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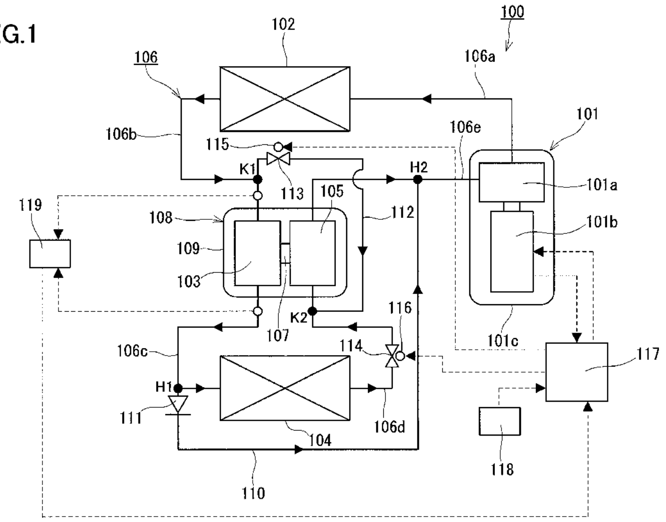
(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus 100 is provided with a working fluid circuit 106 and a first bypass passage 112. The working fluid circuit 106 is formed of a first compressor 101, a heat radiator 102, an expander 103, an evaporator 104, a second compressor 105, and flow passages 106a to 106e connecting these components in this order. The expander 103 and the second compressor 105 are coupled to each other by a power-recovery shaft 107 so that the second compressor 105 is driven by the power recovered by the expander 103. The first bypass passage 112 communicates between a portion from the discharge port of the first compressor 101 to the suction port of the expander 103 in the working fluid circuit 106 and a portion from the outlet of the evaporator 104 to the suction port of the second compressor 105 in the working fluid circuit 106, at the time of activation of the refrigeration cycle apparatus 100.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration cycle apparatus.

BACKGROUND ART

[0002] A refrigeration cycle apparatus 500 shown in Fig. 9 is conventionally known as a refrigeration cycle apparatus provided with an expander that recovers power by expanding a working fluid, and a second compressor that preliminarily increases the pressure of the working fluid (for example, see JP 2003-307358 A). With reference to Fig. 9, the configuration of the conventional refrigeration cycle apparatus 500 is described.

[0003] As shown in Fig. 9, the refrigeration cycle apparatus 500 is provided with a working fluid circuit 6 formed of a first compressor 1, a heat radiator 2, an expander 3, an evaporator 4, a second compressor 5, and flow passages 10a to 10e connecting these components in this order. The second compressor 5 is coupled to the expander 3 by a power-recovery shaft 7, and is driven by receiving mechanical energy recovered by the expander 3, via the power-recovery shaft 7.

[0004] Further, a bypass passage 8 that bypasses the second compressor 5, and a bypass valve 9 that controls the flow of the working fluid in the bypass passage 8 are provided therein. The upstream end of the bypass passage 8 is connected to the flow passage 10d connecting the outlet of the evaporator 4 and the suction port of the second compressor 5. The downstream end of the bypass passage 8 is connected to the flow passage 10e connecting the discharge port of the second compressor 5 and the suction port of the first compressor 1.

[0005] The refrigeration cycle apparatus 500 is activated according to the following procedures. First, the first compressor 1 starts operating, and the bypass valve 9 is opened. This allows the working fluid in the evaporator 4 to be drawn into the first compressor 1 through the bypass passage 8 as shown by solid arrows in Fig. 9. The working fluid with the pressure increased in the first compressor 1 is discharged therefrom, thereby causing an increase in the pressure at the suction port of the expander 3. As a result of this, a pressure difference is caused between before and after the expander 3, as shown in Fig. 10, so that the expander 3 and the second compressor 5 can be activated rapidly. After the expander 3 and the second compressor 5 are activated, the bypass valve 9 is closed. The working fluid flowing out of the evaporator 4 is drawn into the second compressor 5 through the flow passage 10d, as shown by dashed arrows in Fig. 9. In this way, a smooth transfer to regular operation can be achieved by providing the bypass passage 8.

CITATION LIST

Patent Literature

[0006] Patent Literature 1: JP 2003-307358 A

SUMMARY OF INVENTION

Technical Problem

[0007] In the refrigeration cycle apparatus 500, only the expander 3 is involved in the activation of the expander 3 and the second compressor 5, whereas the second compressor 5 does not contribute thereto. Rather, the second compressor 5 acts as a load at the time of activation of the expander 3. That is, friction or the like between the power-recovery shaft 7 and the component parts of the second compressor 5 acts as a driving resistance in the expander 3.

[0008] Meanwhile, in the regular operation of the refrigeration cycle apparatus 500, the second compressor 5 and the expander 3 are coupled to each other by the power-recovery shaft 7 that is commonly shared therebetween and thus have identical rotation rates, as well as forming the working fluid circuit 6 of a single channel. Accordingly, the volume of the second compressor 5 and the volume of the expander 3 need to be set so that the mass of the working fluid to be drawn by the second compressor 5 per unit time is equal to the mass of the working fluid to be drawn by the expander 3 per unit time.

[0009] Fig. 11 is a Mollier diagram when carbon dioxide is used as the working fluid in the conventional refrigeration cycle apparatus 500. As shown in Fig. 11, in the regular operation of the conventional refrigeration cycle apparatus 500, the working fluid drawn by the second compressor 5 has a pressure of 40 kg/cm^2 and a temperature of about 10°C (point A in Fig. 11). At this time, the working fluid has a density of 108.0 kg/m^3. The working fluid drawn by the expander 3 has a pressure of 100 kg/cm^2 and a temperature of 40°C (point C in Fig. 11). At this time, the working fluid has a density of 628.61 kg/m^3.

[0010] Here, the suction volume (m^3) of the second compressor 5 is referred to as Vc, the suction volume (m^3) of the expander 3 is referred to as Ve, and the rotation rate (S^{-1}) of the power-recovery shaft 7 per second is referred to as N. The mass (kg/s) of the working fluid that the second compressor 5 can draw per second and the mass (kg/s) of the working fluid that the expander 3 can draw per second can be expressed respectively by Formula 1 and Formula 2.

[0011]

Formula 1:

$$\text{(The mass of the working fluid that the second compressor 5 can draw per second)} = 108.0 \times Vc \times N$$

[0012]

Formula 2:

$$\text{(The mass of the working fluid that the expander 3 can draw per second)} = 628.61 \times Ve \times N$$

[0013] When the mass of the working fluid that the second compressor 5 can draw per second is equal to the mass of the working fluid that the expander 3 can draw per second, the suction volume Vc of the second compressor 5 can be expressed by Formula 3 from the above-mentioned Formula 1 and Formula 2.

[0014]

Formula 3:

$$Vc = (628.61/108.0) \times Ve \approx 5.8 \times Ve$$

[0015] That is, the expander 3 needs to drive the second compressor 5 having a suction volume that is about 5.8 times that of the expander 3, at the time of activation of the refrigeration cycle apparatus 500. Further, the larger the ratio between the density of the working fluid to be drawn by the second compressor 5 and the density of the working fluid to be drawn by the expander 3, the larger the ratio between the suction volume of the second compressor 5 and the suction volume of the expander 3 also should be. In other words, the suction volume of the expander 3 becomes smaller with respect to the suction volume of the second compressor 5, and the driving resistance of the expander 3 at the time of activation of the second compressor 5 relatively increases. Accordingly, there is a possibility that the expander 3 cannot drive the second compressor 5 at the time of activation, depending on the operational conditions of the refrigeration cycle apparatus 500. Instead, it might be necessary to impose an excess pressure, as compared to that in the regular operation, on the suction port side of the expander 3, so that a driving force necessary to drive the second compressor 5 should be obtained, possibly resulting in a problem of safety, such as pressure resistance.

[0016] The present invention aims to solve the above-mentioned conventional problems, and it is an object of the present invention to provide a refrigeration cycle apparatus that can be activated surely and stably.

Solution to Problem

[0017] That is, the present invention provide a refrigeration cycle apparatus including: a working fluid circuit formed of a first compressor for compressing a working fluid, a heat radiator for cooling the working fluid compressed by the first compressor, an expander for expanding the working fluid cooled by the heat radiator and recovering power from the working fluid, an evaporator for evaporating the working fluid that has been expanded by the expander, a second compressor for increasing the pressure of the working fluid that has been evaporated by the evaporator and supplying it to the first compressor, and flow passages connecting these components in this order; a power-recovery shaft coupling the expander to the second compressor so that the second compressor is driven by the power that has been recovered by the expander; a first bypass passage for communicating between a portion from the discharge port of the first compressor to the suction port of the expander in the working fluid circuit and a portion from the outlet of the evaporator to the suction port of the second compressor in the working fluid circuit; and a first bypass valve, provided on the first bypass passage, for controlling the flow of the working fluid in the first bypass passage.

Advantageous Effects of Invention

[0018] According to the refrigeration cycle apparatus of the present invention, a working fluid at high pressure that is equivalent to one supplied to the suction port of the expander can be supplied to the suction port of the second compressor at the time of activation. On the other hand, the pressure at the discharge port of the second compressor is equalized with that at the suction port of the first compressor, that is, the pressure becomes relatively low. In other words, a large pressure difference can be caused between before and after the second compressor. Therefore, the refrigeration cycle apparatus of the present invention can be activated surely and stably independent of operational conditions.

BRIEF DESCRIPTION OF DRAWINGS

[0019]

Fig. 1 is a configuration diagram of the refrigeration cycle apparatus in Embodiment 1 of the present invention.
Fig. 2 is a flow chart of the activation control of the refrigeration cycle apparatus in Embodiment 1 of the present invention.
Fig. 3 is a configuration diagram of the refrigeration cycle apparatus in Embodiment 2 of the present invention.
Fig. 4 is a flow chart of the activation control of the refrigeration cycle apparatus in Embodiment 2 of the present invention.
Fig. 5 is a configuration diagram of the refrigeration cycle apparatus in Embodiment 3 of the present invention.
Fig. 6A is a schematic view showing the state at the time of activation of the refrigeration cycle apparatus in Embodiments 1 and 2.
Fig. 6B is a schematic view showing the state at the time of activation of the refrigeration cycle apparatus in Embodiment 3.
Fig. 7 is a configuration diagram of the refrigeration cycle apparatus in Reference Example.
Fig. 8A is a schematic view showing the flow of the working fluid at the time of activation of a conventional refrigeration cycle apparatus.
Fig. 8B is a schematic view showing the flow of the working fluid at the time of activation of the refrigeration cycle apparatus in Embodiment 1, Embodiment 2 and Reference Example.
Fig. 9 is a configuration diagram of the conventional refrigeration cycle apparatus.
Fig. 10 is a schematic view showing the state at the time of activation of the refrigeration cycle apparatus shown in Fig. 9.
Fig. 11 is a Mollier diagram when carbon dioxide is used as a working fluid in the conventional refrigeration cycle apparatus.

DESCRIPTION OF EMBODIMENTS

[0020] Hereinafter, several embodiments of the present invention are described with reference to the drawings. It should be noted that the present invention is not limited to the following embodiments.

Embodiment 1

<Configuration of refrigeration cycle apparatus 100>

[0021] Fig. 1 is a configuration diagram showing a refrigeration cycle apparatus 100 in Embodiment 1 of the present invention. As shown in Fig. 1, the refrigeration cycle apparatus 100 is provided with a working fluid circuit 106 formed by sequentially connecting a first compressor 101, a heat radiator 102, an expander 103, an evaporator 104 and a second compressor 105, with flow passages (pipes) 106a to 106e. As a working fluid, a refrigerant such as carbon dioxide can be used.

[0022] The first compressor 101 is constituted by arranging a compression mechanism 101a and a motor 101b for driving the compression mechanism 101a in a single closed casing 101c holding lubrication oil. The first compressor 101 compresses the working fluid to high temperature and high pressure. A scroll compressor or a rotary compressor, for example, can be used as the first compressor 101. The discharge port of the first compressor 101 is connected to the inlet of the heat radiator 102 via the flow passage 106a.

[0023] The heat radiator 102 allows the working fluid that has been compressed to high temperature and high pressure by the first compressor 101 to radiate heat. (The heat radiator 102 cools the working fluid that has been compressed to high temperature and high pressure by the first compressor 101.) The outlet of the heat radiator 102 is connected to the suction port of the expander 103 via the flow passage 106b.

[0024] The expander 103 expands the working fluid that has flowed out of the heat radiator 102 and is at intermediate temperature and high pressure. The expander 103 converts the expansion energy (power) of the working fluid into mechanical energy so as to recover it. The discharge port of the expander 103 is connected to the inlet of the evaporator 104 via the flow passage 106c. A scroll expander or a rotary expander, for example, can be used as the expander 103. In addition, a fluid pressure motor expander can be used as the expander 103. The fluid pressure motor expander is a fluid machine that recovers power from a working fluid by sequentially performing processes of drawing the working fluid from the heat radiator 102 and discharging the drawn working fluid into the evaporator 104 without performing any substantial expansion process in the working chamber. The detailed structure and the operational principle of the fluid pressure motor expander is disclosed, for example, in WO 2008/050654 A.

[0025] The evaporator 104 evaporates the working fluid at low temperature and low pressure that has been expanded by the expander 103, by heating. The outlet of the evaporator 104 is connected to the suction port of the second compressor 105 via the flow passage 106d.

[0026] The second compressor 105 draws the working fluid that has flowed out of the evaporator 104 and is at intermediate temperature and low pressure. The second compressor 105 discharges it into the first compressor 101 after preliminarily increasing the pressure thereof. The discharge port of the second compressor 105 is connected to the suction port of the first compressor 101 via the flow passage 106e. A scroll compressor or a rotary compressor can be used as the second compressor 105. In addition, a fluid pressure motor compressor can be used as the second compressor 105. The fluid pressure motor compressor is a fluid machine that increases the pressure of a working fluid by substantially sequentially performing processes of drawing the working fluid from the evaporator 104 and discharging the drawn working fluid into the first compressor 101. In other words, the fluid pressure motor compressor is a fluid machine that allows substantially no volume change of the working fluid in a working chamber. The fluid pressure motor compressor has basically the same structure as the fluid pressure motor expander, and the above-mentioned literature discloses it in detail.

[0027] The expander 103 and the second compressor 105 are accommodated in a single closed casing 109 holding lubrication oil. The expander 103 is coupled to the second compressor 105 by a power-recovery shaft 107. The expander 103, the second compressor 105 and the power-recovery shaft 107 function as a power recovery system 108 that drives the second compressor 105 by transferring the mechanical energy (power) recovered by the expander 103 to the second compressor 105 via the power-recovery shaft 107.

[0028] In Embodiment 1, the second compressor 105 has a larger volume than the expander 103. The ratio (Vc/Ve) of the volume Vc of the second compressor 105 with respect to the volume Ve of the expander 103 is set, for example, to the range of 5 to 15. Particularly, in the case of using a working fluid, such as carbon dioxide, that forms a refrigeration cycle with a large pressure difference, the ratio (Vc/Ve) also tends to be large. Generally, the larger the ratio (Vc/Ve), the larger the driving force (torque) is required for the self-activation of the power recovery system 108.

In this regard, "the volume of the second compressor 105" means a confined volume, that is, the volume of the working chamber at the completion of the drawing process. This should be applied to the volume of the expander 103 as well.

[0029] The refrigeration cycle apparatus 100 is further provided with a first bypass passage 112 and a first bypass valve 113. The first bypass passage 112 is connected to the working fluid circuit 106 so as to communicate between the flow passage 106b connecting the outlet of the heat radiator 102 to the suction port of the expander 103, and the flow passage 106d connecting the outlet of the evaporator 104 to the suction port of the second compressor 105. The first bypass valve 113 is provided on the first bypass passage 112, and controls the flow of the working fluid in the first bypass passage 112.

[0030] The upstream end K1 of the first bypass passage 112 is connected to the flow passage 106b, and the downstream end K2 of the first bypass passage 112 is connected to the flow passage 106d. That is, the first bypass passage 112 is a flow passage that allows the working fluid in the flow passage 106b to be drawn directly into the second compressor 105, before the power-recovery shaft 107 is rotated, while bypassing the expander 103 and the evaporator 104.

[0031] As long as the pressure at the suction port of the second compressor 105 can be increased at the time of activation of the refrigeration cycle apparatus 100, the position of the upstream end K1 is not limited to the position shown in Fig. 1. That is, the position of the upstream end K1 of the first bypass passage 112 is not specifically limited, as long as a portion from the discharge port of the first compressor 101 to the suction port of the expander 103 in the working fluid circuit 106 and a portion from the outlet of the evaporator 104 to the suction port of the second compressor 105 in the working fluid circuit 106 can be communicated with each other. Specifically, the first bypass passage 112 may be connected to the working fluid circuit 106 in such a way as to communicate between the flow passage 106a connecting the discharge port of the first compressor 101 to the inlet of the heat radiator 102, and the flow passage 106d connecting the outlet of the evaporator 104 to the suction port of the second compressor 105. Depending on the case, the first bypass passage 112 may be branched from the heat radiator 102. For example, in the case where the heat radiator 102 is composed of an upstream part and a downstream part, the first bypass passage 112 can be easily branched from a portion between these two parts.

[0032] The first bypass valve 113 is provided in the upstream end section of the first bypass passage 112. The "upstream end section" corresponds to a section defined between the upstream end K1 and the point of $L_1/4$ from the upstream end K1 toward the downstream end K2, when the full length of the first bypass passage 112 is referred to as L_1. However, the position of the first bypass valve 113 is not specifically limited, and may be provided in the downstream end section of the first bypass passage 112, for example. The "downstream end section" corresponds to a section defined between the downstream end K2 and the point of $L_1/4$ from the downstream end K2 toward the upstream end K1. The first bypass valve 113 used in Embodiment 1 is an on-off valve, though it is not limited thereto. In the case where the first bypass valve 113 is provided at the upstream end K1 or the downstream end K2, a three-way valve can be used as the first bypass valve 113. The use of a three-way valve is advantageous in that the number of pipe connections can be reduced.

[0033] The refrigeration cycle apparatus 100 is further provided with an activation assist valve 114 provided on the working fluid circuit 106 at a point that is located between the outlet of the evaporator 104 and the suction port of the second compressor 105, and that is closer to the evaporator 104 than the downstream end K2 of the first bypass passage 112 is. The activation assist valve 114 controls the flow of the working fluid in the flow passage 106d. An on-off valve can be used as the activation assist valve 114.

[0034] Upon opening the first bypass valve 113, the working fluid in the flow passage 106b is allowed to flow directly into the suction port of the second compressor 105 through the first bypass passage 112. At that time, the working fluid can be prevented from flowing, from the evaporator 104 into the second compressor 105, by closing the activation assist valve 114.

[0035] The refrigeration cycle apparatus 100 is further provided with a second bypass passage 110 and a second bypass valve 111. The second bypass passage 110 is connected to the working fluid circuit 106 so as to communicate between the flow passage 106c connecting the discharge port of the expander 103 to the inlet of the evaporator 104, and the flow passage 106e connecting the discharge port of the second compressor 105 to the suction port of the first compressor 101. That is, the second bypass passage 110 bypasses the evaporator 104 and the second compressor 105. The second bypass valve 111 is provided on the second bypass passage 110, and controls the flow of the working fluid in the second bypass passage 110.

[0036] The upstream end H1 of the second bypass passage 110 is connected to the flow passage 106c, and the downstream end H2 of the second bypass passage 110 is connected to the flow passage 106e. That is, the second bypass passage 110 is a flow passage that allows the working fluid in the flow passage 106c to be drawn directly into the first compressor 101, while bypassing the evaporator 104 and the second compressor 105.

[0037] However, as long as the first compressor 101 can draw the working fluid in the evaporator 104 at the time of activation of the refrigeration cycle apparatus 100, the position of the upstream end H1 is not limited to the position shown in Fig. 1. The upstream end H1 may be positioned at any point in the zone from the discharge port of the expander 103 to the downstream end K2 of the first bypass passage 112. That is, the second bypass passage 110 may be connected to the working fluid circuit 106 in such a way as to communicate between a portion from the outlet of the evaporator 104 to the downstream end K2 of the first bypass passage 112 in the working fluid circuit 106 (a part of the flow passage 106d), and a portion from the discharge port of the second compressor 105 to the suction port of the first compressor 101 in the working fluid circuit 106 (flow passage 106e). Depending on the case, the second bypass passage 110 may be branched from the evaporator 104. For example, in the case where the evaporator 104 is composed of an upstream part and a downstream part, the second bypass passage 110 can be easily branched from a portion between these two parts.

[0038] The second bypass valve 111 is provided in the upstream end section of the second bypass passage 110. The "upstream end section" corresponds to a section defined between the upstream end H1 and the point of $L_2/4$ from the upstream end H1 toward the downstream end H2, when the full length of the second bypass passage 111 is referred to as L_2. The second bypass valve 111 may be provided also in the downstream end section of the second bypass passage 111. The "downstream end section" corresponds to a section defined between the downstream end H2 and the point of $L_2/4$ from the downstream end H2 toward the upstream end H1. Although the second bypass valve 111 used in Embodiment 1 is a check valve, it is not limited thereto. An on-off valve or a three-way valve may be used therefor.

[0039] When the pressure at the outlet of the second bypass valve 111 is lower than the pressure at the inlet thereof, the second bypass valve 111 allows the working fluid in the flow passage 106c to flow into the second bypass passage 110. That is, when the pressure in the flow passage 106e is lower than the pressure in the flow passages between the discharge port of the expander 103 and the suction port of the second compressor 105 (the flow passage 106c, the evaporator 104 and the flow passage 106d), the working fluid in the flow passage 106c is allowed to flow directly into the suction port of the first compressor 101 through the second bypass passage 110.

[0040] The refrigeration cycle apparatus 100 is further provided with a controller 117 for controlling opening and closing of the first bypass valve 113 and the activation assist valve 114. The first bypass valve 113 and the activation assist valve 114 are provided respectively with valve opening and closing devices 115 and 116. The valve opening and closing devices 115 and 116 typically are composed of an actuator for actuating valves such as a solenoid, and are controlled by the controller 117. The controller 117 typically is composed of a microcomputer. An input apparatus 118 provided with an activation button is connected to the controller 117. Upon input of an operation command to the controller 117 through the input apparatus 118, a specific control program stored in the internal memory of the controller 117 is executed. For example, by turning on the activation button, an activation command (activation signal) is transmitted from the input apparatus 118 to the controller 117. In response to the reception of the activation command, the controller 117 performs a specific activation control to be described later with reference to Fig. 2. Further, the controller 117 controls the operation of the motor 101b that drives the first compressor 101.

[0041] The refrigeration cycle apparatus 100 is further provided with an activation detector 119 for detecting that the second compressor 105 has been activated. The activation detector 119 transmits the detection signal to the controller 117. The controller 117 detects the activation of the second compressor 105 on the basis of the acquisition of the detection signal. A temperature detector, a pressure detector, or the like can be used as the activation detector 119. The temperature detector when used as the activation detector 119, for example, includes a temperature detecting element such as a thermocouple and a thermistor, and detects the difference ΔT between the temperature of the working fluid to be drawn into the expander 103 and the temperature of the working fluid discharged from the expander 103. The pressure detector when used as the activation detector 119, for example, includes a piezoelectric element, and detects the difference ΔP between the pressure of the working fluid to be drawn into the expander 103 and the pressure of the working fluid discharged from the expander 103. Further, a timer for measuring the time elapsed from the time point of the activation of the first compressor 101 may be provided as the activation detector 119 for detecting the activation of the second compressor 105. Such a timer can be provided also as a function of the controller 117. In this case, the controller 117 itself can serve as the activation detector 119. Furthermore, a contact or noncontact displacement sensor for detecting the driving of the power-recovery shaft 107, such as an encoder, may be provided as the activation detector 119 for detecting the activation of the second compressor 105.

[0042] Depending on the type of the activation detector 119, the method for detecting that "the second compressor 105 has been activated" differs as follows.

[0043] In the case of the temperature detector, a specific value T_1 that has been experimentally or theoretically determined is set by the controller 117. The controller 117 detects that "the second compressor 105 has been activated" when the temperature difference ΔT detected by the temperature detector exceeds the specific value T_1.

[0044] In the case of the pressure detector, a specific value P_1 that has been experimentally or theoretically determined is set by the controller 117. The controller 117 detects that "the second compressor 105 has been activated" when the pressure difference ΔP detected by the pressure detector exceeds the specific value P_1.

[0045] The following is the reason why the activation of the second compressor 105 can be detected from the comparison between the temperature difference ΔT and the specific value T_1, or from the comparison between the pressure difference ΔP and the specific value P_1. When the first compressor 101 is activated, the working fluid discharged from the first compressor 101 is supplied to the suction port of the second compressor 105 through the first bypass passage 112. This activates the power recovery system 108. At this time, the second compressor 105 serves as a driving source, and therefore the power recovery system 108 starts rotating before a large temperature difference is made between the suction temperature of the first compressor 101 and the discharge temperature of the first compressor 101. At the time of activation of the rotation of the power recovery system 108, the pressure difference in the refrigeration cycle apparatus 100 has not yet become large enough, and thus the power to rotate the power recovery system 108 is low. Therefore, the rotation rate of the power recovery system 108 also is low. When the rotation rate of the power recovery system 108 is low, the rotation rate of the expander 103 also is low. This state corresponds to the "narrow state" in terms of the expansion valve. Accordingly, the discharge temperature and the discharge pressure of the first compressor 101 gradually increase as well.

[0046] As the discharge temperature and the discharge pressure of the first compressor 101 increase, the power to rotate the expander 103 and the second compressor 105 also increases, so that the rotation rate of the power recovery system 108 becomes high. Then, once a high rotation rate is achieved, the power recovery system 108 stably rotates under the influence of the inertial force. It is desirable that the first bypass passage 112 is kept open until such a stable rotation state is achieved.

[0047] On the other hand, the suction temperature of the expander 103 gradually increases from substantially the same temperature as the outdoor air temperature at the stopped state. The discharge temperature (or discharge pressure) of the expander 103 depends on the suction temperature (or suction pressure) of the expander 103. For example, supposing that the outdoor air temperature is 10°C, the suction temperature, the discharge temperature, the suction pressure and the discharge pressure of the expander 103 at the time of activation of the power recovery system 108 and in the regular operation of the power recovery system 108 each are shown as follows. It should be noted that the following values are calculated with an expansion ratio = 2.0.

<At the time of activation>

[0048]

Suction temperature: 10°C
Suction pressure: 5.0 MPa
Discharge temperature: -3.0°C
Discharge pressure: 3.2 MPa
Difference between suction temperature and discharge temperature: 13°C
Difference between suction pressure and discharge pressure: 1.8 MPa

<In regular operation>

[0049]

Suction temperature: 40°C
Suction pressure: 10.0 MPa
Discharge temperature: 13.4°C
Discharge pressure: 4.9 MPa
Difference between suction temperature and discharge temperature: 26.6°C
Difference between suction pressure and discharge pressure: 5.1 MPa

[0050] When the power recovery system 108 is activated in the state where the discharge temperature and the discharge pressure of the first compressor 101 are low, the suction temperature of the expander 103 and the discharge temperature of the expander 103 each gradually increase, as mentioned above. The difference between the suction temperature and the discharge temperature also gradually grows. This also can be applied to the pressure. Therefore, it is possible to detect the activation of the second compressor 105 (the activation of the power recovery system 108) by setting appropriate values as the specific values T_1 and P_1 (for example, slightly larger values than the temperature difference and the pressure difference at the time of activation).
[0051] It also is possible to detect the activation of the second compressor 105 on the basis of the discharge temperature of the expander 103 or the discharge pressure of the expander 103, instead of the temperature difference Δ and the pressure difference ΔT. When the power recovery system 108 is activated, the expander 103 also rotates. After drawing the working fluid, the expander 103 expands the drawn working fluid and discharges it. Therefore, the working fluid discharged from the expander 103 has lower temperature and pressure than before being drawn thereinto. It is possible to determine that the second compressor 105 has been activated, by capturing a sudden change in the temperature (or pressure) as well as monitoring the temperature (or pressure) at the discharge port of the expander 103 in chronological terms.
[0052] In the case of using a timer, a specific time t that has been experimentally or theoretically determined is set by the controller 117. The controller 117 transmits a control signal to the motor 101b of the first compressor 101 and starts measuring the time by the timer. The controller 117 detects that "the second compressor 105 has been activated" when the time measured by the timer exceeds the specific time t.
[0053] The "specific time t" is written in the activation control program to be executed in the controller 117. For example, the time from the time point of the activation of the first compressor 101 to the activation of the second compressor 105 is actually measured under various operational conditions (such as outdoor air temperature). Then, the time from which the activation of the second compressor 105 is determinable in all the operational conditions can be set as the "specific time t". Theoretically, a model of the refrigeration cycle apparatus 100 is constructed, and a pressure difference that is necessary and sufficient to activate the power recovery system 108 is estimated by computer simulation. Then, using parameters such as the volume of the first compressor 101 and the filling amount of the working fluid in the working fluid circuit 106, the initial activation time necessary to produce the estimated pressure difference is calculated. The calculated initial activation time can be set as the "specific time t".

<Operation of refrigeration cycle apparatus 100>

[0054] Fig. 2 is a flow chart of the activation control of the refrigeration cycle apparatus 100. The refrigeration cycle apparatus 100 starts the regular operation after performing the activation control shown in Fig. 2. In an operation standby state, the first compressor 101 is stopped, the first bypass valve 113 is closed, and the activation assist valve 114 is opened. Thus, the pressure of the working fluid in the working fluid circuit 106 is substantially uniform. A fan or a pump for causing a fluid (air or water) that should exchange heat with the working fluid to flow into the heat radiator 102 is actuated after the completion of the activation control. Similarly, a fan or a pump for causing a fluid that should exchange heat with the working fluid to flow into the evaporator 104 also is actuated after the completion of the activation control.

[0055] In step S11, in response to the reception of the activation command from the input apparatus 118, the controller 117 transmits a control signal to the valve opening and closing devices 115 and 116 so that the first bypass valve 113 is opened and the activation assist valve 114 is closed (step S12). This allows the first bypass passage 112 to be opened, and the flow passage 106d to be closed between the outlet of the evaporator 104 and the downstream end K2 of the first bypass passage 112.

[0056] Subsequently, the controller 117 starts supplying power to the motor 101b so that the first compressor 101 is activated (step S13). This allows the working fluid in the flow passage 106e and the second bypass passage 110 to be drawn into the first compressor 101. Here, instead of opening the first bypass valve 113 before the activation of the first compressor 101, it also is possible to open the first bypass valve 113 in response to the activation of the first compressor 101. Similarly, in response to the activation of the first compressor 101, the activation assist valve 114 may be closed. That is, there is no problem as long as the working fluid is allowed to flow in the first bypass passage 112 after the activation of the first compressor 101 and before the rotation of the power-recovery shaft 107.

[0057] Once the first compressor 101 starts drawing the working fluid, the pressure in the flow passage 106e and the second bypass passage 110 decreases. This causes the second bypass valve 111 to be opened, so that the working fluid on the upstream side of the second bypass valve 111, that is, the working fluid in the flow passages from the discharge port of the expander 103 to the activation assist valve 114 (the flow passage 106c, the evaporator 104 and a part of the flow passage 106d) flows into the second bypass passage 110. The working fluid that has flown into the second bypass passage 110 is drawn into the first compressor 101 to be compressed therein, and discharged into the flow passage 106a. Accordingly, the pressure in the flow passages from the discharge port of the expander 103 to the activation assist valve 114 (the flow passage 106c, the evaporator 104 and a part of the flow passage 106d) decreases.

[0058] On the other hand, once the first compressor 101 is activated, the pressure in the flow passages from the discharge port of the first compressor 101 to the suction port of the expander 103 (the flow passage 106a, the heat radiator 102 and the flow passage 106b) increases. The compressed working fluid flows also into the flow passage 106d between the activation assist valve 114 and the suction port of the second compressor 105 through the first bypass passage 112. This causes the pressure in the flow passage from the activation assist valve 114 to the suction port of the second compressor 105 (a part of the flow passage 106d) to increase.

[0059] As a result, as shown in Fig. 6A, the pressure at the suction port of each of the expander 103 and the second compressor 105 is rendered relatively high, and the pressure at the discharge port of each of the expander 103 and the second compressor 105 is rendered relatively low. That is, a pressure difference can be caused not only between the suction port and the discharge port of the expander 103, but also between the suction port and the discharge port of the second compressor 105. The pressure difference of the working fluid acts on each of the expander 103 and the second compressor 105, and thus self-activation of the power recovery system 108 can be easily achieved.

[0060] Upon detecting the activation of the second compressor 105 through the activation detector 119 (step S14), the controller 117 transmits a control signal to the valve opening and closing devices 115 and 116 so that the first bypass valve 113 is closed and the activation assist valve 114 is opened (step S15). Specifically, the controller 117 detects the activation of the second compressor 105 by receiving the detection signal from the activation detector 119, and thereafter closes the first bypass valve 113 and opens the activation assist valve 114. This allows the first bypass passage 112 to be closed, and the flow passage 106d to be opened. After the completion of the activation control, the refrigeration cycle apparatus 100 is transferred to the regular operation in which the working fluid is circulated in the working fluid circuit 106.

[0061] In the transfer to the regular operation, the pressure at the downstream end H2 of the second bypass passage 110 exceeds the pressure at the upstream end H1 thereof due to the increase of the pressure in the second compressor 105. Therefore, the second bypass valve 111 serving as a check valve is closed. The pressure in the flow passage 106e and the second bypass passage 110 on the downstream side of the second bypass valve 111 is higher than the pressure in the flow passage 106c, the evaporator 104 and the flow passage 106d, and thus the second bypass valve 111 is kept closed. This allows the working fluid to be circulated in the working fluid circuit 106 during the regular operation.

[0062] It should be noted that the working fluid in the liquid phase might be drawn into the second compressor 105 at the time of activation of the refrigeration cycle apparatus 100, though it depends also on the conditions such as outdoor air temperature. Therefore, the fluid pressure motor compressor described above can be used suitably as the second compressor 105. This is because the fluid pressure motor compressor allows substantially no volume change of the working fluid to be caused in the working chamber and therefore is capable of accepting the working fluid in a liquid phase to be drawn therein to some extent.

[0063] Further, when the first compressor 101 draws the working fluid in the regular operation, a pressure pulsation might occur in the flow passage 106e on the basis that the working fluid is confined in the compression mechanism 101a. According to Embodiment 1, a part of the second bypass passage 110 (the part from the second bypass valve 111 to the downstream end H2) can function as a buffer space to allow the volume of the flow passage 106e to extend. Therefore, the pulse width of the pressure pulsation that has occurred in the flow passage 106e can be expected to be reduced, resulting in an enhancement in the operational reliability of the refrigeration cycle apparatus 100.

[0064] Similarly, when the second compressor 105 draws the working fluid, a pressure pulsation might occur in the flow passage 106d on the basis that the working fluid is confined in the working chamber of the second compressor 105. According to Embodiment 1, a part of the first bypass passage 112 (the part from the first bypass valve 113 to the downstream end K2) can function as a buffer space to allow the volume of the flow passage 106d to extend. Therefore, the pulse width of the pressure pulsation that has occurred in the flow passage 106d can be expected to be reduced, resulting in an enhancement in the operational reliability of the refrigeration cycle apparatus 100.

[0065] In order to stop the operation of the refrigeration cycle apparatus 100, the rotation rate of the first compressor 101 is progressively reduced, for example. After the first compressor 101 is stopped, the working fluid travels through the first compressor 101, the expander 103 and the second compressor 105, taking sufficient time. Therefore, the pressure difference in the working fluid circuit 106 naturally disappears, so that the pressure becomes substantially uniform to be stabilized. This allows the expander 103 and the second compressor 105 to be stopped naturally.

<Effects of the refrigeration cycle apparatus 100>

[0066] At the time of activation of the refrigeration cycle apparatus 100, the first bypass valve 113 is opened, and the activation assist valve 114 is closed, according to Embodiment 1. Therefore, the working fluid in the flow passages from the discharge port of the first compressor 101 to the suction port of the expander 103 can be supplied to the suction port of the second compressor 105 through the first bypass passage 112. This causes the pressure at the suction port of the second compressor 105 to increase. Further, the working fluid in the flow passages from the discharge port of the expander 103 to the activation assist valve 114 can be supplied directly to the first compressor 101 through the second bypass passage 110 in addition to the working fluid in the flow passage 106e.

[0067] On the other hand, once the first compressor 101 starts drawing the working fluid, the pressure in the flow passage 106e and the second bypass passage 110 on the downstream side of the second bypass valve 111 decreases. This allows the second bypass valve 111 serving as a check valve to be opened. The working fluid in the flow passages from the discharge port of the expander 103 to the activation assist valve 114 flows into the second bypass passage 110, and is drawn into the first compressor 101 together with the working fluid in the second bypass passage 110 and the flow passage 106e.

[0068] As described above, according to the refrigeration cycle apparatus 100, a pressure difference can be caused not only between the suction port and the discharge port of the expander 103 but also between the suction port and the discharge port of the second compressor 105. Therefore, the power recovery system 108 can be activated stably and surely, resulting in an improvement in the reliability of the refrigeration cycle apparatus 100.

Embodiment 2

<Configuration of refrigeration cycle apparatus 200>

[0069] Fig. 3 is a configuration diagram of a refrigeration cycle apparatus 200 in Embodiment 2 of the present invention. As shown in Fig. 3, the refrigeration cycle apparatus 200 differs from Embodiment 1 in that a three-way valve is used as the first bypass valve 201. That is, the first bypass valve 201 functions both as the first bypass valve 113 and the activation assist valve 114 in Embodiment 1. In Embodiment 2, common parts with Embodiment 1 are designated with identical reference numerals, and the detailed description thereof is omitted.

[0070] In Embodiment 2, the first bypass valve 201 is provided at the junction of the downstream end K2 of the first bypass passage 112 and the flow passage 106d. This makes it possible to open and close the first bypass passage 112 and to open and close the flow passage 106d with one valve, easily and conveniently. Specifically, the channel for the working fluid can be switched easily and conveniently between (a) the state where the flow passage 106d is opened, and the first bypass passage 112 is closed (for example, in the regular operation), and (b) the state where the first bypass passage 112 is opened, and the flow passage 106d is closed at the junction with the downstream end K2 of the first bypass passage 112 (for example, in the activation control). Thus, the configuration of the refrigeration cycle apparatus 200 can be simplified in Embodiment 2. The first bypass valve 201 may be provided at the junction of the upstream end K1 of the first bypass passage 112 and the flow passage 106b.

[0071] A valve switching device 202 is provided in the first bypass valve 201. The valve switching device 202 is typically composed of an actuator such as a solenoid, and controlled by the controller 117.

<Operation of refrigeration cycle apparatus 200>

[0072] Fig. 4 is a flow chart of the activation control of the refrigeration cycle apparatus 200. The refrigeration cycle apparatus 200 starts the regular operation after performing the activation control shown in Fig. 4. In an operation standby state, the first compressor 101 is stopped, the flow passage 106d is opened by the first bypass valve 201, and the first bypass passage 112 is closed (the above state (a)). The pressure of the working fluid in the working fluid circuit 106 is substantially uniform.

[0073] In step S21, in response to the reception of the activation command from the input apparatus 118, the controller 117 transmits a control signal to a valve control device 202 so that the state is switched from the above-described state (a) to the state (b) (step S22).

[0074] Subsequently, the controller 117 starts supplying power to the motor 101b so that the first compressor 101 is activated (step S23). This allows the working fluid in the flow passage 106e and the second bypass passage 110 to be drawn into the first compressor 101. The process of step S22 may be carried out in response to the activation of the first compressor 101.

[0075] Once the first compressor 101 starts drawing the working fluid, the pressure in the flow passage 106e and the second bypass passage 110 decreases. This causes the second bypass valve 111 to be opened, so that the working fluid on the upstream side of the second bypass valve 111, that is, the working fluid in the flow passages from the discharge port of the expander 103 to the first bypass valve 201 (the flow passage 106c, the evaporator 104 and a part of the flow passage 106d) flows into the second bypass passage 110. The working fluid that has flown into the second bypass passage 110 is drawn into the first compressor 101 to be compressed therein, and discharged into the flow passage 106a. Accordingly, the pressure in the flow passages from the discharge port of the expander 103 to the first bypass valve 201 (the flow passage 106c, the evaporator 104, a part of the flow passage 106d) also decreases.

[0076] On the other hand, once the first compressor 101 is activated, the pressure in the flow passages from the discharge port of the first compressor 101 to the suction port of the expander 103 (the flow passage 106a, the heat radiator 102 and the flow passage 106b) increases. The compressed working fluid flows also into the flow passage 106d between the first bypass valve 201 and the suction port of the second compressor 105 through the first bypass passage 112. This causes the pressure in the flow passage from the first bypass valve 201 to the suction port of the second compressor 105 (a part of the flow passage 106d) to increase. As is the case of Embodiment 1, the state shown in Fig. 6A is established, and thus self-activation of the power recovery system 108 can be easily achieved.

[0077] Upon detecting the activation of the second compressor 105 through the activation detector 119 (step S24), the controller 117 transmits a control signal to the valve switching device 202 so that the state is switched from the above-described state (b) to the state (a) (step S25). This causes the first bypass valve 201 to be switched, and the first bypass passage 112 to be closed. After the completion of the activation control, the refrigeration cycle apparatus 200 is transferred to the regular operation.

[0078] Also in Embodiment 2, a part of the second bypass passage 110 (the part from the second bypass valve 111 to the downstream end H2) can function as a buffer space to allow the volume of the flow passage 106e to extend. Accordingly, as has been described in Embodiment 1, the pulse width of the pressure pulsation that has occurred in the flow passage 106e can be expected to be reduced, resulting in an enhancement in the operational reliability of the refrigeration cycle apparatus 200.

[0079] Similarly, the first bypass passage 112 can function as a buffer space to allow the volume of the flow passage 106b to extend. Accordingly, the pulse width of the pressure pulsation that has occurred in the flow passage 106b can be expected to be reduced, resulting in an enhancement in the operational reliability of the refrigeration cycle apparatus 200.

<Effects of refrigeration cycle apparatus 200>

[0080] At the time of activation of the refrigeration cycle apparatus 200, the first bypass passage 112 is opened, and the flow passage 106d is closed at the junction with the downstream end K2 of the first bypass passage 112, according to Embodiment 2. Therefore, the working fluid in the flow passages from the discharge port of the first compressor 101 to the suction port of the expander 103 can be supplied to the suction port of the second compressor 105 through the first bypass passage 112. This causes the pressure at the suction port of the second compressor 105 to increase. Further, the working fluid in the flow passages from the discharge port of the expander 103 to the first bypass valve 201 can be supplied directly to the first compressor 101 through the second bypass passage 110 in addition to the working fluid in the flow passage 106e.

[0081] On the other hand, once the first compressor 101 starts drawing the working fluid, the pressure in the flow passage 106e and the second bypass passage 110 on the downstream side of the second bypass valve 111 decreases. This allows the second bypass valve 111 serving as a check valve to be opened. The working fluid in the flow passages from the discharge port of the expander 103 to the first bypass valve 201 flows into the second bypass passage 110, and is drawn into the first compressor 101 together with the working fluid in the second bypass passage 110 and the flow passage 106e.

[0082] Furthermore, according to the refrigeration cycle apparatus 200, the pressure loss of the working fluid due to the evaporator 104 and the second compressor 105 can be avoided, and the pressure decrease of the working fluid to be drawn by the first compressor 101 can be suppressed, at the time of activation. These allow a reduction in the power required to increase the pressure of the working fluid by the first compressor 101.

[0083] As described above, according to the refrigeration cycle apparatus 200, a pressure difference can be caused not only between the suction port and the discharge port of the expander 103 but also between the suction port and the discharge port of the second compressor 105. Therefore, the power recovery system 108 can be activated stably and surely, resulting in an improvement in the reliability of the refrigeration cycle apparatus 200.

Embodiment 3

[0084] Embodiments 1 and 2 are provided with the second bypass passage 110 and the second bypass valve 111. However, these are not always necessary. That is, a refrigeration cycle apparatus 300 with a configuration in which the second bypass passage 110 and the second bypass valve 111 are omitted can be proposed, as shown in Fig. 5.

[0085] According to the refrigeration cycle apparatus 300, the first bypass valve 113 is opened, and the activation assist valve 114 is closed, at the time of activation. In the state where the power recovery system 108 has not been activated, the first compressor 101 can draw only the working fluid in the flow passage 106e. That is, focusing on the amount of the working fluid that the first compressor 101 can draw thereinto, Embodiment 3 may be less advantageous than Embodiments 1 and 2. However, according also to Embodiment 3, a pressure difference can be caused not only between the suction port and the discharge port of the expander 103 but also between the suction port and the discharge port of the second compressor 105 (see Fig. 6A). Accordingly, even if the second bypass passage 110 and the second bypass valve 111 are omitted, the power recovery system 108 can be activated easily and surely.

[0086] Furthermore, it also is possible to omit the activation assist valve 114 in the refrigeration cycle apparatus 300. In that case, a pressure difference is caused only between the suction port and the discharge port of the second compressor 105, as shown in Fig. 6B. However, in the case where the volume of the second compressor 105 is sufficiently larger than the volume of the expander 103, the driving resistance of the second compressor 105 is relatively larger than the driving resistance of the expander 103. Accordingly, the state shown in Fig. 6B is more advantageous for the activation of the power recovery system 108 than the state shown in Fig. 10.

Reference Example

[0087] A refrigeration cycle apparatus 400 shown in Fig. 7 differs from the conventional refrigeration cycle apparatus 500 (see Fig. 9) in the position of the upstream end H1 of the bypass passage 110. Specifically, the upstream end H1 of the bypass passage 110 is positioned on the flow passage 106c connecting the discharge port of the expander 103 to the inlet of the evaporator 104. Except that, the refrigeration cycle apparatus 400 has the same configuration including the method for detecting the activation as the refrigeration cycle apparatus 100 that has been described with reference to Fig. 1, etc.

[0088] According to the refrigeration cycle apparatus 400, as the refrigeration cycle apparatus 500 that has been described with reference to Fig. 9, a pressure difference cannot be caused between the suction port and the discharge port of the second compressor 105. However, the refrigeration cycle apparatus 400 allows the following advantageous effects to be obtained on the basis of the difference in the position of the upstream end H1 of the bypass passage 110. That is, according to the refrigeration cycle apparatus 400, the pressure loss of the working fluid due to the evaporator 104 and the second compressor 105 can be avoided during a constant period before and after the activation, and thereby the pressure decrease of the working fluid to be drawn by the first compressor 101 can be suppressed. These result in a reduction in the power required for the first compressor 101 to increase the pressure of the working fluid, thus making it easy to form a stable operation state more rapidly.

[0089] As shown in Fig. 8A, the working fluid in the liquid phase tends to be retained in a comparatively downstream portion inside the evaporator 4 in the state where the conventional refrigeration cycle apparatus 500 (Fig. 9) is stopped. This can be seen also from the Mollier diagram of Fig. 10. If the refrigeration cycle apparatus 500 is activated in the state where the working fluid in the liquid phase is retained inside the evaporator 4, the working fluid in the vapor phase inside the flow passages 10c and 10d, and the working fluid in the vapor phase inside the evaporator 4 proceed in the first compressor 1 or the second compressor 5, while passing through the inside of the evaporator 4. Since the working fluid travels a comparatively long distance, the pressure loss also is comparatively large. Furthermore, there is a possibility that the working fluid in the liquid phase is drawn into the first compressor 101, and there also is a possibility that the working fluid in the liquid phase serves as a resistance and increases the pressure loss.

[0090] In contrast, according to the refrigeration cycle apparatus 400 of Reference Example, the working fluid in the vapor phase flows back in the evaporator 104, and is drawn directly into the first compressor 101 through the bypass passage 110, as shown in Fig. 8. The working fluid in the liquid phase travels inside the evaporator 104 while being vaporized, and is drawn into the first compressor 101 through the bypass passage 110. Thus, the pressure in the evaporator 104, that is, the suction pressure of the first compressor 101 is maintained substantially constant. The working fluid in the liquid phase never serves as a resistance, and the pressure loss of the working fluid in the vapor phase is comparatively low. Moreover, the possibility that the working fluid in the liquid phase is drawn into the first compressor 101 at the time of activation is low, and therefore stable activation can be achieved.

[0091] The refrigeration cycle apparatus 100 and 200 of Embodiments 1 and 2 also are provided with the bypass passage 110, and therefore the above-mentioned effects can be obtained at the time of activation.

INDUSTRIAL APPLICABILITY

[0092] The refrigeration cycle apparatus of the present invention is useful as equipments such as water heaters, air conditioners, dryers, etc.

Claims

1. A refrigeration cycle apparatus comprising:

a working fluid circuit formed of a first compressor for compressing a working fluid, a heat radiator for cooling the working fluid compressed by the first compressor, an expander for expanding the working fluid cooled by the heat radiator and recovering power from the working fluid, an evaporator for evaporating the working fluid expanded by the expander, a second compressor for increasing the pressure of the working fluid evaporated by the evaporator and supplying it to the first compressor, and flow passages connecting these components in this order;
a power-recovery shaft coupling the expander to the second compressor so that the second compressor is driven by the power recovered by the expander;
a first bypass passage for communicating between a portion from a discharge port of the first compressor to a suction port of the expander in the working fluid circuit and a portion from an outlet of the evaporator to a suction port of the second compressor in the working fluid circuit; and
a first bypass valve for controlling flow of the working fluid in the first bypass passage, the first bypass valve being provided on the first bypass passage.

2. The refrigeration cycle apparatus according to claim 1, further comprising:

an activation assist valve provided on the working fluid circuit at a point that is located between the outlet of the evaporator and the suction port of the second compressor and that is closer to the evaporator than a downstream end of the first bypass passage is.

3. The refrigeration cycle apparatus according to claim 2, wherein
the first bypass valve is provided in an upstream end section or a downstream end section of the first bypass passage.

4. The refrigeration cycle apparatus according to claim 2 or 3, wherein
the first bypass valve is an on-off valve or a three-way valve.

5. The refrigeration cycle apparatus according to any one of claims 1 to 4, further comprising:

a second bypass passage for communicating between a portion from a discharge port of the expander to a downstream end of the first bypass passage in the working fluid circuit and a portion from a discharge port of the second compressor to a suction port of the first compressor in the working fluid circuit.

6. The refrigeration cycle apparatus according to claim 5, further comprising:

a second bypass valve for controlling flow of the working fluid in the second bypass passage, the second bypass valve being provided on the second bypass passage.

7. The refrigeration cycle apparatus according to any one of claims 2 to 4, wherein
the first bypass valve is opened before activation of the first compressor or in response to the activation of the first compressor.

8. The refrigeration cycle apparatus according to any one of claims 2 to 4, wherein the first bypass valve is closed after activation of the second compressor.

9. The refrigeration cycle apparatus according to claim 8, further comprising:

an activation detector for detecting the activation of the second compressor; and
a controller for controlling opening and closing of the first bypass valve, wherein
the controller detects the activation of the second compressor by receiving a detection signal from the activation detector, and closes the first bypass valve.

10. The refrigeration cycle apparatus according to claim 9, wherein
the activation detector is a temperature detector for detecting a difference between a temperature of the working fluid to be drawn into the expander and a temperature of the working fluid discharged from the expander, and
the activation of the second compressor is detected when the temperature difference exceeds a specific value.

11. The refrigeration cycle apparatus according to claim 9, wherein
the activation detector is a pressure detector for detecting a difference between a pressure of the working fluid to be drawn into the expander and a pressure of the working fluid discharged from the expander, and
the activation of the second compressor is detected when the pressure difference exceeds a specific value.

12. The refrigeration cycle apparatus according to claim 9, wherein
the activation detector is a timer for measuring time elapsed from a time point of activation of the first compressor, and
the activation of the second compressor is detected when the time measured by the timer exceeds a specific time.

13. The refrigeration cycle apparatus according to claim 2, wherein
the activation assist valve is closed before activation of the first compressor, or in response to the activation of the first compressor.

14. The refrigeration cycle apparatus according to claim 2, wherein
the activation assist valve is opened after activation of the second compressor.

15. The refrigeration cycle apparatus according to claim 14, further comprising:

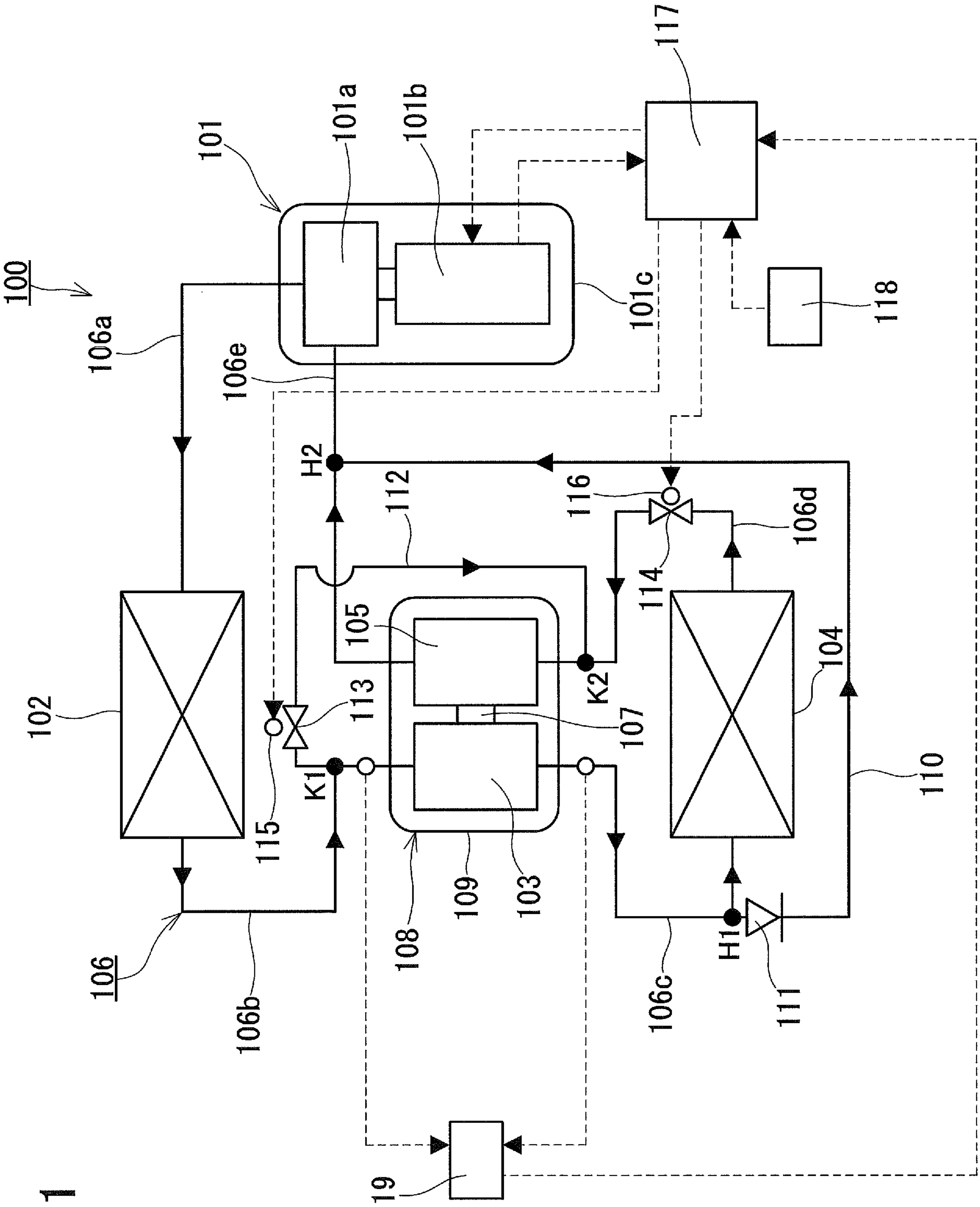
an activation detector for detecting the activation of the second compressor; and
a controller for controlling opening and closing of the activation assist valve, wherein
the controller detects the activation of the second compressor by receiving a detection signal from the activation detector, and opens the activation assist valve.

16. The refrigeration cycle apparatus according to claim 15, wherein
the activation detector is a temperature detector for detecting a difference between a temperature of the working fluid to be drawn into the expander and a temperature of the working fluid discharged from the expander, and
the activation of the second compressor is detected when the temperature difference exceeds a specific value.

17. The refrigeration cycle apparatus according to claim 15, wherein
the activation detector is a pressure detector for detecting a difference between a pressure of the working fluid to be drawn into the expander and a pressure of the working fluid discharged from the expander, and
the activation of the second compressor is detected when the pressure difference exceeds a specific value.

18. The refrigeration cycle apparatus according to claim 15, wherein
the activation detector is a timer for measuring time elapsed from a time point of activation of the first compressor, and
the activation of the second compressor is detected when the time measured by the timer exceeds a specific time.

19. The refrigeration cycle apparatus according to any one of claims 1 to 18, wherein
the expander and the second compressor are accommodated in a single closed casing.


100
101
101a
101b
101c
102
103
104
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106
106a
106b
106c
106d
106e
107
108
109
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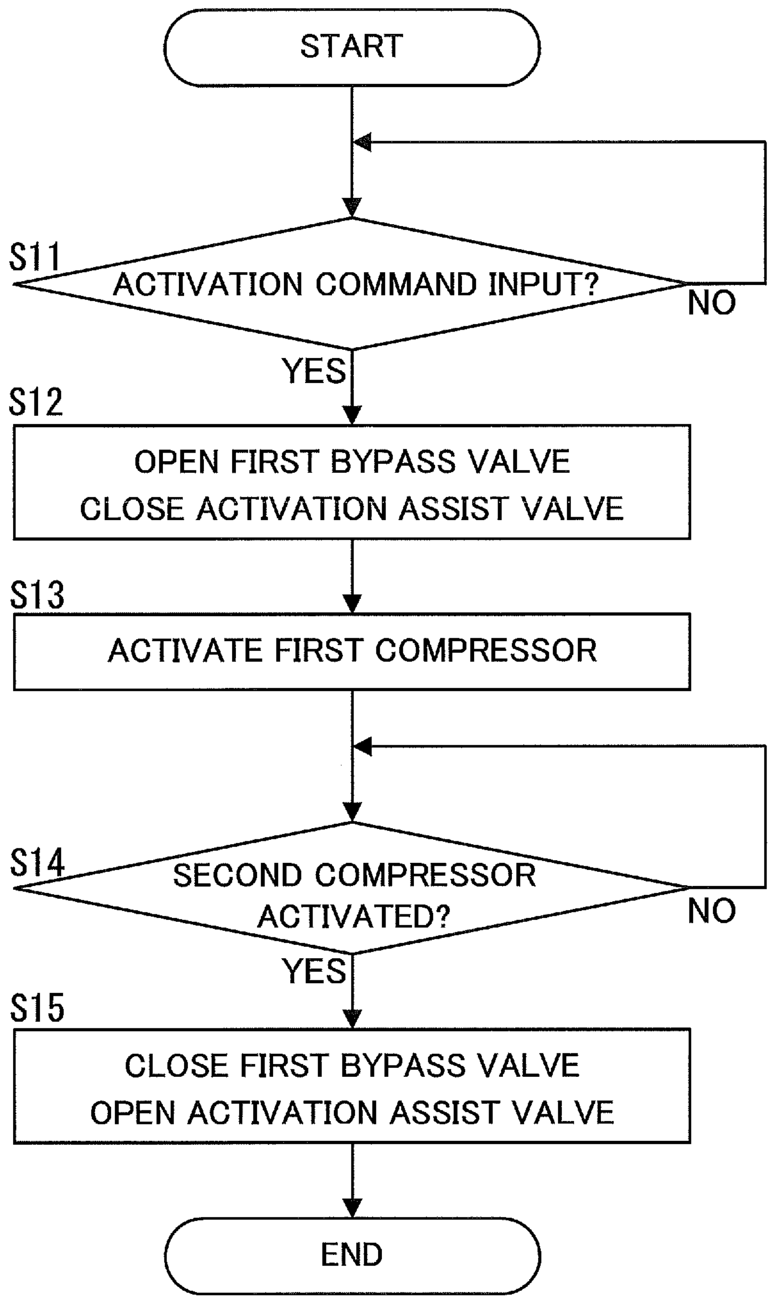
111
112
113
114
115
116
117
118
119
H1
H2
K1
K2

FIG.1

FIG.2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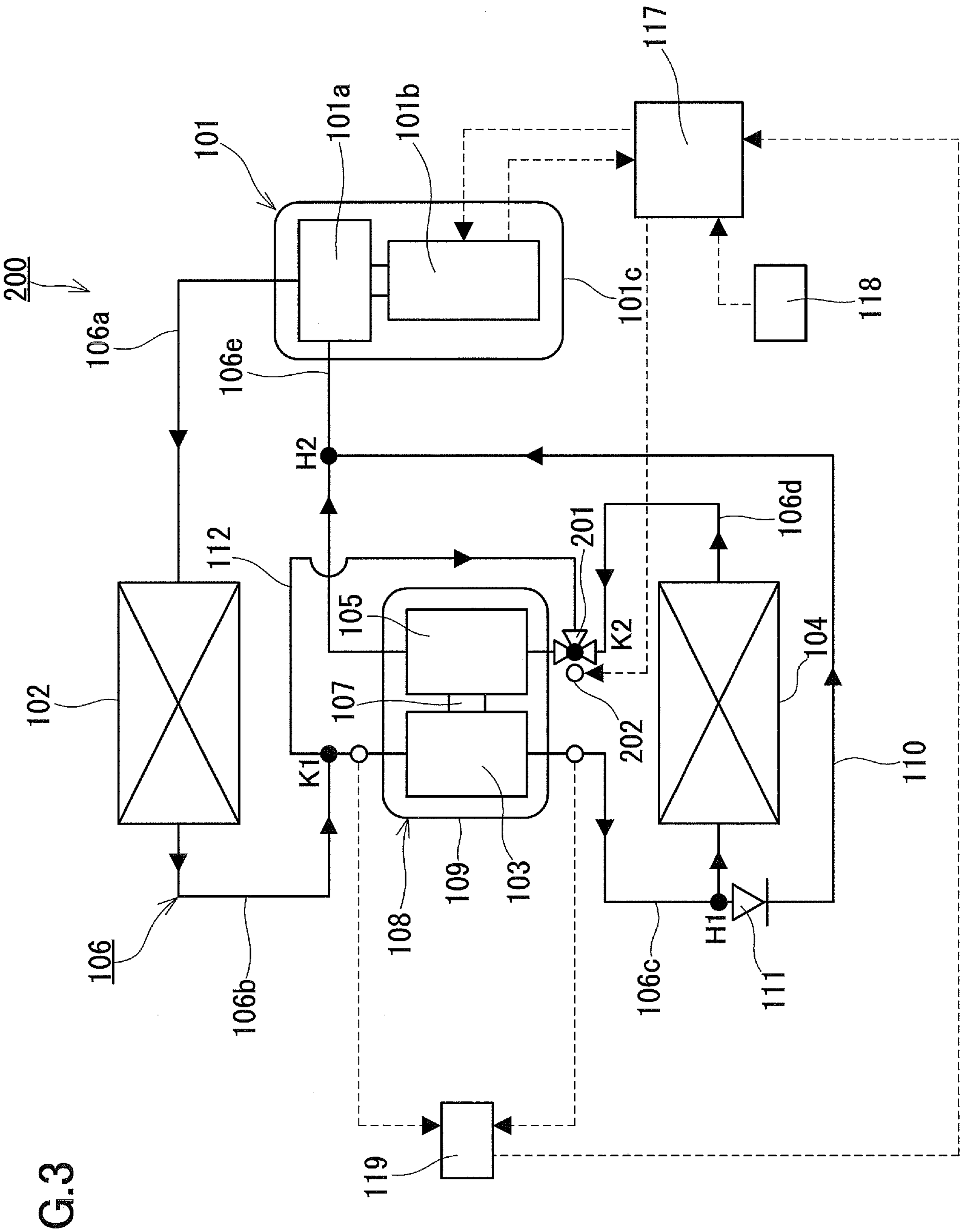
S11
ACTIVATION COMMAND INPUT?
NO
YES
S12
OPEN FIRST BYPASS VALVE
CLOSE ACTIVATION ASSIST VALVE
S13
ACTIVATE FIRST COMPRESSOR
S14
SECOND COMPRESSOR ACTIVATED?
NO
YES
S15
CLOSE FIRST BYPASS VALVE
OPEN ACTIVATION ASSIST VALVE
END


200
101
101a
101b
101c
117
118
106a
106e
H2
112
201
106d
105
K2
102
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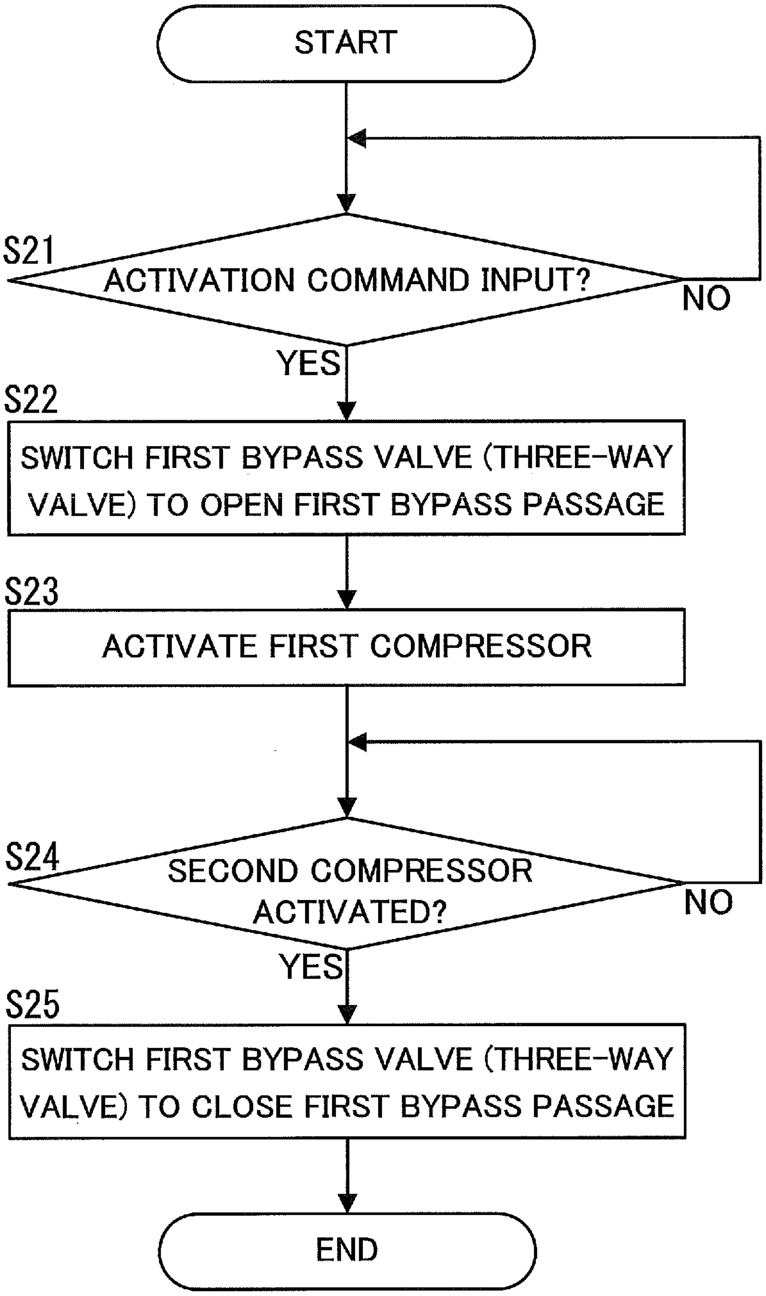
H1
106c
111
119

FIG.3

FIG.4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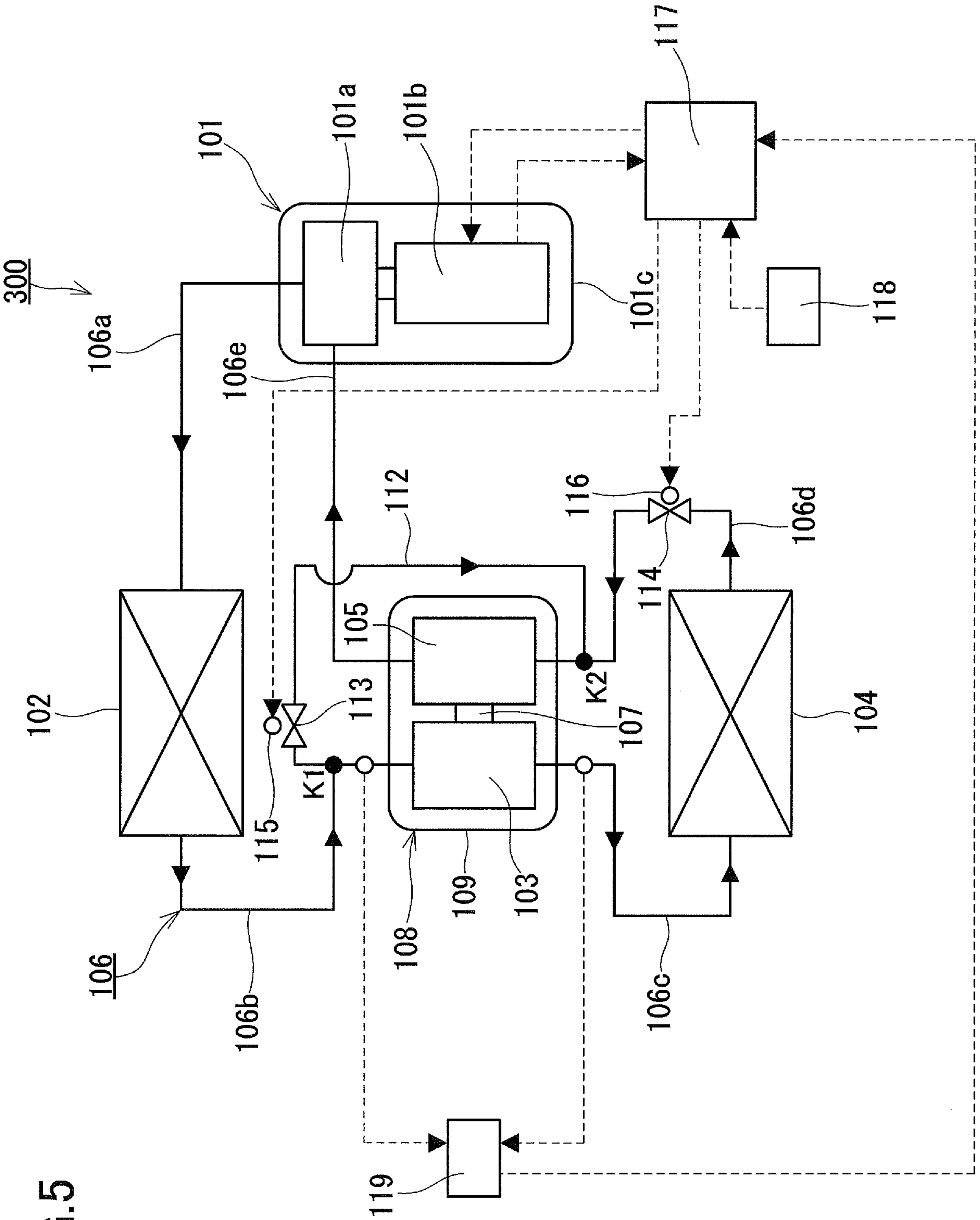
S21
ACTIVATION COMMAND INPUT?
NO
YES
S22
SWITCH FIRST BYPASS VALVE (THREE-WAY VALVE) TO OPEN FIRST BYPASS PASSAGE
S23
ACTIVATE FIRST COMPRESSOR
S24
SECOND COMPRESSOR ACTIVATED?
NO
YES
S25
SWITCH FIRST BYPASS VALVE (THREE-WAY VALVE) TO CLOSE FIRST BYPASS PASSAGE
END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101
101a
101b
101c
117
118
106a
106e
112
116
106d
114
102
105
113
K2
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115
K1
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108
106
106b
106c
119

FIG.5

FIG.6A

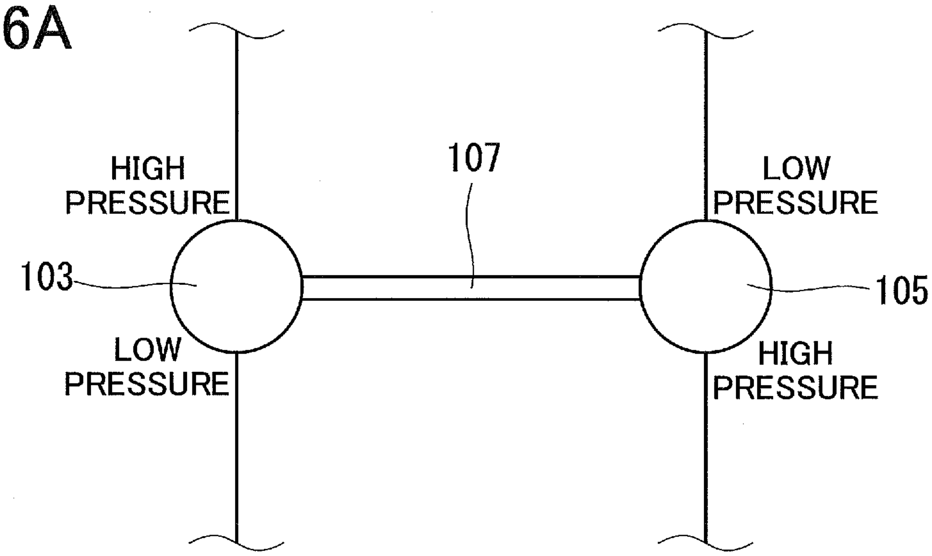
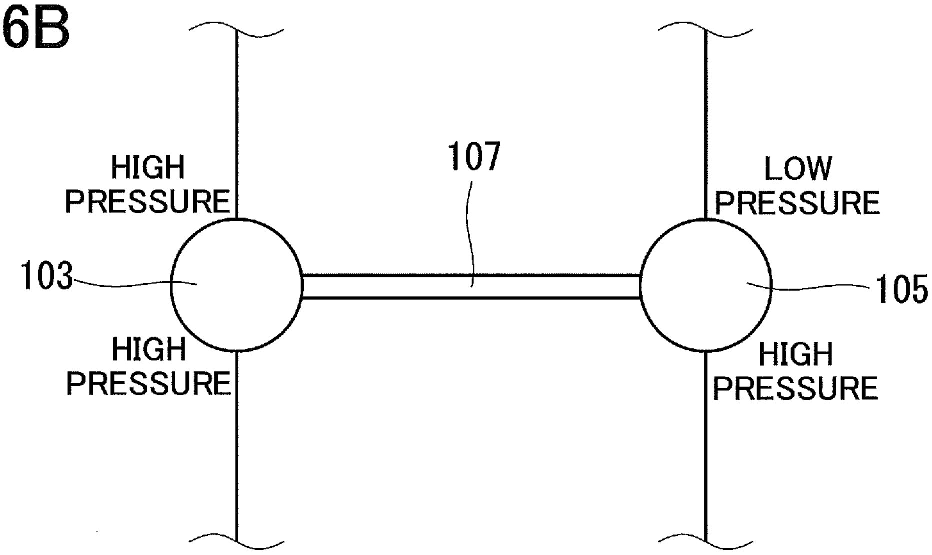

107
HIGH PRESSURE
LOW PRESSURE
103
105
LOW PRESSURE
HIGH PRESSURE

FIG.6B


107
HIGH PRESSURE
LOW PRESSURE
103
105
HIGH PRESSURE
HIGH PRESSURE

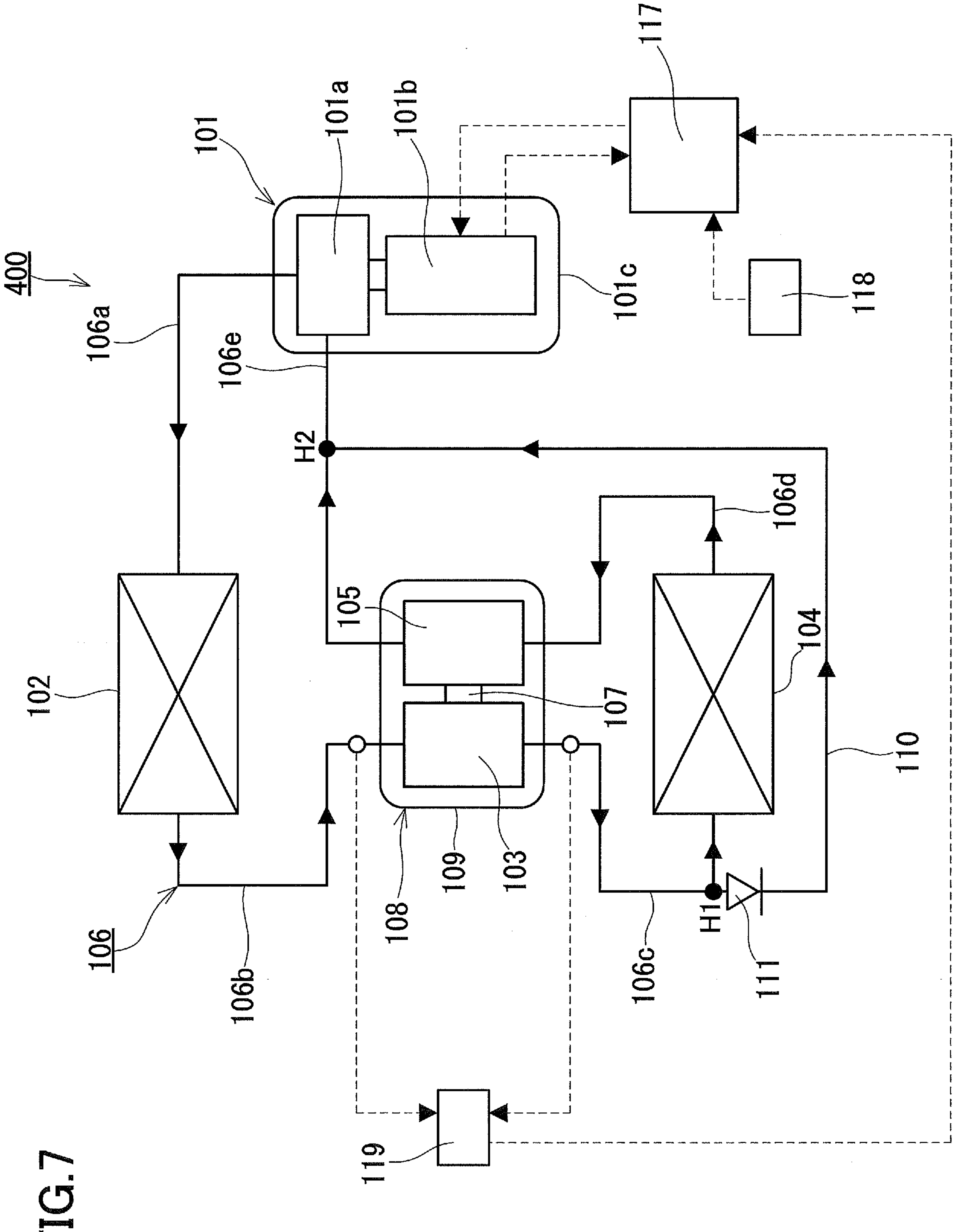

400
101
101a
101b
101c
117
118
106a
106e
H2
106d
102
105
107
104
110
103
109
108
106
106b
106c
H1
111
119

FIG.7

FIG.8A

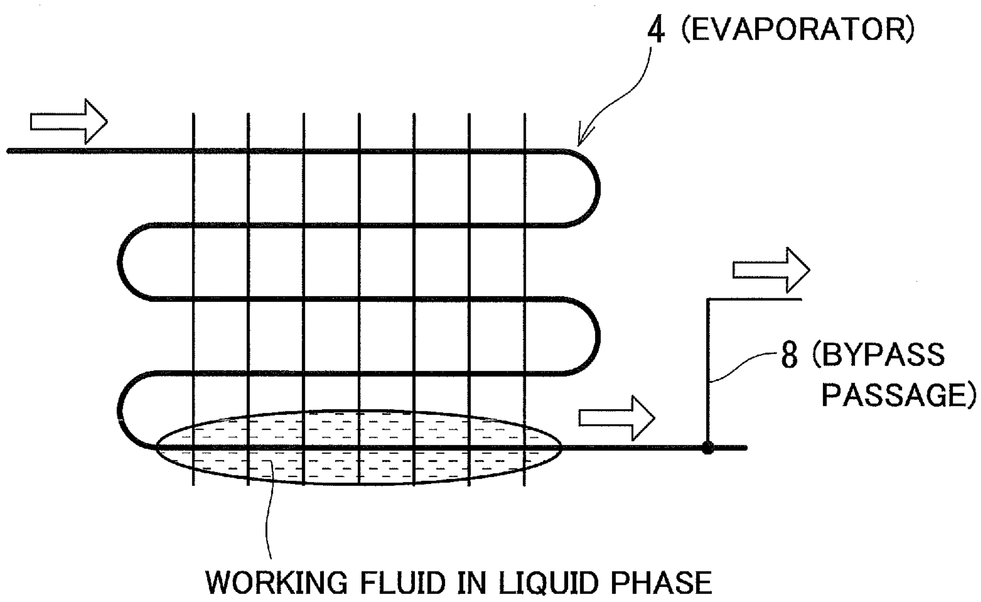

4 (EVAPORATOR)
8 (BYPASS PASSAGE)
WORKING FLUID IN LIQUID PHASE

FIG.8B

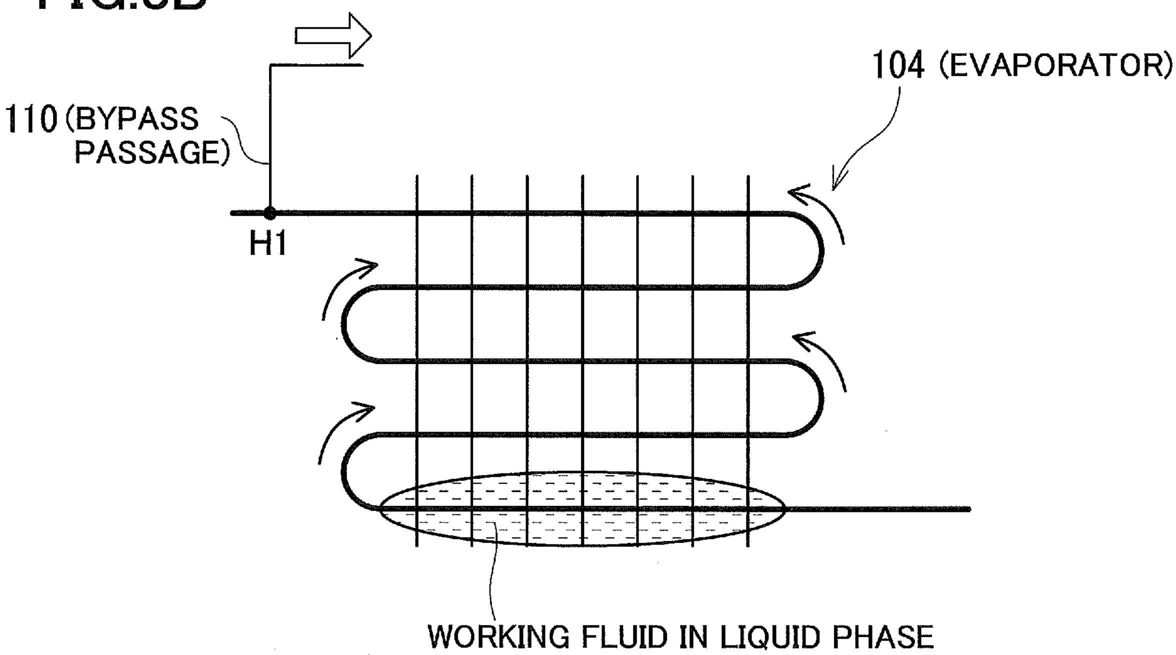

104 (EVAPORATOR)
110 (BYPASS PASSAGE)
H1
WORKING FLUID IN LIQUID PHASE

FIG.9

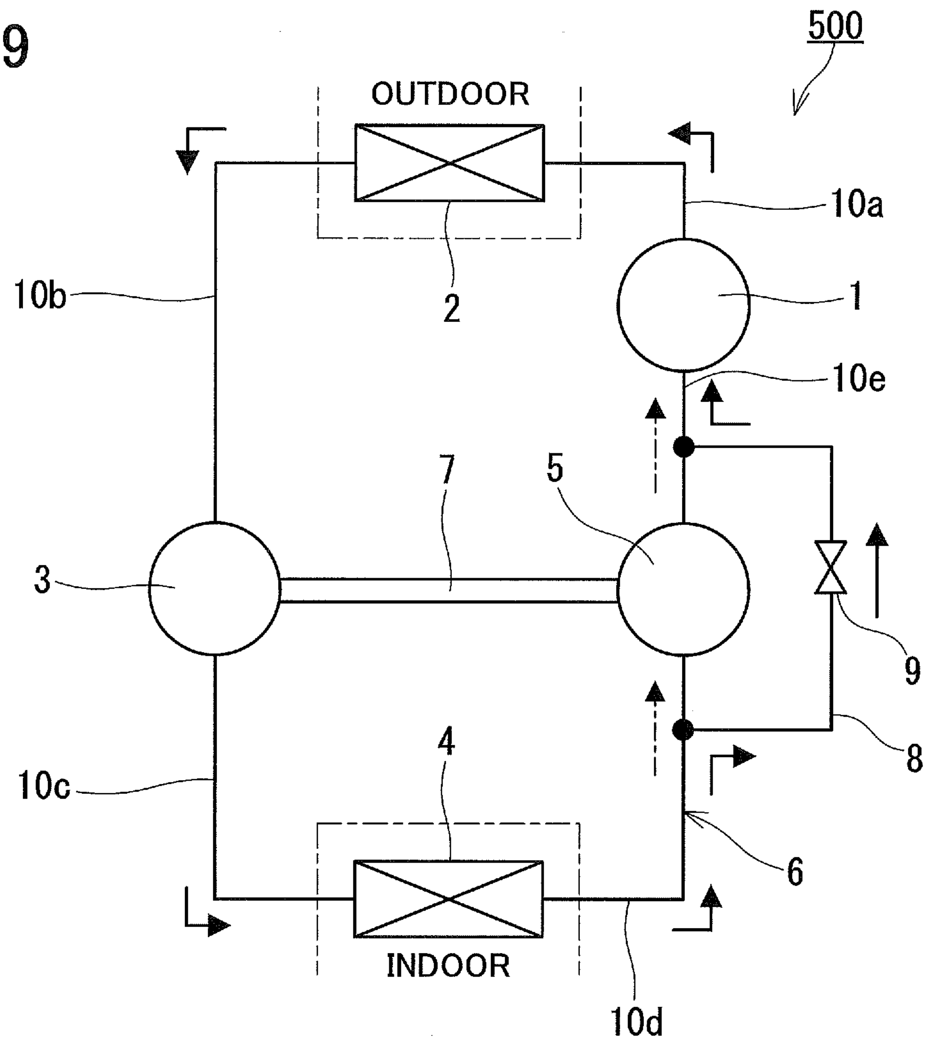


FIG.10

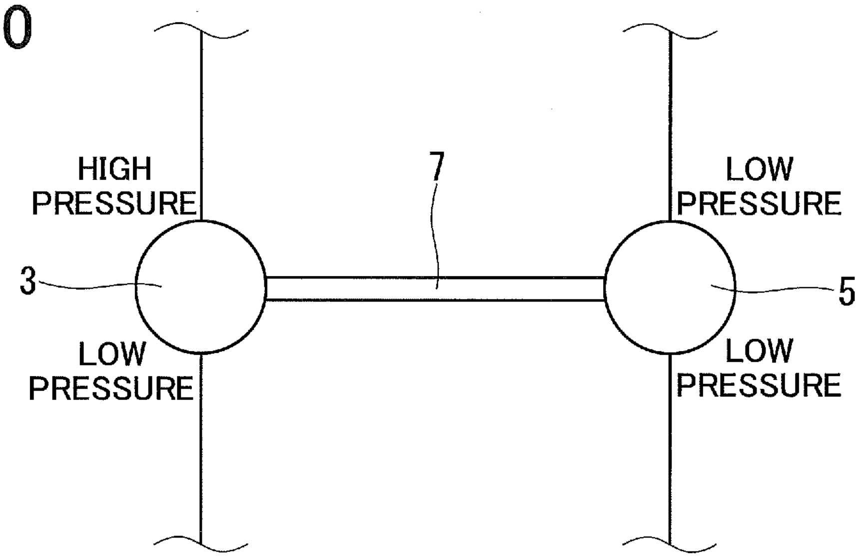
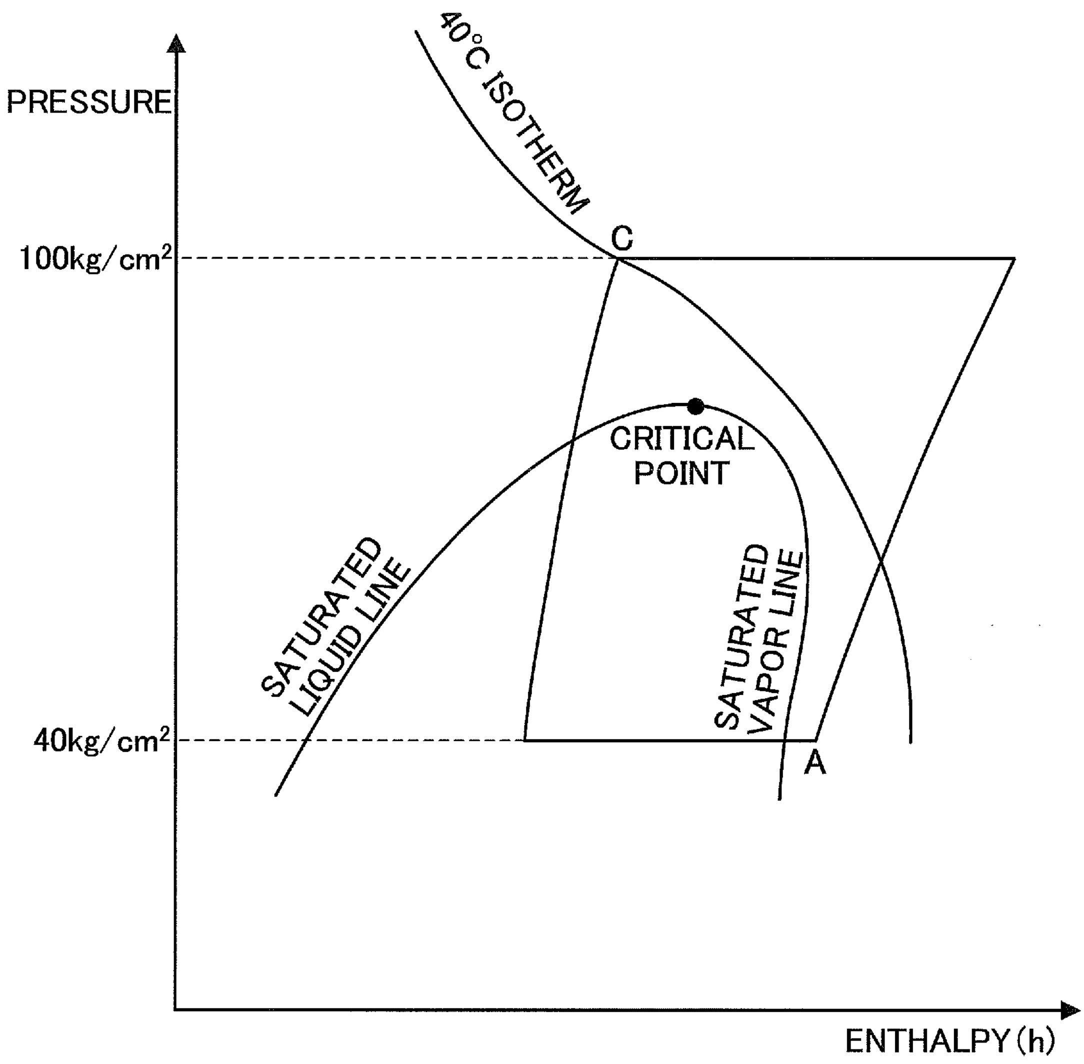


FIG.11



CO_2 Mollier diagram

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/007066

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, *F25B1/10*(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, F25B1/10

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2006-71257 A (Daikin Industries, Ltd.), 16 March 2006 (16.03.2006), fig. 1 to 4; paragraphs [0030] to [0044] & WO 2006/013970 A1	1,5,6,19 2-4,7-18
Y A	JP 3-286968 A (Aisin Seiki Co., Ltd.), 17 December 1991 (17.12.1991), fig. 1; page 4, upper left column, line 1 to page 5, upper right column, line 6 & US 5131235 A	1,5,6,19 2-4,7-18
A	JP 2004-251558 A (Matsushita Electric Industrial Co., Ltd.), 09 September 2004 (09.09.2004), entire text; all drawings (Family: none)	1-19

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

☐ See patent family annex.

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search
17 February, 2010 (17.02.10)

Date of mailing of the international search report
02 March, 2010 (02.03.10)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2009/007066

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 2007-155277 A (Valeo Thermal Systems Japan Corp.), 21 June 2007 (21.06.2007), entire text; all drawings (Family: none)	1-19

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003307358 A **[0002] [0006]**
- WO 2008050654 A **[0024]**