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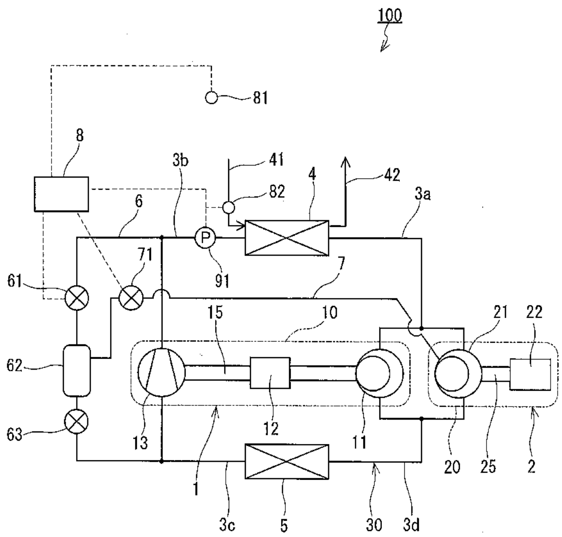
(54) ## REFRIGERATION CYCLE DEVICE

(57) A refrigeration cycle apparatus (100) includes an expander-compressor unit (1) including a first compression mechanism (11) and an expansion mechanism (13), and a sub compressor (2) including a second compression mechanism (21). The first compression mechanism (11) is connected in parallel with the second compression mechanism (21) in a refrigerant circuit (30). The refrigeration cycle apparatus (100) further includes a bypass passage (6) bypassing the expansion mechanism (13). A first flow control valve (61), a gas-liquid separator (62) and a second flow control valve (63) are provided sequentially to the bypass passage (6) from an upstream side. An injection passage (7) guides a gas refrigerant separated from a liquid refrigerant in the gas-liquid separator (62) to the second compression mechanism (21).

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration cycle apparatus used for water heaters, air conditioners, etc., having an expansion mechanism and compression mechanisms.

BACKGROUND ART

[0002] In recent years, for the purpose of further enhancing the efficiencies of refrigeration cycle apparatuses, there have been proposed power recovery type refrigeration cycle apparatuses using an expansion mechanism instead of an expansion valve, in which the expansion mechanism recovers the pressure energy as power during a process in which a refrigerant is expanded, and thus the electric power required for driving the compression mechanism is reduced by the amount of the power recovered. Such refrigeration cycle apparatuses use an expander-compressor unit, in which a motor, a compression mechanism, and an expansion mechanism are coupled by a shaft.

[0003] Since the compression mechanism is coupled to the expansion mechanism by the shaft in the expander-compressor unit, the refrigeration cycle apparatus is subjected to a so-called constraint of constant density ratio, in which the ratio between the density of the suction refrigerant in the compression mechanism and the density of the suction refrigerant in the expansion mechanism is fixed to the ratio between their suction capacities. Thus, there may be a case where the displacement of the compression mechanism is insufficient, or the displacement of the expansion mechanism is insufficient, depending on the operational conditions. In order to ensure adequate recovery power so that COP (Coefficient of Performance) of the refrigeration cycle apparatus is kept high even under operational conditions where the displacement of the compression mechanism is insufficient, there also have been proposed refrigeration cycle apparatuses using a secondary compressor in addition to the expander-compressor unit (see JP 2007-132622 A, for example).

[0004] Fig. 6 is a configuration diagram showing the refrigeration cycle apparatus described in JP 2007-132622A. In this refrigeration cycle apparatus, a first compression mechanism 101 of an expander-compressor unit 100 is disposed in parallel with a second compression mechanism 111 of a sub compressor 110 in a refrigerant circuit 140. Specifically, the first compression mechanism 101 and the second compression mechanism 111 are connected to a radiator 120 by a first pipe 141 and to an evaporator 130 by a fourth pipe 144. An expansion mechanism 103 of the expander-compressor unit 100 is connected to the radiator 120 by a second pipe 142 and to the evaporator 130 by a third pipe 143. In the refrigeration cycle apparatus of JP 2007-132622 A, in order to prevent an excess or shortage from occurring in the amount of the refrigerant flowing into the expansion mechanism 103, the rotation speed of a first motor 102 of the expander-compressor unit 100 and the rotation speed of a second motor 112 of the sub compressor 110 can be determined, respectively, according to a temperature of outside air, etc.

[0005] Furthermore, the refrigeration cycle apparatus of JP 2007-132622 A has a bypass passage 160 bypassing the expansion mechanism 103, and an injection passage 150 for supplying additionally the refrigerant to the expansion mechanism 103 during the expansion process of the refrigerant. The bypass passage 160 and the injection passage 150 are provided with a bypass valve 161 and an injection valve 151, respectively, for controlling the flow rate. In the refrigeration cycle apparatus of JP 2007-132622 A, the bypass valve 161 is in a closed state and the injection valve 151 is in an opened state in winter. An opening of the injection valve 151 is determined according to the temperature of outside air, etc. Thereby, it is possible to cope even with the case where the displacement of the expansion mechanism 103 is insufficient.

[0006] In some cases, the refrigeration cycle apparatus is required to have temporarily a high heat radiating capacity from the viewpoint of, for example, water heating load and a space heating load. In order to meet this requirement, it is conceivable to increase the rotation speeds of the motors of the expander-compressor unit and the sub compressor to increase the circulation amount of the refrigerant.

[0007] However, increasing the rotation speeds of the motors lowers the efficiencies of the motors, resulting in a decrease in the COP of the refrigeration cycle apparatus.

[0008] The present invention has been accomplished in view of the foregoing. The present invention is intended to increase the heat radiating capacity while keeping the COP high in a refrigeration cycle apparatus including an expansion mechanism and compression mechanisms.

DISCLOSURE OF INVENTION

[0009] In recent years, it has been proposed to perform injection into the compression mechanism in order to increase the heat radiating capacity temporarily. For example, WO 2007/072760 discloses a configuration of a refrigeration cycle apparatus including an expander-compressor unit, in which a gas-liquid separator is provided to a bypass passage bypassing an expansion mechanism, and a gas refrigerant separated in this gas-liquid separator is injected into a compression mechanism. It is conceivable to use this configuration for an refrigeration cycle apparatus of a parallel compression mechanisms system including an expander-compressor unit and a sub compressor as shown in Fig. 6. More specifically, it is conceivable to provide a gas-liquid separator to the bypass passage 160 and supply the gas refrigerant from this gas-liquid separator to the first compression mechanism 101 of the expander-compressor unit 100.

[0010] However, since the expander-compressor unit 100 has a configuration in which the expansion mechanism 103 is accommodated in a closed casing, the expander-compressor unit 100 has a lower temperature than that of the sub compressor 110. Moreover, since the closed casing of the expander-compressor unit 100 has a larger volumetric capacity than that of a closed casing of the sub compressor 110, the expander-compressor unit 100 radiates a larger amount of heat into the air. Accordingly, the temperature of the expander-compressor unit 100 becomes further lower than that of the sub compressor 110. Thus, when, for example, the rotation speed of the first motor 102 of the expander-compressor unit 100 is equal to that of the second motor 112 of the sub compressor 110, the refrigerant sent out from the expander-compressor unit 100 into the first pipe 141 has a lower temperature than that of the refrigerant sent out from the sub compressor 110 into the first pipe 141. In such a situation, when the refrigerant after the heat radiation is injected into the first compression mechanism 101 of the expander-compressor unit 100, the temperature of the refrigerant sent out from the expander-compressor unit 100 into the first pipe 141 is lowered further. As a result, the difference between the temperature of the refrigerant sent out from the compressor 100 to the first pipe 141 and the temperature of the refrigerant sent out from the compressor 110 to the first pipe 141 is increased. This means that the refrigerants having largely different temperatures are merged with each other, deteriorating the stability of the refrigeration cycle.

[0011] The present invention has been accomplished in view of the foregoing. More specifically, the present invention provides a refrigeration cycle apparatus including: an expander-compressor unit including a first compression mechanism for compressing a refrigerant, and an expansion mechanism for recovering power from the refrigerant expanding; a sub compressor including a second compression mechanism for compressing the refrigerant, the second compression mechanism being connected in parallel with the first compression mechanism in a refrigerant circuit; a radiator for radiating heat from the refrigerant discharged from the first compression mechanism and the second compression mechanism; an evaporator for evaporating the refrigerant discharged from the expansion mechanism; a first pipe for guiding the refrigerant from the first compression mechanism and the second compression mechanism to the radiator; a second pipe for guiding the refrigerant from the radiator to the expansion mechanism; a third pipe for guiding the refrigerant from the expansion mechanism to the evaporator; a fourth pipe for guiding the refrigerant from the evaporator to the first compression mechanism and the second compression mechanism; a bypass passage extending from the second pipe to the third pipe so as to bypass the expansion mechanism; a first flow control valve, a gas-liquid separator and a second flow control valve provided sequentially to the bypass passage from an upstream side; and an injection passage for guiding a gas refrigerant separated from a liquid refrigerant in the gas-liquid separator to the second compression mechanism.

[0012] This configuration makes it possible to increase the circulation amount of the refrigerant passing through the radiator by the supply of the gas refrigerant to the second compression mechanism through the injection passage, that is, by so-called injection. This allows the heat radiating capacity to be increased temporarily while keeping the COP high. Moreover, the injection into the second compression mechanism can reduce the difference between the temperature of the refrigerant sent out from the expander-compressor unit into the first pipe and the temperature of the refrigerant sent out from the sub compressor into the first pipe. Thereby, it is possible to increase the heat radiating capacity without spoiling the stability of the refrigeration cycle but rather while keeping it in a satisfactory state.

BRIEF DESCRIPTION OF DRAWINGS

[0013]

Fig. 1 is a schematic configuration diagram of a refrigeration cycle apparatus according to one embodiment of the present invention.

Fig. 2A is a Mollier diagram when injection is not performed, and Fig. 2B is a Mollier diagram when the injection is performed.

Fig. 3 is a flow chart of an injection operation performed by a controller.

Fig. 4 is a schematic configuration diagram of a refrigeration cycle apparatus according to a modified example.

Fig. 5 is a schematic configuration diagram of a refrigeration cycle apparatus according to another modified example.

Fig. 6 is a schematic configuration diagram of a conventional refrigeration cycle apparatus.

BEST MODE FOR CARRYING OUT THE INVENTION

[0014] Hereinafter, embodiments of the present invention will be described with reference to the drawings.

[0015] Fig. 1 shows a refrigeration cycle apparatus 100 according to one embodiment of the present invention. The refrigeration cycle apparatus 100 includes a refrigerant circuit 30. The refrigerant circuit 30 is composed of an expander-compressor unit 1, a sub compressor 2, a radiator 4, an evaporator 5, and first to fourth pipes (refrigerant pipes) 3a to 3d connecting these components.

[0016] The expander-compressor unit 1 has a first closed casing 10 accommodating a first compression mechanism 11, a first motor 12, and an expansion mechanism 13 connected to each other with a first shaft 15. The sub compressor 2 has a second closed casing 20 accommodating a second compression mechanism 21 and a second motor 22 connected to each other with a second shaft 25. The first compression mechanism 11 and the second compression mechanism 21 are connected to the radiator 4 via the first pipe 3a in which two branch pipes are merged into one main pipe. The radiator 4 is connected to the expansion mechanism 13 via the second pipe 3b. The expansion mechanism 13 is connected to the evaporator 5 via the third pipe 3c. The evaporator 5 is connected to the first compression mechanism 11 and the second compression mechanism 21 via the fourth pipe 3d in which one main pipe is branched into two branch pipes. More specifically, the first compression mechanism 11 and the second compression mechanism 21 are disposed in parallel with each other in the refrigerant circuit 30. In other words, the first compression mechanism 11 is connected in parallel with the second compression mechanism 21 in the refrigerant circuit 30.

[0017] The refrigerant compressed by the first compression mechanism 11 and that compressed by the second compression mechanism 21 are discharged into the first pipe 3a from the first compression mechanism 11 and the second compression mechanism 21, and then merged with each other while flowing through the first pipe 3a so as to be guided to the radiator 4. The refrigerants compressed by the compression mechanisms 11 and 21 may be discharged from the compression mechanisms 11 and 21 once into the closed casings 10 and 20, and then discharged from the closed casings 10 and 20 into the first pipe 3a. The refrigerant guided to the radiator 4 radiates heat there, and then is guided to the expansion mechanism 13 through the second pipe 3b. The refrigerant guided to the expansion mechanism 13 expands there. At this time, the expansion mechanism 13 recovers power from the refrigerant expanding. The expanded refrigerant is discharged from the expansion mechanism 13 into the third pipe 3c and guided to the evaporator 5. The refrigerant guided to the evaporator 5 absorbs heat there, and then is divided while flowing through the fourth pipe 3d so as to be guided to the first compression mechanism 11 and the second compression mechanism 21.

[0018] Preferably, the first compression mechanism 11 has the same displacement volume as that of the second compression mechanism 21. This makes it possible to construct the first compression mechanism 11 and the second compression mechanism 21 with common components, thereby reducing the costs.

[0019] The refrigerant circuit 30 is filled with the refrigerant that reaches a supercritical state in a high pressure portion (a portion from the first compression mechanism 11 and the second compression mechanism 21 to the expansion mechanism 13 through the radiator 4). In the present embodiment, the refrigerant circuit 30 is filled with carbon dioxide (CO_2) serving as the refrigerant. The type of the refrigerant is not particularly limited. The refrigerant may be a refrigerant (for example, a fluorocarbon refrigerant) that does not turn into a supercritical state during operation.

[0020] The refrigeration cycle apparatus 100 of the present embodiment is used in a water heater that supplies hot water held in a hot water reservoir tank to a hot water tap, as a heat pump unit for heating water to produce hot water. That is, the radiator 4 functions as a heat exchanger for exchanging heat between the refrigerant and water so as to heat the water. The refrigeration cycle apparatus 100 further includes a feed pipe 41 for feeding water from the hot water reservoir tank (not shown) to the radiator 4, and a return pipe 42 for returning the hot water produced in the radiator 4 to the hot water reservoir tank (not shown).

[0021] The refrigeration cycle apparatus 100 further includes a bypass passage 6 extending from the second pipe 3b to the third pipe so as to bypass the expansion mechanism 13. A first flow control valve 61, a gas-liquid separator 62, and a second flow control valve 63 are provided to the bypass passage 6 sequentially from an upstream side. The gas-liquid separator 62 and the second compression mechanism 21 of the sub compressor 2 are connected to each other with an injection passage 7. The injection passage 7 guides the gas refrigerant separated from the liquid refrigerant in the gas-liquid separator 62 to the second compression mechanism 21. The injection passage 7 is provided with an opening and closing valve 71.

[0022] The first flow control valve 61 serves to permit or inhibit the flow of the refrigerant through the bypass passage 6. The first flow control valve 61 also serves to adjust a pressure of a high pressure side (hereinafter merely referred to as a "high pressure") in a refrigeration cycle when the gas refrigerant is supplied to the second compression mechanism 21 through the injection passage 6, that is, when so-called injection is performed. In the present embodiment, an expansion valve is used as the first flow control valve 61.

[0023] In contrast, the second flow control valve 63 serves to determine a pressure in the gas-liquid separator 62, that is, a pressure of the refrigerant to be injected (intermediate pressure Pm). The injection passage 7 opens to a compression chamber with a variable volumetric capacity inside the second compression mechanism 21. The opening position is set so that the injection passage 7 is in communication with the compression chamber when the compression chamber has a particular intermediate volumetric capacity. The intermediate pressure Pm is determined so as to be equal to or higher than specified pressure Pb found based on the opening position. Since the intermediate pressure Pm has only to be equal to or higher than the specified pressure Pb, a fixed throttle (an orifice, for example) is used as the second flow control valve 63 in the present embodiment.

[0024] The opening and closing valve 71 serves to permit or inhibit the flow of the gas refrigerant through the injection passage 7.

[0025] Moreover, the refrigeration cycle apparatus 100 includes a controller 8 for controlling mainly rotation speeds of the first motor 12 and the second motor 22, the first flow control valve 61, and the opening and closing valve 71. In the present embodiment, the controller 8 is connected to an outside air temperature sensor (an outside air temperature detecting means) 81 for detecting a temperature of outside air, an incoming water temperature sensor (an incoming water temperature detecting means) 82 for detecting a temperature of the water flowing through a feed pipe 91, that is, a temperature of the incoming water to the radiator 4, and a pressure sensor (a pressure detecting means) 91 for detecting the pressure of the high pressure side in the refrigeration cycle. In the present embodiment, the pressure sensor 91 is provided to the second pipe 3b at a position located upstream of a position at which the bypass passage 6 joins to the second pipe 3b. However, the pressure sensor 91 may be provided to the main pipe of the first pipe 3a.

[0026] Next, the control performed by the controller 8 will be described. Before that, a description will be made first with respect to the cases where the injection is performed and not performed.

[0027] Fig. 2A and Fig. 2B are provided to show the difference between a Mollier diagram when the injection is performed and a Mollier diagram when the injection is not performed. As shown in Fig. 2B, when the injection is performed, the refrigerant (Point E) that has exited from the radiator 4 is divided into the refrigerant that flows toward Point F through the expansion mechanism 13 and the refrigerant that flows toward Point H through the bypass passage 6. Furthermore, the gas refrigerant in the refrigerant, at Point G in the gas-liquid separator 62, that came to have the intermediate pressure Pm in the bypass passage 6 flows through the injection passage 7, and thereafter is merged with the refrigerant compressed from Point A to Point B, and reaches Point C. Then, the refrigerant at Point C is compressed further and reaches Point D. This is the behavior of the refrigerant when the injection is performed.

[0028] Next, a description will be made with respect to the principle of attaining high efficiency by injecting the gas refrigerant separated in the gas-liquid separator 62 into the second compression mechanism 21 of the sub compressor 2, with reference to Fig. 2A and Fig. 2B.

[0029] In the case where the injection is performed, an amount of increase in enthalpy when the suction refrigerant to the second compression mechanism 21 is compressed to the intermediate pressure Pm is referred to as a, and an amount of increase in enthalpy when the refrigerant that has been merged with the injected refrigerant is compressed to a specified pressure is referred to as c. Also in the case where the injection is not performed, with the intermediate pressure Pm being estimated, an amount of increase in enthalpy when the suction refrigerant to the second compression mechanism 21 is compressed to the intermediate pressure Pm is referred to as a, and an amount of increase in enthalpy when the refrigerant is compressed from the intermediate pressure Pm to a specified pressure is referred to as b. With the circulation amount of the refrigerant being referred to as Gr, the difference between the compression power when the injection is performed and the compression power when the injection is not performed is as follows.

- Compression power when the injection is not performed: $Gr \times (a + b)$
- Compression power when the injection is performed: $Gr \times a + (Gr + \alpha) \times c$, where α denotes the amount of the injection.
- The difference between these compression powers: $Gr \times (a + b) - Gr \times (a + c) = Gr \times (b - c)$ (α, the amount of the injection, is excluded from the comparison.)

[0030] Here, $b > c$ holds according to the gradient of the isoentropic curve. Thus, when the injection is performed, it is possible to reduce the compression power by an amount corresponding to $Gr \times (b - c)$ from the compression power required when the injection is not performed. Thus, the COP can be enhanced.

[0031] The controller 8 performs a starting operation first, and then performs a steady operation. During the steady operation, the opening and closing valve 71 and the first flow control valve 61 are in a closed state. Furthermore, the controller 8 performs an injection operation when the heat radiating capacity needs to be increased temporarily during the steady operation. Fig. 3 shows a flow chart of this injection operation.

[0032] First, the controller 8 judges whether required load Qm [kW] is not less than specified value Q1 [kW] determined in advance (Step S1). When the refrigeration cycle apparatus 100 is used in a water heater as in the present embodiment, the required load Qm can be found from the difference between a tapping temperature set by a user and a temperature of the hot water held in the hot water reservoir tank when the user set the tapping temperature with a remote controller or the like. If the difference between the temperature set by the user and the temperature of the hot water held in the hot water reservoir tank is doubled, the required load is doubled as well. The specified value Q1 can be defined, for example, as the maximum heating capacity of the radiator 4 when the injection is not performed.

[0033] If the required load Qm is less than the specified value Q1 (No in Step S1), the controller 8 compares Qm with Q1 once again. If the required load Qm is equal to or more than the specified value Q1 (YES in Step S1), the controller 8 opens the opening and closing valve 71 (Step S2). At this time, the opening of the opening and closing valve 71 preferably is in a fully opened state. This is because although it is possible to adjust arbitrarily an injection flow rate (a flow rate of the refrigerant flowing through the injection passage 7) and control the heating capacity by controlling the opening of the opening and closing valve 71, narrowing the opening of the opening and closing valve 71 causes a pressure loss and lowers the effect of increasing the heat radiating capacity by the injection.

[0034] Subsequently, the controller 8 calculates proper pressure (optimal pressure) Pa of the refrigerant to be guided to the radiator 4 through the first pipe 3a, based on the temperature of the incoming water detected by the incoming water temperature sensor 82 and the temperature of outside air detected by the outside air temperature sensor 81 (Step S3). Thereafter, the controller 8 opens the first flow control valve 61 to a specified opening (Step S4). As a result, the gas refrigerant separated in the gas-liquid separator 62 is injected into the second compression mechanism 21 of the sub compressor 2, initiating the injection. As the specified opening of the first flow control valve 61, it is possible to measure, experimentally in advance, an opening that allows the proper pressure Pa to be obtained, and store the opening in a memory of the controller 8 in accordance with the temperature of outside air, etc..

[0035] After the injection is initiated, the controller 8 detects pressure Pd of the high pressure side in the refrigeration cycle with the pressure sensor 91 (Step S5), and judges whether the pressure Pd detected by the pressure sensor 91 is equal to the proper pressure Pa calculated in Step S3 (Step S6). If Pd = Pa fails to hold (No in Step S6), the controller 8 adjusts the opening of the first flow control valve 61 (Step S7). The high pressure in the refrigeration cycle is lowered when the opening of the first flow control valve 61 is increased, and is increased when the opening of the first flow control valve 61 is decreased. Thus, the opening of the first flow control valve 61 is adjusted so that the opening is increased if Pd > Pa and the opening is decreased if Pd < Pa. Then, Step S5 and Step S6 are performed once again, and Steps S7, S5, and S6 are repeated until Pd = Pa holds.

[0036] If Pd = Pa holds (YES in Step S6), the sequence proceeds to Step S8, and the controller 8 maintains the present state until the required load Qm becomes less than the specified value Q1. Thereafter, if the required load Qm becomes less than the specified value Q1, the controller 8 closes the opening and closing valve 71 and the first flow control valve 61 (Step S9) and returns to the steady operation.

[0037] As described above, in the refrigeration cycle apparatus 100 of the present embodiment, the injection into the second compression mechanism 21 can increase the circulation amount of the refrigerant passing through the radiator 4. Thereby, it is possible to increase temporarily the heat radiating capacity while keeping the COP high. The injection into the second compressor 21 can increase the heating capacity of the radiator 4 by approximately 4% without increasing the rotation speeds of the first motor 12 and the second motor 22. For example, assuming that the heating capacity of the radiator 4 is 5 kW when the injection is not preformed, the heating capacity can be improved to 5.2 kW by performing the injection.

[0038] Moreover, the injection into the second compression mechanism 21 can reduce the difference between the temperature of the refrigerant sent out from the expander-compressor unit 1 into the first pipe 3a and the temperature of the refrigerant sent out from the sub compressor 2 into the first pipe 3a. Thereby, it is possible to increase the heat radiating capacity without spoiling the stability of the refrigeration cycle but rather while keeping it in a satisfactory state.

[0039] Moreover, since the injection passage 7 is provided with the opening and closing valve 71 in the present embodiment, it is possible to perform a defrosting operation by opening the first flow control valve 61 while keeping the opening and closing valve 71 closed. In the defrosting operation, the thermal energy of the refrigerant of the high pressure side melts the frost formed on the evaporator 5. If the defrosting operation is performed, it is preferable to use, for example, an opening-adjustable opening and closing valve as the second flow control valve 63 instead of the fixed throttle. This configuration allows the opening of the second flow control valve 63 to be in the fully opened state when the defrosting operation is performed. Thereby, the occurrence of the pressure loss can be avoided.

(Modified Example)

[0040] Although the fixed throttle is used as the second flow control valve 63 in the above-mentioned embodiment, it also is possible to use an expansion valve as the second flow control valve 63. In this case, a second pressure sensor (a second pressure detecting means) 92 for detecting the pressure in the gas-liquid separator 62 may be provided as in a refrigeration cycle apparatus 100A according to a modified example shown in Fig. 4, and the opening of the second flow control valve 63 may be adjusted by the controller 8 so that the intermediate pressure Pm detected by the pressure sensor 92 becomes equal to or higher than the specified pressure Pb. In the example shown in Fig. 4, the pressure sensor 92 is provided to the bypass passage 6, between the first flow control valve 61 and the gas-liquid separator 62.

[0041] Or, instead of the pressure sensor 92, a refrigerant temperature sensor 84 for detecting the temperature of the refrigerant in the gas-liquid separator 62 may be provided as shown in Fig. 4 so that the controller 8 estimates the intermediate pressure Pm based on the temperature of the refrigerant detected by the refrigerant temperature sensor 84. The opening of the second flow control valve 63 may be adjusted by the controller 8 so that the estimated intermediate pressure Pm becomes equal to or higher than the specified pressure Pb. Since the refrigerant flowing through the bypass passage 6 turns from a supercritical state to a gas-liquid two phase state because of a pressure reduction in the refrigerant caused by the first flow control valve 61, the intermediate pressure Pm can be estimated based on the temperature of the refrigerant in the gas-liquid separator 62.

[0042] Instead of providing the pressure sensor 91 for detecting the pressure Pd of the high pressure side of the refrigeration cycle, it also is possible to use a configuration such as a configuration of a refrigeration cycle apparatus 100B according to a modified example shown in Fig. 5. In the refrigeration cycle apparatus 100B, the main pipe of the first pipe 3a is provided with a refrigerant temperature sensor (a refrigerant temperature detecting means) 83 for detecting a temperature of the refrigerant being guided to the radiator 4 through the first pipe 3a. The controller 8 calculates a pressure of the refrigerant being guided to the radiator 4, that is, the high pressure Pd in the refrigeration cycle, based on the temperature of the refrigerant detected by the refrigerant temperature sensor 83 and the temperature of outside air detected by the outside air temperature sensor 81. Then, the controller 8 adjusts the opening of the first flow control valve 61 so that the calculated high pressure Pd is equal to the proper pressure Pa. That is, the flow chart in this case is given by merely replacing Step S5 in the flow chart shown in Fig. 3 with the step of calculating Pd. Thereby, the production cost can be reduced because the temperature sensor is less expensive than the pressure sensor.

INDUSTRIAL APPLICABILITY

[0043] The refrigeration cycle apparatus of the present invention is useful as a means for recovering expansion energy of a refrigerant in a refrigeration cycle so as to recover power.

Claims

1. A refrigeration cycle apparatus comprising:

an expander-compressor unit including a first compression mechanism for compressing a refrigerant, and an expansion mechanism for recovering power from the refrigerant expanding;
a sub compressor including a second compression mechanism for compressing the refrigerant, the second compression mechanism being connected in parallel with the first compression mechanism in a refrigerant circuit;
a radiator for radiating heat from the refrigerant discharged from the first compression mechanism and the second compression mechanism;
an evaporator for evaporating the refrigerant discharged from the expansion mechanism;
a first pipe for guiding the refrigerant from the first compression mechanism and the second compression mechanism to the radiator;
a second pipe for guiding the refrigerant from the radiator to the expansion mechanism;
a third pipe for guiding the refrigerant from the expansion mechanism to the evaporator;
a fourth pipe for guiding the refrigerant from the evaporator to the first compression mechanism and the second compression mechanism;
a bypass passage extending from the second pipe to the third pipe so as to bypass the expansion mechanism;
a first flow control valve, a gas-liquid separator and a second flow control valve provided sequentially to the bypass passage from an upstream side; and
an injection passage for guiding a gas refrigerant separated from a liquid refrigerant in the gas-liquid separator to the second compression mechanism.

2. The refrigeration cycle apparatus according to claim 1, wherein the injection passage is provided with an opening and closing valve.

3. The refrigeration cycle apparatus according to claim 2, further comprising a controller that opens the opening and closing valve and the first flow control valve when a required load is equal to or more than a specified value determined in advance.

4. The refrigeration cycle apparatus according to claim 3, wherein:
the radiator is a heat exchanger for exchanging heat between the refrigerant and water so as to produce hot water;
the refrigeration cycle apparatus further comprises an incoming water temperature detecting means for detecting a temperature of the incoming water to the radiator, and an outside air temperature detecting means for detecting a temperature of outside air; and
the controller calculates a proper pressure of the refrigerant to be guided to the radiator through the first pipe, based on the temperature of the incoming water detected by the incoming water temperature detecting means and the temperature of outside air detected by the outside air temperature detecting means.

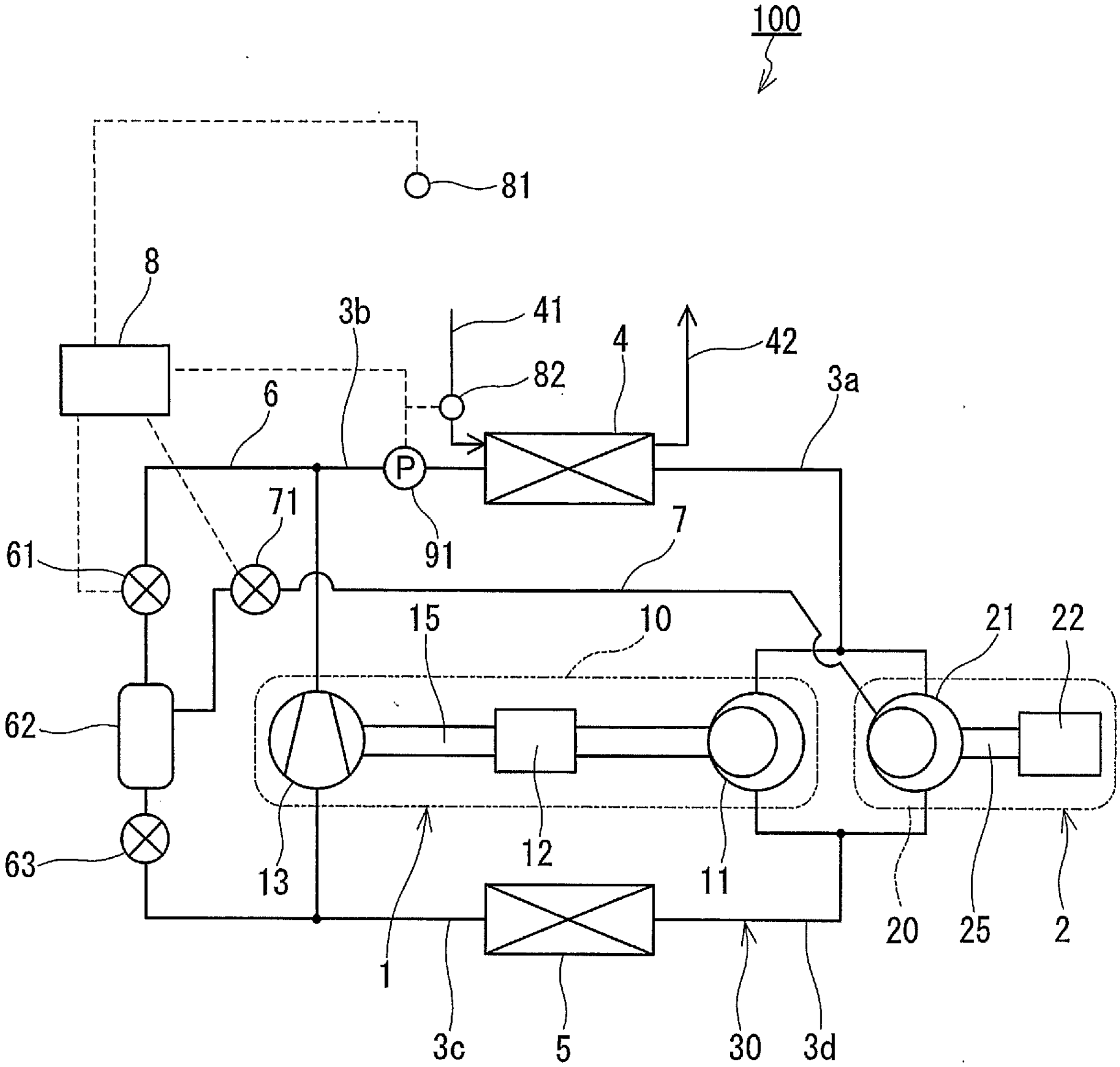
5. The refrigeration cycle apparatus according to claim 4, further comprising a pressure detecting means for detecting a pressure of a high pressure side in a refrigeration cycle,
wherein the controller adjusts an opening of the first flow control valve so that the pressure detected by the pressure detecting means is equal to the proper pressure.

6. The refrigeration cycle apparatus according to claim 4, further comprising a refrigerant temperature detecting means for detecting a temperature of the refrigerant being guided to the radiator through the first pipe,
wherein the controller calculates a pressure of the refrigerant being guided to the radiator based on the temperature of the refrigerant detected by the refrig-

erant temperature detecting means and the temperature of outside air detected by the outside air temperature detecting means, and adjusts an opening of the first flow control valve so that the calculated pressure is equal to the proper pressure.

7. The refrigeration cycle apparatus according to claim 1, wherein the refrigerant is carbon dioxide.

FIG.1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81
8
3b
41
4
42
82
6
3a
P
61
71
91
7
15
10
21
22
62
63
13
12
11
20
25
2
1
3c
5
30
3d

FIG.2A

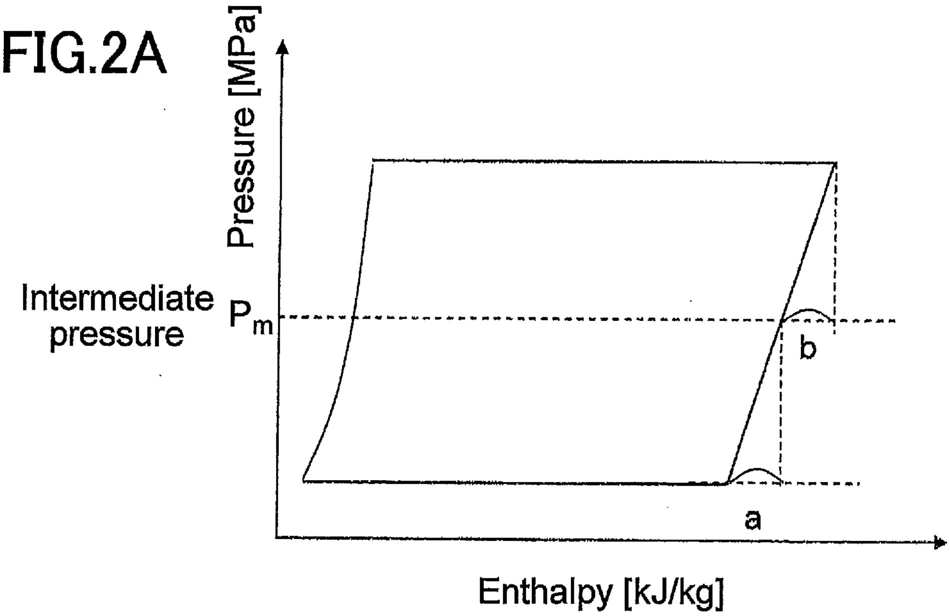

Pressure [MPa]
Intermediate pressure
Pm
b
a
Enthalpy [kJ/kg]

FIG.2B

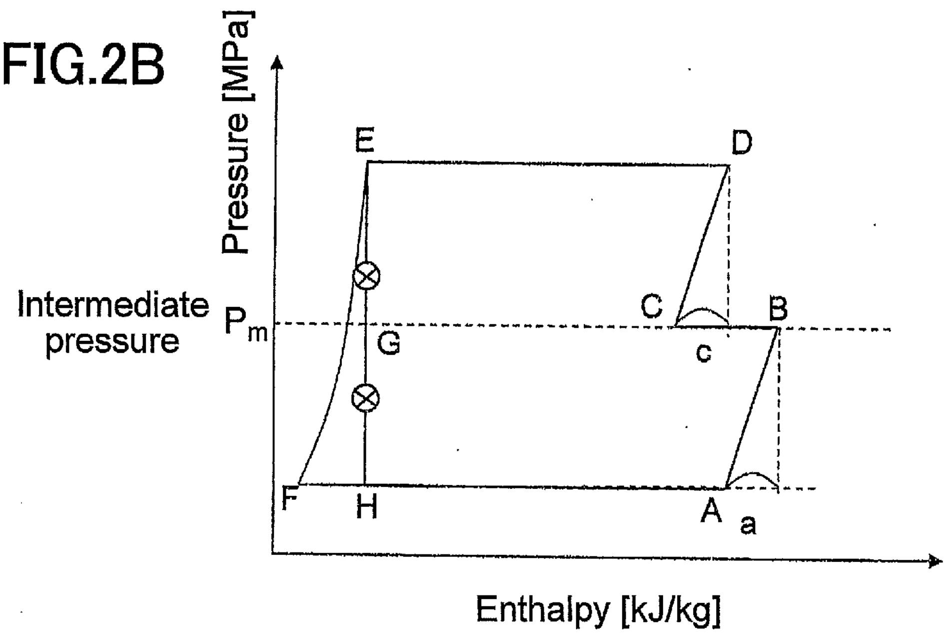

Pressure [MPa]
E
D
Intermediate pressure
Pm
C
B
G
c
F
H
A
a
Enthalpy [kJ/kg]

FIG.3

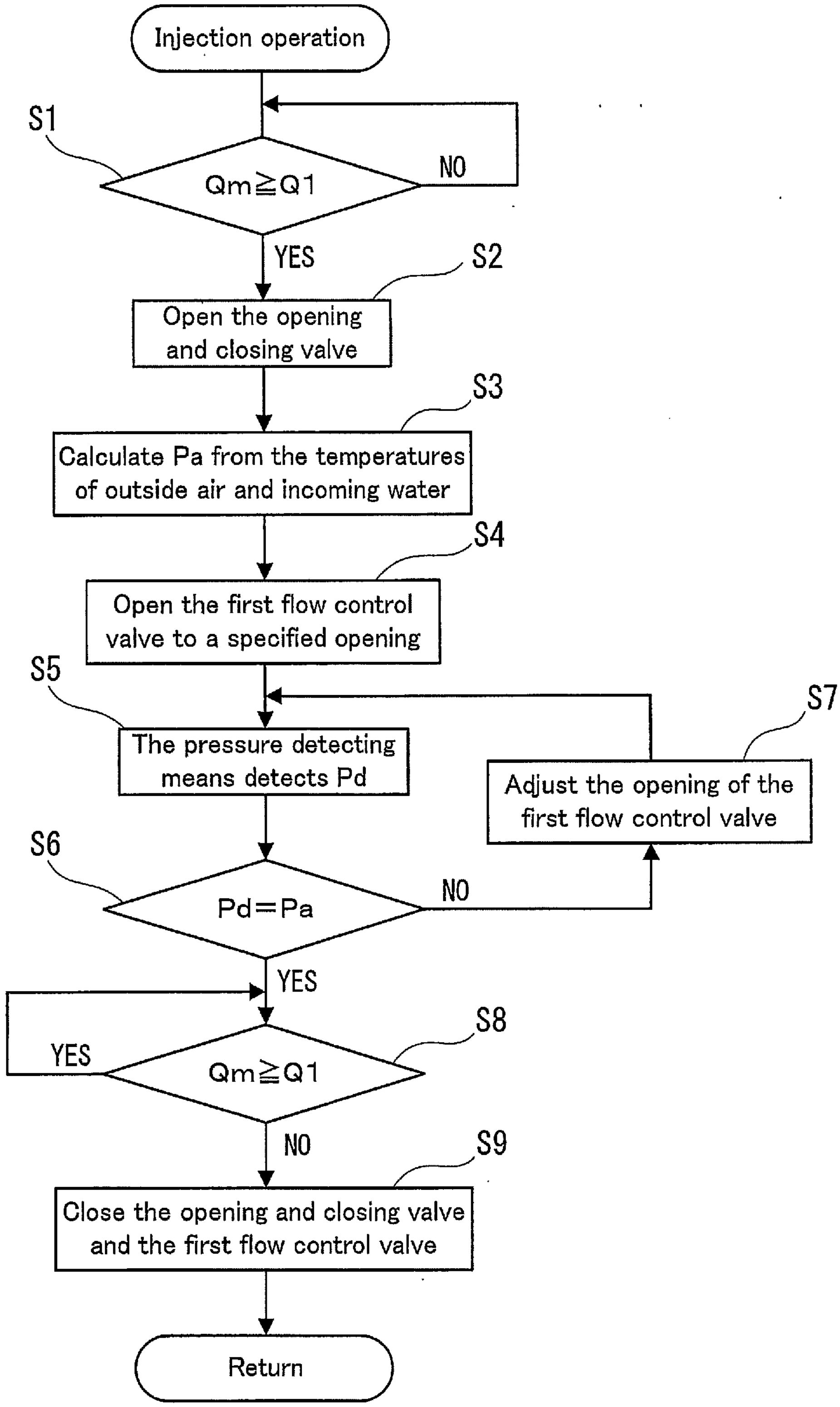

Injection operation
S1
Qm≧Q1
NO
YES
S2
Open the opening and closing valve
S3
Calculate Pa from the temperatures of outside air and incoming water
S4
Open the first flow control valve to a specified opening
S5
The pressure detecting means detects Pd
S7
Adjust the opening of the first flow control valve
S6
Pd=Pa
NO
YES
S8
YES
Qm≧Q1
NO
S9
Close the opening and closing valve and the first flow control valve
Return

FIG.4

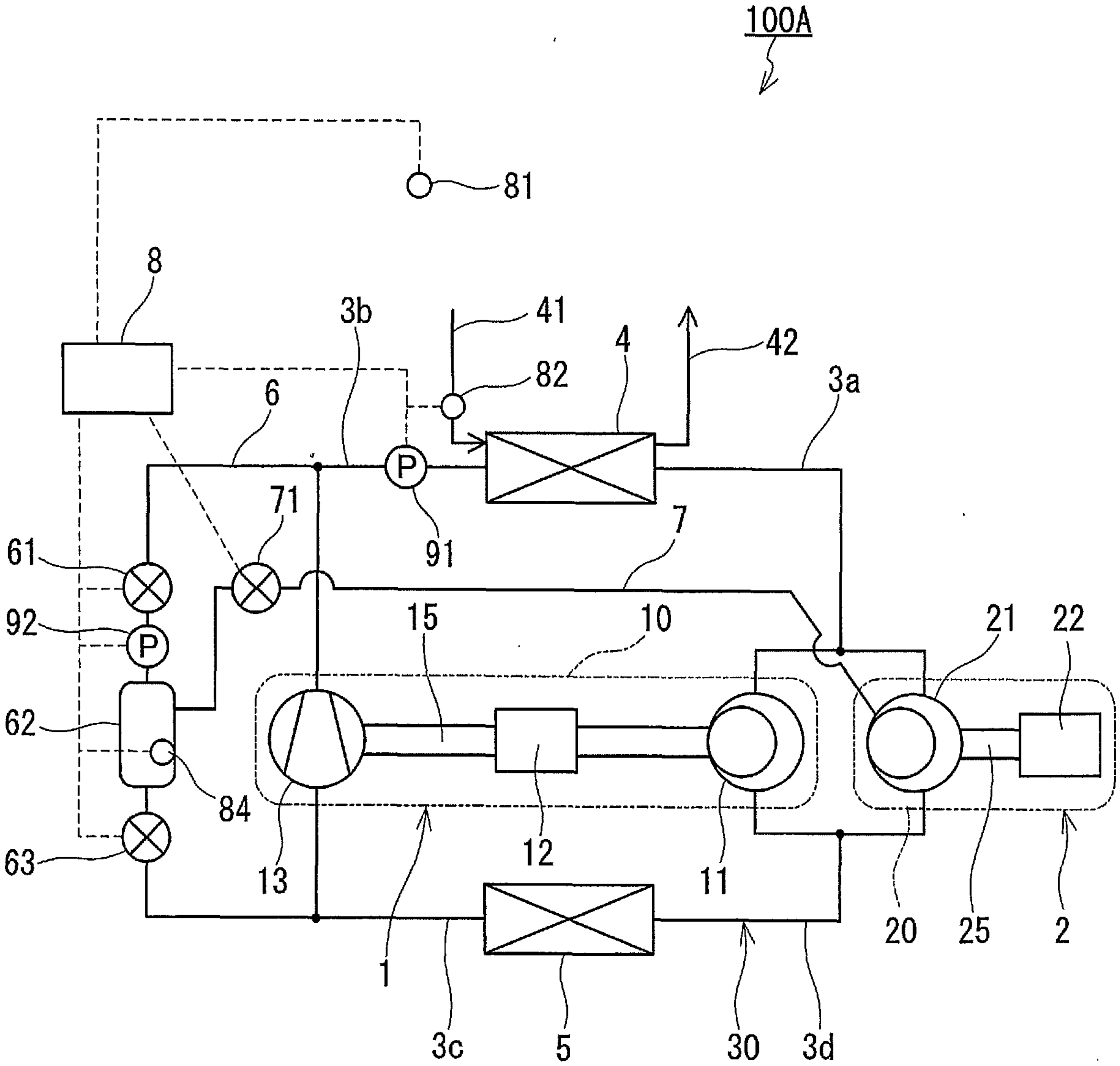

100A
81
8
3b
41
4
42
82
3a
6
P
91
71
7
61
92
P
15
10
21
22
62
84
63
13
12
11
20
25
2
1
3c
5
30
3d

FIG.5

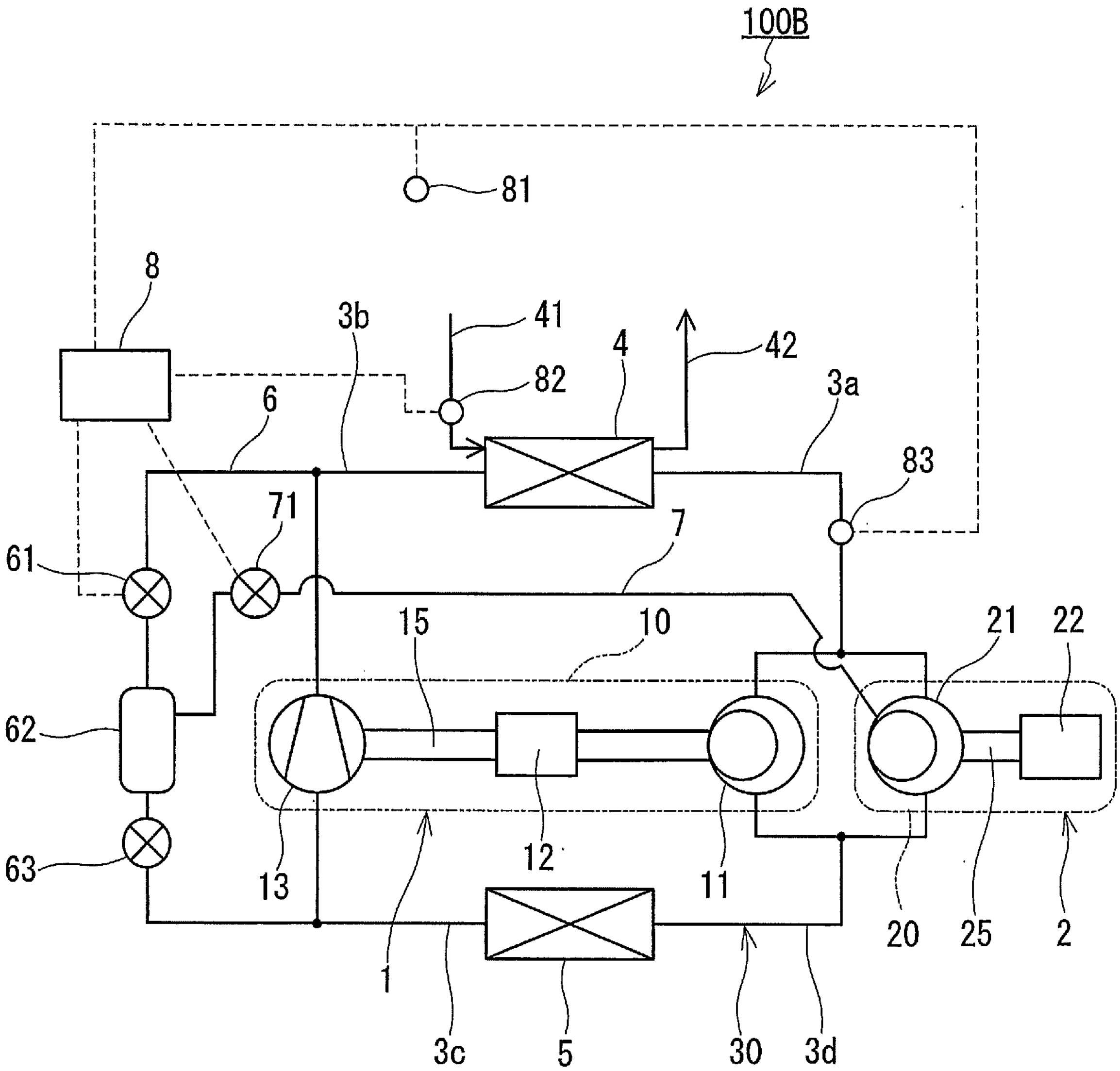
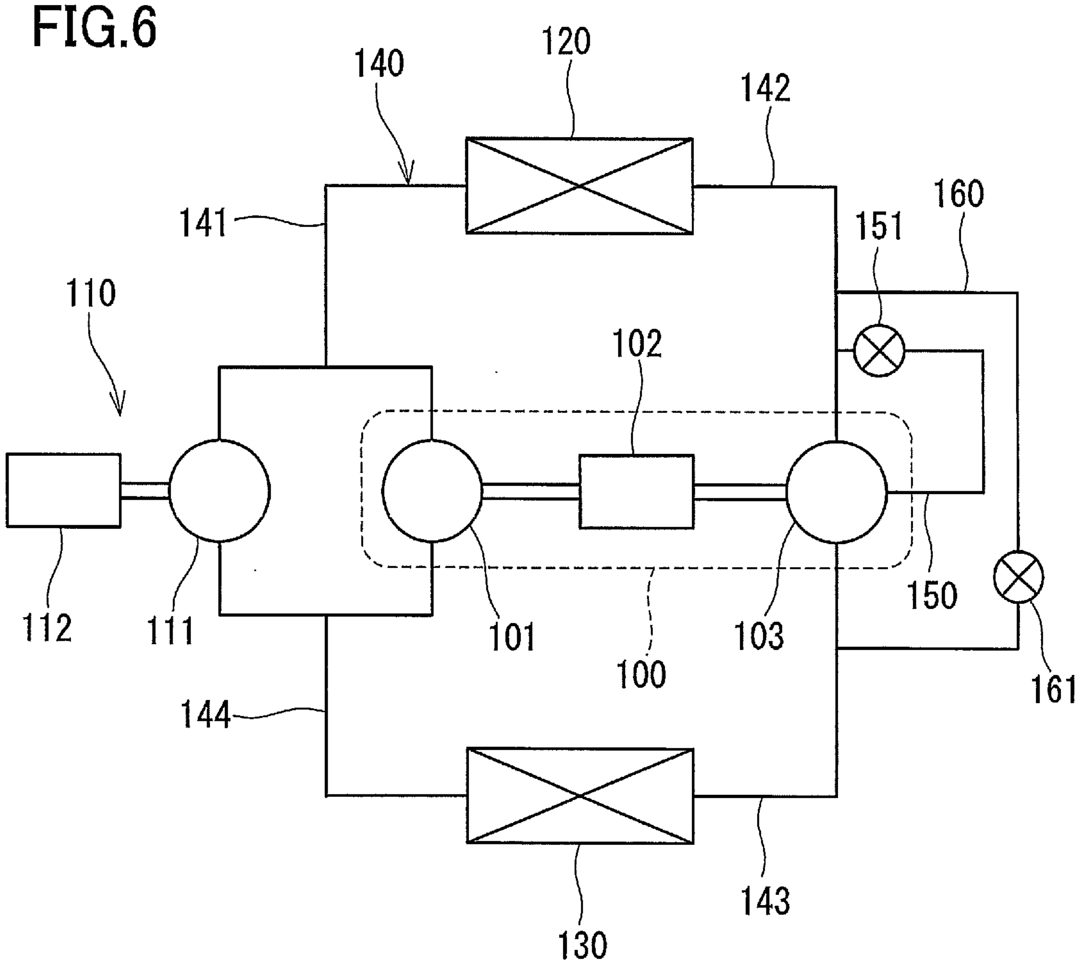

100B
81
8
3b
41
4
42
3a
82
6
83
71
61
7
15
10
21
22
62
13
12
11
63
20
25
2
1
3c
5
30
3d

FIG.6


140
120
142
141
160
151
110
102
112
111
101
100
103
150
161
144
130
143

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/000613

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2009
Kokai Jitsuyo Shinan Koho	1971-2009	Toroku Jitsuyo Shinan Koho	1994-2009

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.
A	JP 2007-132622 A (Daikin Industries, Ltd.), 31 May, 2007 (31.05.07), Fig. 1; Par. Nos. [0021] to [0051] (Family: none)	1-7
A	WO 2007/072760 A1 (Matsushita Electric Industrial Co., Ltd.), 28 June, 2007 (28.06.07), Full text; all drawings & US 2007/0151266 A1	1-7

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search 26 March, 2009 (26.03.09)	Date of mailing of the international search report 14 April, 2009 (14.04.09)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/000613

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-212006 A (Daikin Industries, Ltd.), 29 July, 2004 (29.07.04), Full text; all drawings & US 2006/0059929 A1 & EP 1586832 A1 & WO 2004/063642 A1 & DE 60320036 D & DE 60320036 T & AT 390606 T & ES 2300640 T	1-7
A	JP 4-340062 A (Nippondenso Co., Ltd.), 26 November, 1992 (26.11.92), Full text; all drawings (Family: none)	1-7
A	GB 2309748 A (City University), 06 August, 1997 (06.08.97), Fig. 9 & US 5833446 A & EP 787891 A2 & WO 1997/028354 A1 & DE 69628406 D & DK 787891 T & ES 2194964 T	1-7
A	JP 2006-527836 A (Career Corp.), 07 December, 2006 (07.12.06), Figs. 4A, 4B & US 2004/0250556 A1 & EP 1649223 A & WO 2005/019743 A1 & KR 10-2006-0022275 A & CN 1836136 A	1-7
A	JP 2006-71183 A (Mitsubishi Electric Corp.), 16 March, 2006 (16.03.06), Full text; all drawings (Family: none)	1-7
A	JP 61-96370 A (Hitachi, Ltd.), 15 May, 1986 (15.05.86), Fig. 5 (Family: none)	1-7

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2007132622 A **[0003] [0004] [0005]**
- WO 2007072760 A **[0009]**