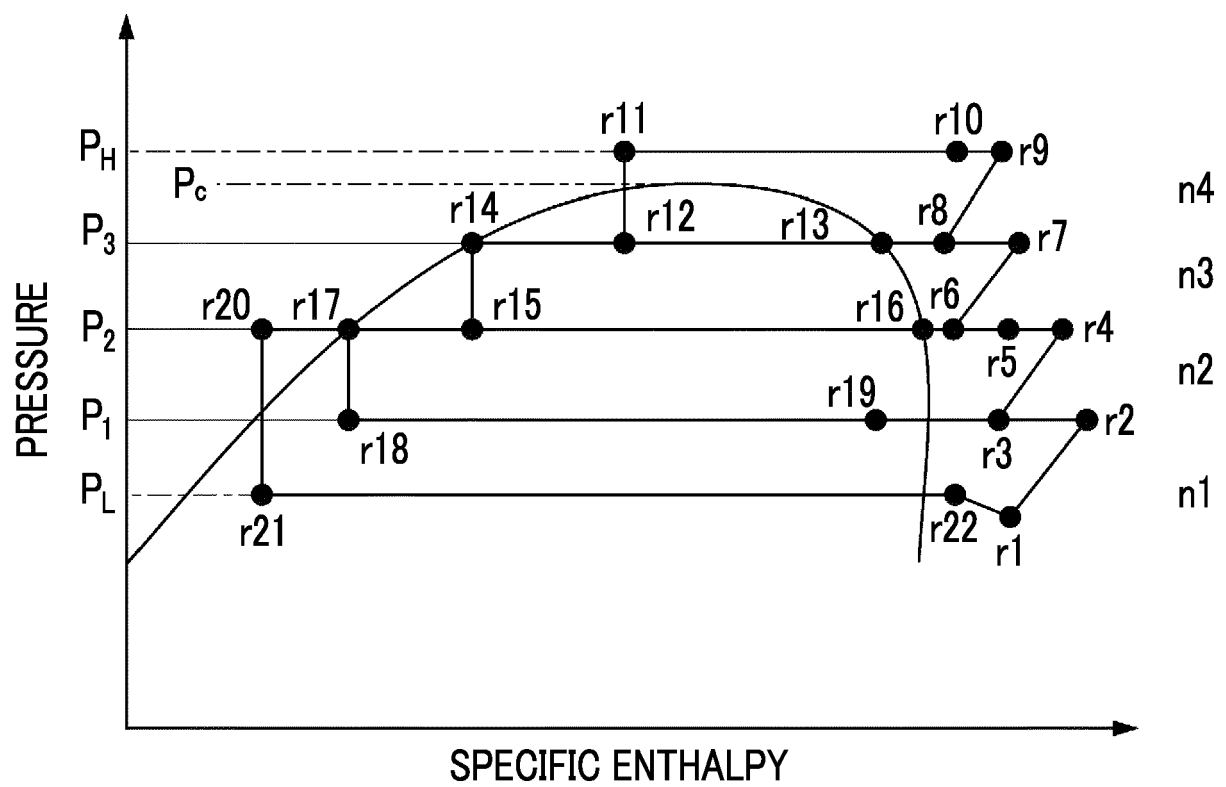


FIG. 5

N: 4



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/004822

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 L; F25B1/00 331E

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.
X	US 2011/0113804 A1 (CHIN, Sim-Won) 19 May 2011 (2011-05-19) paragraphs [0050]-[0117], fig. 1-6	1-5, 7
Y	paragraphs [0050]-[0117], fig. 1-6	6
X	US 2013/0055754 A1 (KIM, Beom-Chan) 07 March 2013 (2013-03-07) paragraphs [0006]-[0014], fig. 1	1-5, 7
Y	paragraphs [0006]-[0014], fig. 1	6
Y	WO 2007/046332 A1 (MAYEKAWA MFG. CO., LTD.) 26 April 2007 (2007-04-26) paragraphs [0033]-[0036], fig. 3-4	6
Y	JP 2013-024436 A (DAIKIN INDUSTRIES LTD) 04 February 2013 (2013-02-04) paragraphs [0022]-[0031], fig. 1-2	6
A	JP 2012-154616 A (LG ELECTRONICS INC) 16 August 2012 (2012-08-16) paragraphs [0074]-[0082], fig. 7	1-7

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

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Date of the actual completion of the international search

08 March 2022

Date of mailing of the international search report

22 March 2022

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International application No.

PCT/JP2022/004822

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JP 2013-024436 A	04 February 2013	(Family: none)	
JP 2012-154616 A	16 August 2012	US 2012/0186295 A1 paragraphs [0082]-[0090], fig. 7 EP 2479517 A1 KR 10-2012-0085070 A CN 102607208 A	

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

REFERENCES CITED IN THE DESCRIPTION

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