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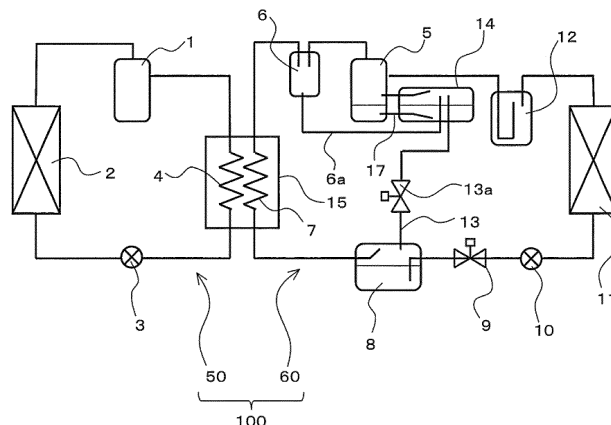
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(54) **REFRIGERATION DEVICE**

(57) A refrigeration apparatus 100 includes a first refrigerant circuit 50 having a first evaporator 4, a second refrigerant circuit 60 having a second condenser 7, and a cascade condenser 15 formed by the first evaporator 4 and the second condenser 7. The second refrigerant circuit 60 of the refrigeration apparatus 100 includes a receiver 8, a tank 14, a bypass 13, and a bypass valve 13a. The receiver is disposed between the second condenser 7 and a second expansion valve 10. The tank 14 is connected to a second compressor 5 and stores excess refrigerating machine oil 18 in the second compressor 5 so as to adjust the amount of refrigerating machine oil 18 in the second compressor 5. The bypass 13 connects the receiver 8 and the tank 14 to each other. The bypass valve 13a is disposed in the bypass 13, opens the bypass 13 when a high-side pressure in the second refrigerant circuit 60 increases to a predetermined pressure or more, and closes the bypass 13 when the high-side pressure in the second refrigerant circuit 60 decreases to the predetermined pressure or less.

cess refrigerating machine oil 18 in the second compressor 5 so as to adjust the amount of refrigerating machine oil 18 in the second compressor 5. The bypass 13 connects the receiver 8 and the tank 14 to each other. The bypass valve 13a is disposed in the bypass 13, opens the bypass 13 when a high-side pressure in the second refrigerant circuit 60 increases to a predetermined pressure or more, and closes the bypass 13 when the high-side pressure in the second refrigerant circuit 60 decreases to the predetermined pressure or less.

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Description

Technical Field

[0001] The present invention relates to a refrigeration apparatus and, more particularly, to a binary refrigeration apparatus including a first refrigerant circuit having an evaporator, a second refrigerant circuit having a condenser, and a cascade condenser formed by the evaporator and the condenser.

Background Art

[0002] As a typical refrigeration apparatus, a binary refrigeration apparatus has conventionally been proposed. This refrigeration apparatus includes a first refrigerant circuit having an evaporator, a second refrigerant circuit having a condenser, and a cascade condenser formed by the evaporator and the condenser. Another binary refrigeration apparatus of this type has also been proposed in which the second refrigerant circuit is configured so that "an expansion tank 65 is connected to a pipe 20S of the compressor 20 on the suction side via a capillary tube 66, the capillary tube 66 is connected in parallel with a check valve 67, and the direction of the expansion tank 65 is defined as the forward direction of the check valve" (see Patent Literature 1).

[0003] Such a refrigeration apparatus generally quickly collects the refrigerant in the second refrigerant circuit through a check valve during the stop of a compressor of the second refrigerant circuit in order to prevent an increase in pressure of the refrigerant in the second refrigerant circuit. In addition, in the refrigeration apparatus, the refrigerant gradually returns from the expansion tank to the second refrigerant circuit through a pressure reducing unit after the start of the compressor of the second refrigerant circuit in order to reduce the start load of the compressor of the second refrigerant circuit.

Citation List

Patent Literature

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication 2007-303792 (Abstract, Fig. 6)

Summary of Invention

Technical Problem

[0005] In a typical binary refrigeration apparatus, assume that the ambient temperature of a second refrigerant circuit is higher than the saturation temperature of the refrigerant (the saturation temperature of the refrigerant flowing through a circuit portion of the second refrigerant circuit on the high-pressure side) on the high-pressure side of the second refrigerant circuit during the

operation of the refrigeration apparatus. In this case, when a compressor of the second refrigerant circuit stops, the pressure in the second refrigerant circuit increases to a pressure corresponding to the ambient temperature. Then, the typical binary refrigeration apparatus recovers the refrigerant from the second refrigerant circuit to the expansion tank in order to prevent an increase in pressure of the refrigerant in the second refrigerant circuit, as described above.

[0006] In the second refrigerant circuit of the binary refrigeration apparatus during operation, the refrigerant density in a circuit portion on the high-pressure side (a circuit portion from the discharge port of the compressor to the pressure reducing unit) is higher than that in a circuit portion on the low-pressure side (a circuit portion from the pressure reducing unit to the suction port of the compressor). Thus, when the compressor of the second refrigerant circuit stops, the pressure in the circuit portion of the second refrigerant circuit on the high-pressure side is higher than that in the circuit portion of the second refrigerant circuit on the low-pressure side. However, in the typical binary refrigeration apparatus, the expansion tank is connected to a pipe on the suction side of the compressor of the second refrigerant circuit, that is, the circuit portion of the second refrigerant circuit on the low-pressure side. Accordingly, the typical binary refrigeration apparatus has a problem that an abnormal increase in pressure cannot be avoided in the circuit portion of the second refrigerant circuit on the high-pressure side when the compressor of the second refrigerant circuit stops.

[0007] In some cases, an on-off valve (an on-off valve that blocks traffic between the circuit portion of the second refrigerant circuit on the high-pressure side and the circuit portion of the second refrigerant circuit on the low-pressure side) for preventing the refrigerant from flowing into the evaporator at the stop of the compressor of the second refrigerant circuit is provided upstream of the evaporator of the second refrigerant circuit. Such an on-off valve further reduces the area of the passage through which the refrigerant flows from the circuit portion of the second refrigerant circuit on the high-pressure side into the circuit portion of the second refrigerant circuit on the low-pressure side. This often makes it impossible to avoid an abnormal increase in pressure of the refrigerant in the circuit portion of the second refrigerant circuit on the high-pressure side, so the above-described problem becomes more serious.

[0008] In addition, in the binary refrigeration apparatus, even when the compressor of the second refrigerant circuit stops, operating the first refrigerant circuit to cool the second refrigerant circuit makes it possible to avoid an abnormal increase in pressure of the refrigerant in the second refrigerant circuit. Thus, the function of the expansion tank is disabled except for the case where the first refrigerant circuit cannot operate because of, for example, power failures. Thus, since the typical binary refrigeration apparatus includes the expansion tank which may not be used, the cost of the binary refrigeration ap-

paratus increases disadvantageously.

[0009] The present invention has been made to solve at least one of the above-described problems, and has as its object to provide a refrigeration apparatus that can prevent an abnormal increase in pressure of a refrigerant in a circuit portion of a second refrigerant circuit on the high-pressure side when a compressor of the second refrigerant circuit stops.

Solution to Problem

[0010] A refrigeration apparatus according to the present invention includes a first refrigerant circuit, a second refrigerant circuit, a cascade condenser, a receiver, a tank, a bypass, and a first on-off valve. The first refrigerant circuit includes a first compressor, a first condenser, a first pressure reducing unit, and a first evaporator that are sequentially connected to each other by pipes. The second refrigerant circuit includes a second compressor, a second condenser, a second pressure reducing unit, and a second evaporator that are sequentially connected to each other by pipes. The cascade condenser is formed by the first evaporator of the first refrigerant circuit and the second condenser of the second refrigerant circuit. The receiver is connected between the second condenser and the second pressure reducing unit of the second refrigerant circuit and stores an excess refrigerant. The tank is connected to the second compressor of the second refrigerant circuit and stores excess refrigerating machine oil in the second compressor so as to adjust an amount of refrigerating machine oil in the second compressor. The bypass connects the receiver and the tank to each other. The first on-off valve is disposed in the bypass, opens the bypass when a high-side pressure in the second refrigerant circuit increases to not less than a predetermined pressure, and closes the bypass when the high-side pressure in the second refrigerant circuit decreases to not more than the predetermined pressure.

Advantageous Effects of Invention

[0011] In the refrigeration apparatus of the present invention, when the second compressor of the second refrigerant circuit stops so that the high-side pressure in the second refrigerant circuit increases to the predetermined pressure or more, the refrigerant in the second refrigerant circuit flows from the receiver disposed in the circuit portion of the second refrigerant circuit on the high-pressure side through the bypass and the first on-off valve and is stored in the tank. Thus, in the refrigeration apparatus of the present invention, when the second compressor of the second refrigerant circuit stops, an abnormal increase in pressure can be avoided in the circuit portion of the second refrigerant circuit on the high-pressure side.

[0012] In addition, in the refrigeration apparatus of the present invention, the tank serving as an expansion tank of a typical refrigeration apparatus also serves as an oil

tank of the second compressor during the operation of the second refrigerant circuit. Thus, the refrigeration apparatus can prevent failure of the second compressor caused by shortage of refrigerating machine oil.

Brief Description of Drawings

[0013]

[Fig. 1] Fig. 1 is a refrigerant circuit diagram illustrating an exemplary configuration of a refrigeration apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a Mollier chart showing the operating state of the refrigeration apparatus of Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a graph showing the relationship among the refrigerant density, the refrigerant temperature, and the refrigerant pressure of a second refrigerant of Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a graph showing the relationship among the internal volume of each component of a second refrigerant circuit, the amount of refrigerant (the amount of second refrigerant) stored in the component, the refrigerant density in the second refrigerant circuit, and the refrigerant pressure, in the refrigeration apparatus of Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a refrigerant circuit diagram showing a portion near the tank of the second refrigerant circuit of Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a refrigerant circuit diagram illustrating an exemplary configuration of a refrigeration apparatus according to Embodiment 2 of the present invention.

[Fig. 7] Fig. 7 is a refrigerant circuit diagram illustrating an exemplary configuration of a refrigeration apparatus according to Embodiment 3 of the present invention.

Description of Embodiments

Embodiment 1

[0014] Fig. 1 illustrates an exemplary configuration of a refrigerant circuit in a refrigeration apparatus according to Embodiment 1 of the present invention.

[0015] As illustrated in Fig. 1, a refrigeration apparatus 100 of Embodiment 1 is implemented in a binary refrigeration apparatus and includes a first refrigerant circuit 50 and a second refrigerant circuit 60.

[0016] The first refrigerant circuit 50 serves as a refrigerant circuit in which a first refrigerant circulates, and includes a first compressor 1, a first condenser 2, a first expansion valve 3, and a first evaporator 4 that are sequentially connected to each other by pipes. The first compressor 1 draws by suction a low-pressure gas first refrigerant, and compresses the first refrigerant into a

high-pressure gas refrigerant. The first condenser 2 exchanges heat between the first refrigerant compressed into a high-pressure gas refrigerant by the first compressor 1 and a heat exchange object such as air, and compresses the first refrigerant into a high-pressure liquid refrigerant. The first expansion valve 3 expands the first refrigerant condensed into a high-pressure liquid refrigerant in the first condenser 2 and reduces its pressure to obtain a low-pressure, two-phase gas-liquid refrigerant. The first evaporator 4 exchanges heat between the first refrigerant expanded and reduced in pressure into a low-pressure, two-phase gas-liquid refrigerant in the first expansion valve 3, and a second refrigerant flowing through the second condenser 7 of the second refrigerant circuit 60, and evaporates the first refrigerant into a low-pressure gas refrigerant. That is, in the refrigeration apparatus 100 of Embodiment 1, the first evaporator 4 of the first refrigerant circuit 50 and the second condenser 7 of the second refrigerant circuit 60 constitute a cascade condenser 15.

[0017] The first expansion valve 3 corresponds to a first pressure reducing unit of the present invention. The first pressure reducing unit may be implemented using, for example, a capillary tube. The "high pressure" and "low pressure" used for the first refrigerant circuit 50 in the above description, and the "high pressure" and "low pressure" to be used for the first refrigerant circuit 50 in the following description refer to relative pressures of the first refrigerant in the first refrigerant circuit 50, and do not refer to absolute pressures of the first refrigerant.

[0018] The second refrigerant circuit 60 serves as a refrigerant circuit in which a second refrigerant circulates, and includes a second compressor 5, a second condenser 7, a second expansion valve 10, and a second evaporator 11 that are sequentially connected to each other by pipes. The second compressor 5 draws by suction a low-pressure gas second refrigerant, and compresses the second refrigerant into a high-pressure gas refrigerant. The second condenser 7 exchanges heat between the second refrigerant compressed into a high-pressure gas refrigerant in the second compressor 5, and the first refrigerant flowing through the first evaporator 4 of the first refrigerant circuit 50, and condenses the second refrigerant into a high-pressure liquid refrigerant or a high-pressure, two-phase gas-liquid refrigerant. The second expansion valve 10 expands the second refrigerant condensed into a high-pressure liquid refrigerant or a high-pressure, two-phase gas-liquid refrigerant in the second condenser 7, and reduces its pressure to obtain a low-pressure, two-phase gas-liquid refrigerant. The second evaporator 11 exchanges heat between the second refrigerant expanded and reduced in pressure into a low-pressure, two-phase gas-liquid refrigerant in the second expansion valve 10, and a heat exchange object such as air, and evaporates the second refrigerant into a low-pressure gas refrigerant.

[0019] The second expansion valve 10 corresponds to a second pressure reducing unit of the present invention.

The second pressure reducing unit may be implemented using, for example, a capillary tube. The "high pressure" and "low pressure" used for the second refrigerant circuit 60 in the above description, and the "high pressure" and "low pressure" to be used for the second refrigerant circuit 60 in the following description refer to relative pressures of a second refrigerant in the second refrigerant circuit 60, and do not refer to absolute pressures of the second refrigerant.

[0020] The second refrigerant circuit 60 of Embodiment 1 also includes an oil separator 6, a receiver 8, an on-off valve 9, an accumulator 12, a bypass 13, a bypass valve 13a, and a tank 14.

[0021] The oil separator 6 is disposed between the second compressor 5 and the second condenser 7, and separates refrigerating machine oil from the second refrigerant discharged from the second compressor 5. The oil separator 6 includes an oil return pipe 6a. The oil return pipe 6a is connected to the suction port of the second compressor 5, and the refrigerating machine oil separated by the oil separator 6 returns to the suction side of the second compressor 5. The receiver 8 is disposed between the second condenser 7 and the second expansion valve 10, and stores an excess second refrigerant. When the two-phase gas-liquid second refrigerant flows out of the second condenser 7, the receiver 8 separates the second refrigerant into gas and liquid second refrigerants, and supplies the liquid second refrigerant to the second expansion valve 10.

[0022] The on-off valve 9 is disposed between the receiver 8 and the second expansion valve 10, and opens and closes a circuit portion between the receiver 8 and the second expansion valve 10. That is, the on-off valve 9 prevents the second refrigerant from flowing into the second evaporator 11. More specifically, the on-off valve 9 blocks traffic between a circuit portion (a circuit portion from the discharge port of the second compressor 5 to the second expansion valve 10) of the second refrigerant circuit 60 on the high-pressure side, and a circuit portion (a circuit portion from the second expansion valve 10 to the suction port of the second compressor 5) of the second refrigerant circuit 60 on the low-pressure side.

[0023] The on-off valve 9 corresponds to a second on-off valve of the present invention.

[0024] The accumulator 12 is disposed between the second evaporator 11 and the second compressor 5. The accumulator 12 separates the second refrigerant that has flowed out of the second evaporator 11 into gas and liquid second refrigerants, and draws the gas second refrigerant by suction into the second compressor 5, thereby preventing liquid back in the second compressor 5. The accumulator 12 stores an excess second refrigerant. The second refrigerant circuit 60 of Embodiment 1 also includes the receiver 8 to store the excess second refrigerant. Thus, if there is no possibility of occurrence of liquid back in the second compressor 5, the accumulator 12 need not be provided.

[0025] The tank 14 has the same function as that of an

expansion tank of a typical refrigeration apparatus (more specifically a binary refrigeration apparatus). The tank 14 is connected to the receiver 8 by the bypass 13. More specifically, in the refrigeration apparatus 100 of Embodiment 1, the circuit portion of the second refrigerant circuit 60 on the high-pressure side is connected to the tank 14 serving as an expansion tank. The bypass 13 includes the bypass valve 13a that opens and closes the bypass 13. The bypass valve 13a is kept closed (the bypass 13 is kept closed) during normal operation. When the second compressor 5 stops and the pressure of the refrigerant on the high-pressure side of the second refrigerant circuit 60 reaches a predetermined pressure or more, the bypass valve 13a is opened (the bypass 13 is opened). That is, in the refrigeration apparatus 100 of Embodiment 1, when the pressure of the refrigerant on the high-pressure side of the second refrigerant circuit 60 reaches the predetermined pressure or more, the second refrigerant in the second refrigerant circuit 60 is stored in the tank 14.

[0026] The bypass valve 13a corresponds to a first on-off valve of the present invention.

[0027] The predetermined pressure refers to a pressure higher than a high-side pressure (the pressure of the refrigerant in the circuit portion of the second refrigerant circuit 60 on the high-pressure side) expected in normal operation, and a pressure lower than an allowable pressure set to prevent a failure of the second refrigerant circuit 60. The high-side pressure of the refrigerant in the second refrigerant circuit 60 is detected by, for example, a pressure sensor (not shown) provided in the circuit portion of the second refrigerant circuit 60 on the high-pressure side.

[0028] The refrigeration apparatus 100 with the aforementioned configuration operates in the following manner.

[0029] Fig. 2 is a Mollier chart showing the operating state of a refrigeration apparatus according to Embodiment 1 of the present invention.

[0030] The operation of the first refrigerant circuit 50 will be described first. A low-pressure gas first refrigerant (point A) in the first refrigerant circuit 50 is drawn by suction into and compressed in the first compressor 1, transforms into a high-pressure gas refrigerant (point B) in the first refrigerant circuit 50, and is discharged from the first compressor 1. The first refrigerant (point B) discharged from the first compressor 1 flows into the first condenser 2, is cooled and condensed by heat exchange with an object such as air (by heating the heat exchange object such as air), and transforms into a high-pressure liquid first refrigerant (point C) in the first refrigerant circuit 50. The first refrigerant flows out of the first condenser 2 flows into the first expansion valve 3, and is expanded and reduced in pressure into a low-pressure, two-phase gas-liquid refrigerant (point D) in the first refrigerant circuit 50. The first refrigerant that has flowed out of the first expansion valve 3 flows into the first evaporator 4 (the cascade condenser 15), is heated and evaporated by the second refrigerant flowing through the second condenser

7 of the second refrigerant circuit 60 (by cooling the second refrigerant flowing through the second condenser 7 of the second refrigerant circuit 60), and transforms into a low-pressure gas first refrigerant (point A) in the first refrigerant circuit 50. Then, the first refrigerant is drawn by suction into the first compressor 1 again. The first refrigerant circuit 50 repeats the above-mentioned series of operations.

[0031] The operation of the second refrigerant circuit 60 will be described next. A low-pressure gas second refrigerant (point E) in the second refrigerant circuit 60 is drawn by suction into and compressed in the second compressor 5, transforms into a high-pressure gas refrigerant (point F) in the second refrigerant circuit 60, and is discharged from the second compressor 5. Refrigerating machine oil is separated by the oil separator 6 from the second refrigerant (point F) discharged from the second compressor 5, and the resulting second refrigerant flows into the second condenser 7 (the cascade condenser 15), is cooled and condensed by the first refrigerant flowing through the first evaporator 4 of the first refrigerant circuit 50 (by heating the first refrigerant flowing through the first evaporator 4 of the first refrigerant circuit 50) and transforms into a high-pressure liquid second refrigerant (point G) in the second refrigerant circuit 60. Upon flowing out of the second condenser 7, the second refrigerant flows into the second expansion valve 10 through the receiver 8 and the on-off valve 9, is expanded and reduced in pressure, and transforms into a low-pressure, two-phase gas-liquid refrigerant (point H) in the second refrigerant circuit 60. Then, the second refrigerant that has flowed out of the second expansion valve 10 is heated and evaporated by a heat exchange object such as air (by cooling the heat exchange object such as air) and transforms into a low-pressure gas first refrigerant (point E) in the second refrigerant circuit 60. Thereafter, the second refrigerant passes through the accumulator 12, and is drawn by suction into the second compressor 5 again. The second refrigerant circuit 60 repeats the above-mentioned series of operations.

[0032] When the refrigeration apparatus 100 that performs the foregoing operation uses the second evaporator 11 of the second refrigerant circuit 60 as a use-side heat exchanger, that is, the second evaporator 11 cools air in a storage space where an object to be cooled is stored, the capacity of the second evaporator 11 is the product of the enthalpy difference between points H and E and the amount of second refrigerant flowing through the second evaporator 11. When the refrigeration apparatus 100 of Embodiment 1 needs to cool the second evaporator 11, the on-off valve 9 is opened so that the second refrigerant flows into the second evaporator 11 and the second compressor 5 is operated. Similarly, the first refrigerant circuit is operated. When cooling of the second evaporator 11 becomes unnecessary, the on-off valve 9 is closed so that the flow of second refrigerant stops, the second compressor 5 is stopped, and the first refrigerant circuit is also stopped.

[0033] If the ambient temperature of the second refrigerant circuit 60 is higher than the saturation temperature of the refrigerant (the saturation temperature of the second refrigerant flowing through the circuit portion of the second refrigerant circuit 60 on the high-pressure side) on the high-pressure side of the second refrigerant circuit 60 during operation, when the second compressor 5 of the second refrigerant circuit 60 stops, the pressure in the second refrigerant circuit 60 increases to a pressure corresponding to the ambient temperature.

[0034] The refrigeration apparatus 100 of Embodiment 1 is assumed to use, for example, a CO₂ refrigerant as the second refrigerant. It is also assumed that the saturation temperature of the refrigerant on the high-pressure side during the operation of the second refrigerant circuit 60 is lower than a critical temperature (31.1 [degrees C]) of the CO₂ refrigerant. In such a case, the pressure of the refrigerant in the second refrigerant circuit 60 in an OFF state is illustrated in Fig. 3.

[0035] Fig. 3 illustrates the relationship among the refrigerant density, the refrigerant temperature, and the refrigerant pressure of the second refrigerant of Embodiment 1 of the present invention. Referring to Fig. 3, the abscissa indicates the temperature of the second refrigerant, and the ordinate indicates the pressure of the second refrigerant. The lines marked with "150", "230", "260", "350", "400", "450", "500", and "550" in Fig. 3 represent the relationships between the refrigerant temperature and the pressure when the refrigerant density (amount of refrigerant [kg]/volume [m³]) of the second refrigerant is 150 [kg/m³], 230 [kg/m³], 260 [kg/m³], 350 [kg/m³], 400 [kg/m³], 450 [kg/m³], 500 [kg/m³], and 550 [kg/m³], respectively.

[0036] As illustrated in Fig. 3, as the temperature of the second refrigerant increases, the pressure of the second refrigerant also increases. As the refrigerant density of the second refrigerant increases, the pressure of the second refrigerant also increases. If, for example, the refrigerant density of the second refrigerant is about 350 [kg/m³] and its temperature is 60 [degrees C], the pressure of the second refrigerant is 10.894 [MPa].

[0037] Thus, in Embodiment 1, the internal volume of the tank 14 is determined such that the pressure of the refrigerant in the second refrigerant circuit 60 falls within an allowable range even when the second refrigerant circuit 60 stops so that the ambient temperature of the second refrigerant circuit 60 increases and the pressure of the refrigerant in the second refrigerant circuit 60 increases.

[0038] Fig. 4 illustrates the relationship among the internal volume of each component of the second refrigeration circuit, the amount of refrigerant (the amount of second refrigerant) stored in the component, the refrigerant density in the second refrigerant circuit, and the refrigerant pressure in the refrigeration apparatus of Embodiment 1 of the present invention. The internal volume of each component of the second refrigerant circuit 60 illustrated in Fig. 4 is determined assuming a second re-

frigerant circuit 60 exhibiting 10 horsepower ([Hp] = x745.7 [W]). The amount of refrigerant stored in the component of the second refrigerant circuit 60 shown in Fig. 4 refers to the amount of refrigerant stored in the component during the operation of a second refrigerant circuit 60 exhibiting 10 horsepower. The "discharge pipe" illustrated in Fig. 4 refers to a pipe extending from the discharge port of the second compressor 5 to the second condenser. The "liquid pipe" refers to a pipe extending from the second condenser 7 to the second expansion valve 10. The "suction pipe" refers to a pipe extending from the second evaporator 11 to the suction port of the second compressor 5. The pipe extending from the second expansion valve 10 to the second evaporator 11 is short and has an internal volume and a refrigerant storage capacity, which are small and ignored in Fig. 4.

[0039] In the second refrigerant circuit 60 shown in Fig. 4, the total internal volume of the second refrigerant circuit 60 is 0.084 [m³] and the amount of refrigerant is 19.36 [kg], and thus the refrigerant density is 230.6 [kg/m³]. At this refrigerant density, when the ambient temperature is 43 [degrees C], the pressure of the refrigerant in the second refrigerant circuit 60 is about 7.696 [MPa], as illustrated in Fig. 2. In this case, to reduce the pressure of the refrigerant in the second refrigerant circuit 60 to a refrigerant pressure of 6.2 [MPa] or less, which is lower than the allowable pressure (6.2 + α [MPa]), the refrigerant density in the second refrigerant circuit 60 needs to be 150 [kg/m³] or lower. More specifically, when the amount of second refrigerant remains the same in the second refrigerant circuit 60 (when the amount of second refrigerant is kept constant at 19.36 [kg]), the necessary internal volume of the second refrigerant circuit 60 is 0.1291 [m³]. That is, the tank 14 needs to have an internal volume of 0.0451 [m³] (= 0.1291 - 0.084).

[0040] The internal volume of the expansion tank of the typical refrigeration apparatus (binary refrigeration apparatus) is similarly determined.

[0041] As illustrated in Fig. 4, in the second refrigerant circuit 60 during operation, the refrigerant density in a circuit portion on the high-pressure side is higher than that in a circuit portion on the low-pressure side. Thus, when the second compressor 5 of the second refrigerant circuit 60 stops so that the second refrigerant in the second refrigerant circuit 60 increases to almost the ambient temperature, the pressure of the refrigerant in the circuit portion of the second refrigerant circuit 60 on the high-pressure side becomes higher than that in the circuit portion of the second refrigerant circuit 60 on the low-pressure side. This is because in the interval from the outlet of the second condenser 7 (cascade condenser 15) on the high-pressure side to the second expansion valve 10, a liquid second refrigerant flows in large amounts and this results in a high refrigerant density, while in the interval from the outlet of the second evaporator 11 on the low-pressure side to the second compressor 5, a gas second refrigerant flows in large amounts and this results in a low refrigerant density. Thus, in a typical refrigeration

apparatus in which a refrigerant is guided from the circuit portion of the second refrigerant circuit 60 on the low-pressure side to the expansion tank, the pressure of the refrigerant in the circuit portion of the second refrigerant circuit 60 on the high-pressure side is often higher than the allowable pressure of the refrigerant in the second refrigerant circuit. In particular, when, as in Embodiment 1, the on-off valve 9 for opening and closing a circuit portion between the receiver 8 and the second expansion valve 10 is provided, the aforementioned problem is more serious. That is, in this case, when the second compressor 5 stops with the on-off valve 9 being closed, the area of the passage through which the second refrigerant flows from the circuit portion of the second refrigerant circuit 60 on the high-pressure side to the circuit portion of the second refrigerant circuit 60 on the low-pressure side further decreases. This often makes it impossible to avoid an abnormal increase in pressure of the refrigerant in the circuit portion of the second refrigerant circuit 60 on the high-pressure side.

[0042] To solve this problem, the second refrigerant circuit 60 of Embodiment 1 has a configuration in which the tank 14 serving as an expansion tank is connected through the bypass 13 and the bypass valve 13a to the receiver 8 disposed in the circuit portion of the second refrigerant circuit 60 on the high-pressure side. When the pressure of the refrigerant in the high-pressure portion of the second refrigerant circuit 60 increases to a predetermined pressure or more, the bypass valve 13a opens, and the second refrigerant on the high-pressure side flows into the tank 14 on the low-pressure side so that the pressure of the refrigerant on the high-pressure side decreases.

[0043] If the second compressor 5 to which electric power is supplied is stopped in normal operation, the pressure of the refrigerant on the high-pressure side can be reduced by opening the on-off valve 9 so that the refrigerant on the high-pressure side flows to the low-pressure side and the pressure of the refrigerant on the high-pressure side is reduced, or the refrigerant on the high-pressure side of the second refrigerant circuit 60 can be cooled so that the pressure of the refrigerant is reduced by operating the first refrigerant circuit 50. Thus, the bypass valve 13a is preferably operable even in a situation, including a power failure, where the on-off valve 9 and the first refrigerant circuit 50 cannot operate. For this reason, the bypass valve 13a is preferably implemented using an on-off valve that mechanically opens and closes in accordance with the high-side pressure of the refrigerant in the second refrigerant circuit 60.

[0044] In this manner, the tank 14 serves as an expansion tank. That is, the tank 14 is used to keep as low as an allowable pressure or less the pressure of the refrigerant in the second refrigerant circuit 60 when the operation of the second refrigerant circuit 60 stops. However, the tank 14 is rarely used to reduce the pressure of the refrigerant in the refrigerant circuit when the second refrigerant circuit 60 stops because of, for example, a power

failure.

[0045] In view of this, in Embodiment 1, the tank 14 serving as an expansion tank is used as an oil tank in normal operation.

[0046] Fig. 5 is a refrigerant circuit diagram showing a portion near the tank of the second refrigerant circuit of Embodiment 1 of the present invention.

[0047] As illustrated in Fig. 5, since the second compressor 5 and the tank 14 are disposed on, for example, the same bottom surface, the bottoms of the second compressor 5 and the tank 14 are flush with each other. The tank 14 stores refrigerating machine oil 18. The second compressor 5 and the tank 14 are connected to each other by two pipes 17. More specifically, one pipe 17 is set closer to the bottom surface shared between the second compressor 5 and the tank 14, and connects the second compressor 5 to the tank 14 at the position where the refrigerating machine oil 18 is present (e.g., at the position near their bottom surface). The other pipe 17 connects the second compressor 5 to the tank 14 at the position where the refrigerating machine oil 18 is absent (e.g., at the position, including the upper part of the tank 14, where a gas second refrigerant fills a vacant space).

[0048] As illustrated in Fig. 1, the tank 14 is also connected to the oil return pipe 6a of the oil separator 6, and the refrigerating machine oil 18 separated in the oil separator 6 returns into the tank 14.

[0049] In this manner, by connecting the second compressor 5 and the tank 14 to each other, the oil surface (the upper surface of the refrigerating machine oil 18) in the second compressor 5 can be made equal in level to the oil surface in the tank 14. Thus, when the amount of refrigerating machine oil in the second compressor 5 decreases, the refrigerating machine oil is supplied from the tank 14, whereas when the amount of refrigerating machine oil 18 in the second compressor 5 increases (when excess refrigerating machine oil 18 is generated), the refrigerating machine oil 18 is discharged to the tank 14 so that variations in amount of refrigerating machine oil 18 can be adjusted. Accordingly, oil shortage and oil compression due to an increase in amount of oil in the second compressor 5 can be avoided.

[0050] Depending, for example, on the operating conditions and configuration of the second refrigerant circuit 60, the maximum amount of refrigerating machine oil 18 stored in components other than the second compressor 5, that is, the maximum amount of refrigerating machine oil 18 stored in pipes (e.g., the discharge pipe, the liquid pipe, and the suction pipe), the oil separator 6, the second condenser 7, the receiver 8, the second evaporator 11, and the accumulator 12 may be approximately equal to the amount of refrigerating machine oil that can be stored in the second compressor 5 during the operation of the second refrigerant circuit 60. For example, in a second refrigerant circuit 60 exhibiting 10 horsepower ([Hp] = x745.7 [W]) shown in Fig. 4, the amount of refrigerating machine oil that can be stored in the second compressor 5 is about 3 [L]. In this case, depending, for example, on

the operating conditions of the second refrigerant circuit 60, the maximum amount of refrigerating machine oil 18 stored in components other than the second compressor 5 may be about 3 [L]. In view of this, to reliably prevent oil shortage in the second compressor 5, the amount of refrigerating machine oil 18 that can be stored in the tank 14 is preferably two or more times that of refrigerating machine oil 18 that can be stored in the second compressor 5. The bottom surfaces of the second compressor 5 and the tank 14 need not always be flush with each other, and the bottom surface of the tank 14 may be set at a level corresponding to the volume, shape, and oil storage capacity of the tank 14 so as to obtain a target amount of oil stored in the second compressor 5 during the operation of the second compressor 5. Although Fig. 1 illustrates a circuit that returns to the tank 14 the refrigerating machine oil separated by the oil separator 6 of the second refrigerant circuit 60, the destination to which the oil return pipe 6a of the oil separator 6 is connected is not limited to the tank 14 as long as the oil return pipe 6a is connected to a member on the suction side of the second compressor 5.

[0051] In the refrigeration apparatus 100 configured as described above in Embodiment 1, when the second compressor 5 of the second refrigerant circuit 60 stops so that the high-side pressure of the refrigerant in the second refrigerant circuit 60 increases to a predetermined pressure or more, the second refrigerant in the second refrigerant circuit 60 flows from the receiver 8 in the circuit portion of the second refrigerant circuit 60 on the high-pressure side through the bypass 13 and the bypass valve 13a and is stored in the tank 14. Thus, in the refrigeration apparatus 100 configured as described above in Embodiment 1, when the second compressor 5 of the second refrigerant circuit 60 stops, an abnormal increase in pressure can be prevented in the circuit portion of the second refrigerant circuit 60 on the high-pressure side.

[0052] In the refrigeration apparatus 100 configured as described above in Embodiment 1 as well, the tank 14 serving as an expansion tank of a typical refrigeration apparatus also serves as an oil tank of the second compressor 5 during the operation of the second refrigerant circuit 60. Thus, in the refrigeration apparatus 100 configured as described in Embodiment 1, a failure of the second compressor 5 due, for example, to shortage of refrigerating machine oil 18 can be prevented.

Embodiment 2

[0053] Embodiment 1 assumes a refrigeration apparatus 100 in which the second refrigerant circuit 60 includes only one second compressor 5. Alternatively, the second refrigerant circuit 60 may include a plurality of second compressors 5. In such a case, the tank 14 may have the following configuration to suppress an increase in cost of the refrigeration apparatus 100. Details which are not particularly referred to in Embodiment 2 are the

same as in Embodiment 1, and the same reference numerals denote components having the same functions and configurations.

[0054] Fig. 6 is a refrigerant circuit diagram illustrating an exemplary configuration of a refrigeration apparatus according to Embodiment 2 of the present invention.

[0055] Unlike Embodiment 1, a refrigeration apparatus 100 of Embodiment 2 includes a second refrigerant circuit 60 including two second compressors 5. The two second compressors 5 are connected to a tank 14 through pipes 17.

[0056] The configuration of the refrigeration apparatus 100 of Embodiment 2 has the same advantages as those of Embodiment 1.

[0057] Also, the configuration of the refrigeration apparatus 100 of Embodiment 2 implements a refrigeration apparatus equipped with tanks 14 fewer than the number of second compressors 5. Thus, an increase in cost of the refrigeration apparatus 100 can be suppressed.

[0058] In Embodiment 2, the refrigeration apparatus 100 includes the two second compressors 5. Alternatively, the refrigeration apparatus 100 may include three or more second compressors 5, as a matter of course. In this case, all the second compressors 5 may be connected to one tank 14, or a plurality of tanks 14 may be provided and connected to the respective second compressors 5. In providing a plurality of tanks 14, some of them may be connected to one second compressor 5, as a matter of course.

Embodiment 3

[0059] When the second refrigerant circuit 60 also serves as an accumulator, the tank 14 as described in Embodiments 1 and 2 may be replaced with a tank 16, which will be described below. Details which are not particularly referred to in Embodiment 3 are the same as in Embodiment 1 or 2, and the same reference numerals denote components having the same functions and configurations.

[0060] Fig. 7 is a refrigerant circuit diagram illustrating an exemplary configuration of a refrigeration apparatus according to Embodiment 3 of the present invention.

[0061] As in Embodiments 1 and 2, a tank 16 of Embodiment 3 is connected to a second compressor 5 through pipes 17, and is connected to a receiver 8 through a bypass 13 and a bypass valve 13a.

[0062] The tank 16 of Embodiment 3 is also connected to a second evaporator 11 and the suction port of the second compressor 5 through refrigerant pipes. With this arrangement, the tank 16 of Embodiment 3 separates a second refrigerant, upon flowing out of the second evaporator 11, into gas and liquid second refrigerants, and draws the gas second refrigerant by suction into the second compressor 5, thereby preventing liquid back in the second compressor 5.

[0063] That is, the tank 16 of Embodiment 3 implements the functions of both the accumulator 12 as de-

scribed in Embodiments 1 and 2 and the tank 14 as described in Embodiments 1 and 2.

[0064] The configuration of the refrigeration apparatus 100 of Embodiment 3 can have the same advantages as those of Embodiments 1 and 2.

[0065] The configuration of the refrigeration apparatus 100 of Embodiment 3 allows the tank 16 to serve as an accumulator. This obviates the need to separately provide an accumulator to suppress an increase in cost of the refrigeration apparatus 100.

Reference Signs List

[0066] 1 first compressor, 2 first condenser, 3 first expansion valve, 4 first evaporator, 5 second compressor, 6 oil separator, 6a oil return pipe, 7 second condenser, 8 receiver, 9 on-off valve, 10 second expansion valve, 11 second evaporator, 12 accumulator, 13 bypass, 13a bypass valve, 14 tank, 15 cascade condenser, 16 tank, 17 pipe, 18 refrigerating machine oil, 50 first refrigerant circuit, 60 second refrigerant circuit, 100 refrigeration apparatus

Claims

1. A refrigeration apparatus comprising:

a first refrigerant circuit including a first compressor, a first condenser, a first pressure reducing unit, and a first evaporator that are sequentially connected to each other by pipes;

a second refrigerant circuit including a second compressor, a second condenser, a second pressure reducing unit, and a second evaporator that are sequentially connected to each other by pipes;

a cascade condenser formed by the first evaporator of the first refrigerant circuit and the second condenser of the second refrigerant circuit; a receiver that is connected between the second condenser and the second pressure reducing unit of the second refrigerant circuit and stores an excess refrigerant;

a tank that is connected to the second compressor of the second refrigerant circuit and stores excess refrigerating machine oil in the second compressor so as to adjust an amount of refrigerating machine oil in the second compressor; a bypass connecting the receiver and the tank to each other; and

a first on-off valve that is disposed in the bypass, opens the bypass when a high-side pressure in the second refrigerant circuit increases to not less than a predetermined pressure, and closes the bypass when the high-side pressure in the second refrigerant circuit decreases to not more than the predetermined pressure.

2. The refrigeration apparatus of claim 1, wherein the second compressor comprises a plurality of second compressors, and the tank is connected to at least two second compressors of the plurality of second compressors and is used to adjust an amount of refrigerating machine oil in the at least two second compressors of the plurality of second compressors.

3. The refrigeration apparatus of claim 1 or 2, wherein an outlet of the second evaporator is connected to the tank, a portion of the tank located above the refrigerating machine oil is connected to a suction port of the second compressor, and the tank also serves as an accumulator.

4. The refrigeration apparatus of any one of claims 1 to 3, further comprising:

an oil separator disposed between the second compressor and the second condenser; and an oil return pipe which is connected to the oil separator and a pipe extending from one of the tank and a suction port of the compressor.

5. The refrigeration apparatus of any one of claims 1 to 4, wherein the first on-off valve includes an on-off valve that mechanically opens and closes in accordance with the high-side pressure in the second refrigerant circuit.

6. The refrigeration apparatus of any one of claims 1 to 5, further comprising:

a second on-off valve that is disposed between the receiver and the second pressure reducing unit, and opens and closes a circuit portion between the receiver and the second pressure reducing unit.

FIG. 1

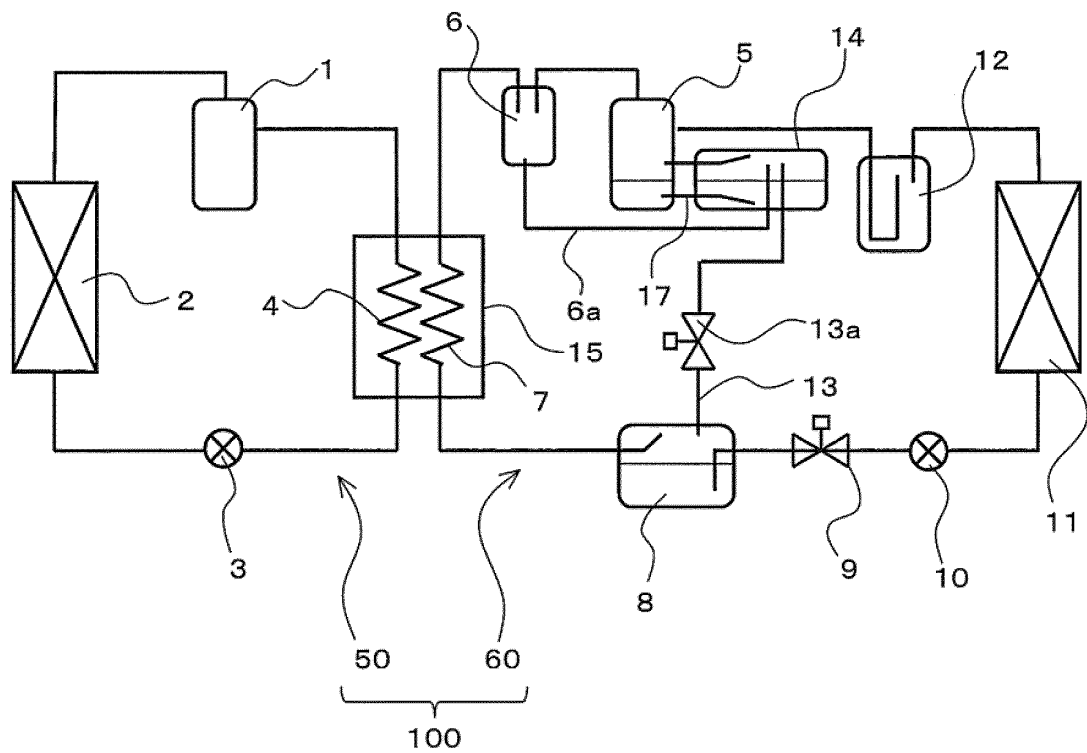


FIG. 2

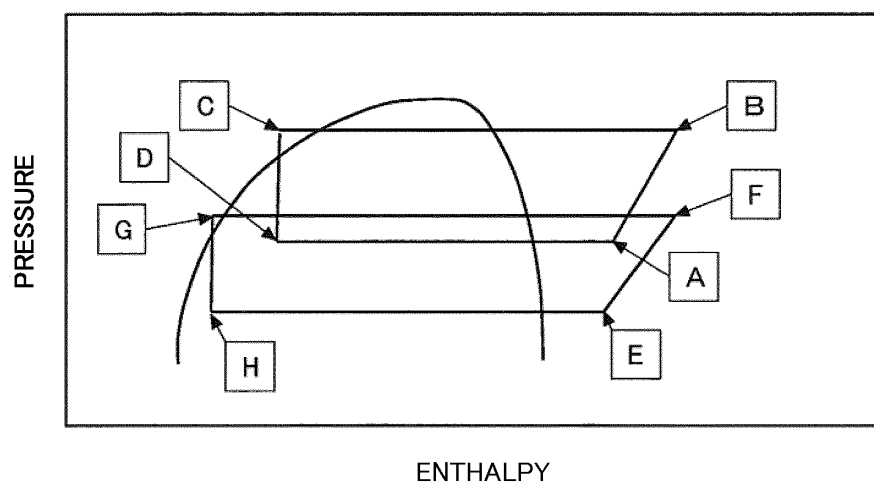


FIG. 3

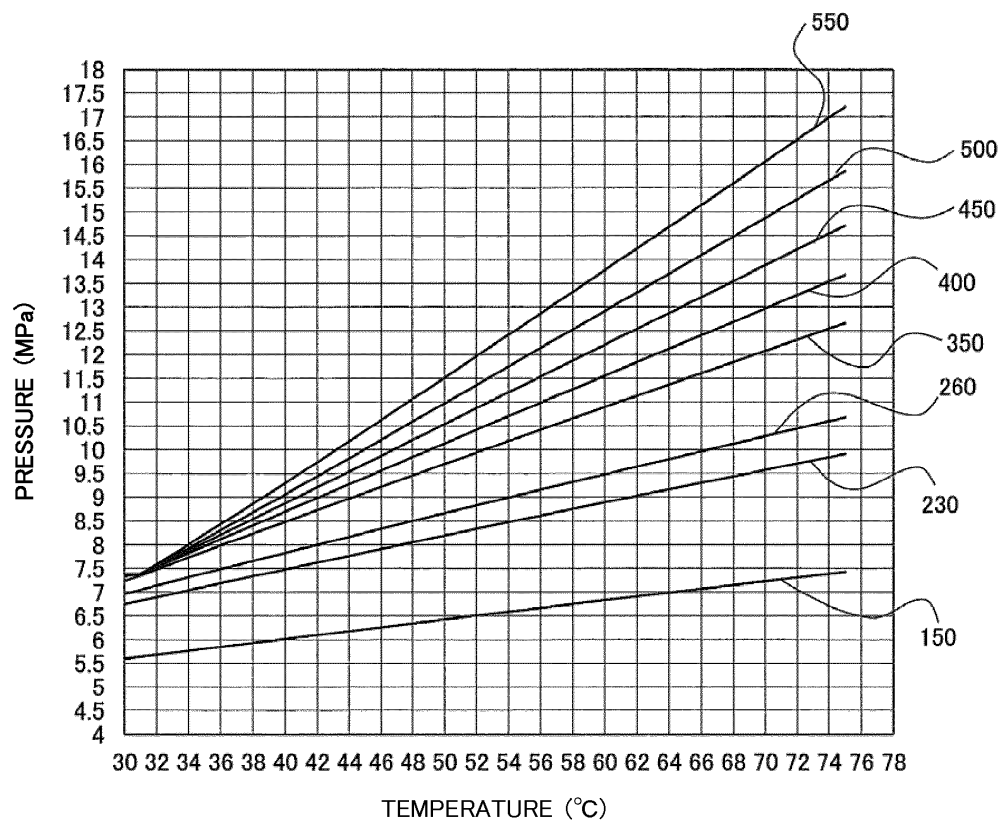
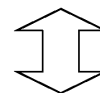


FIG. 4

	REGION	INTERNAL VOLUME (m ³)	AMOUNT OF REFRIGERANT (kg)	REFRIGERANT DENSITY (kg/m ³)	PRESSURE AT 43°C (MPa·abs)
HIGH-PRESSURE SIDE	DISCHARGE PIPE	0.0013	0.110	426.2	
	OIL SEPARATOR	0.0030	0.247		
	CONDENSER	0.0082	3.106		
	RECEIVER	0.0130	3.600		
	LIQUID PIPE	0.0087	7.532		
LOW-PRESSURE SIDE	EVAPORATOR (UC)	0.0200	2.520	95.8	
	SUCTION PIPE	0.0197	1.490		
	ACCUMULATOR	0.0100	0.755		
TOTAL		0.0840	19.36	230.6	7.696



0.1291	19.36	150.0	6.1418
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FIG. 5

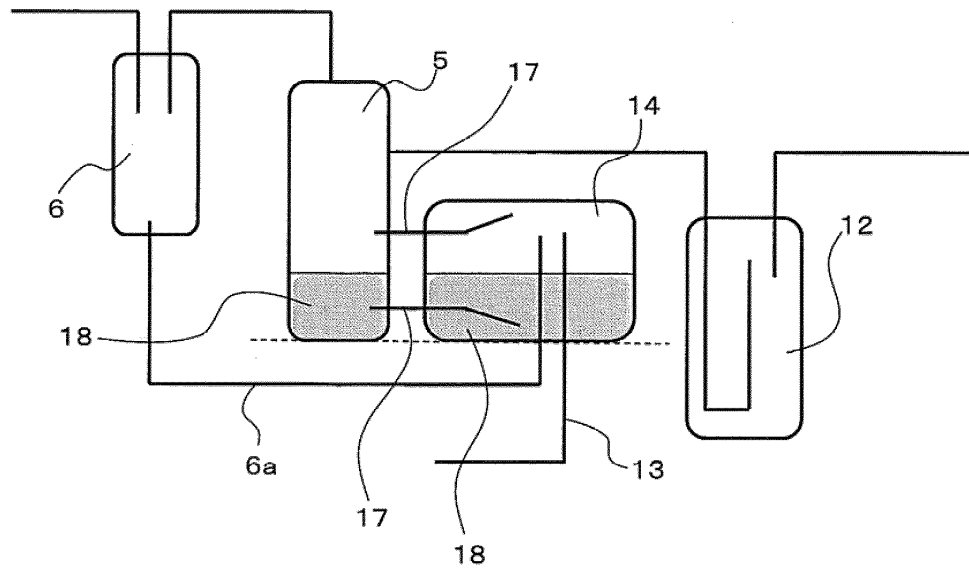


FIG. 6

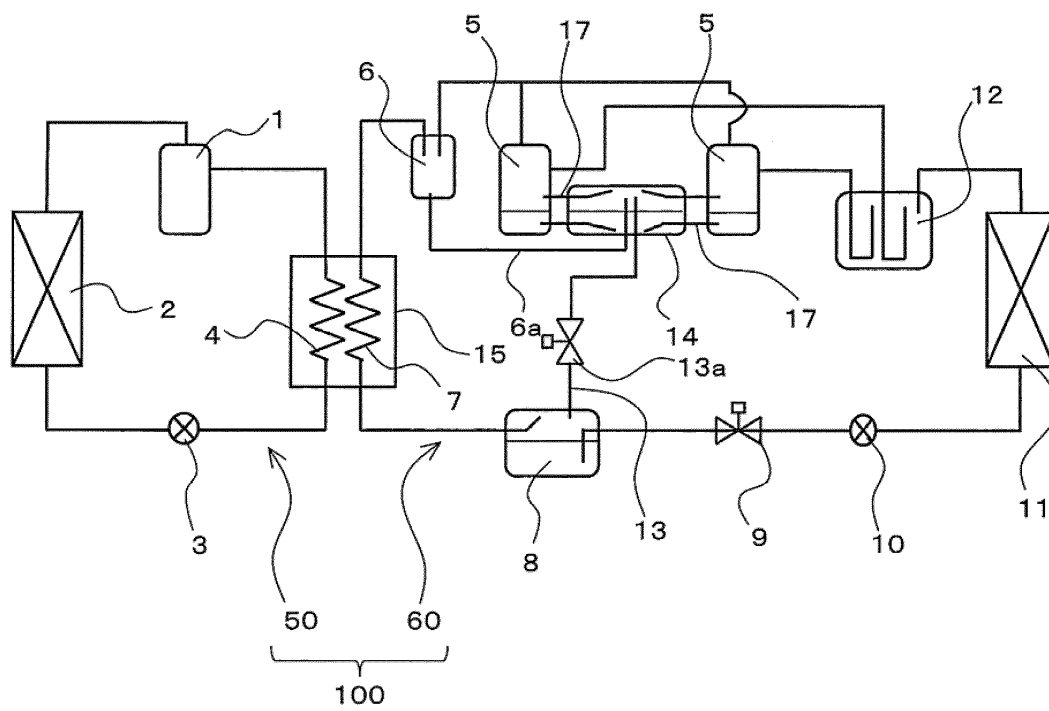
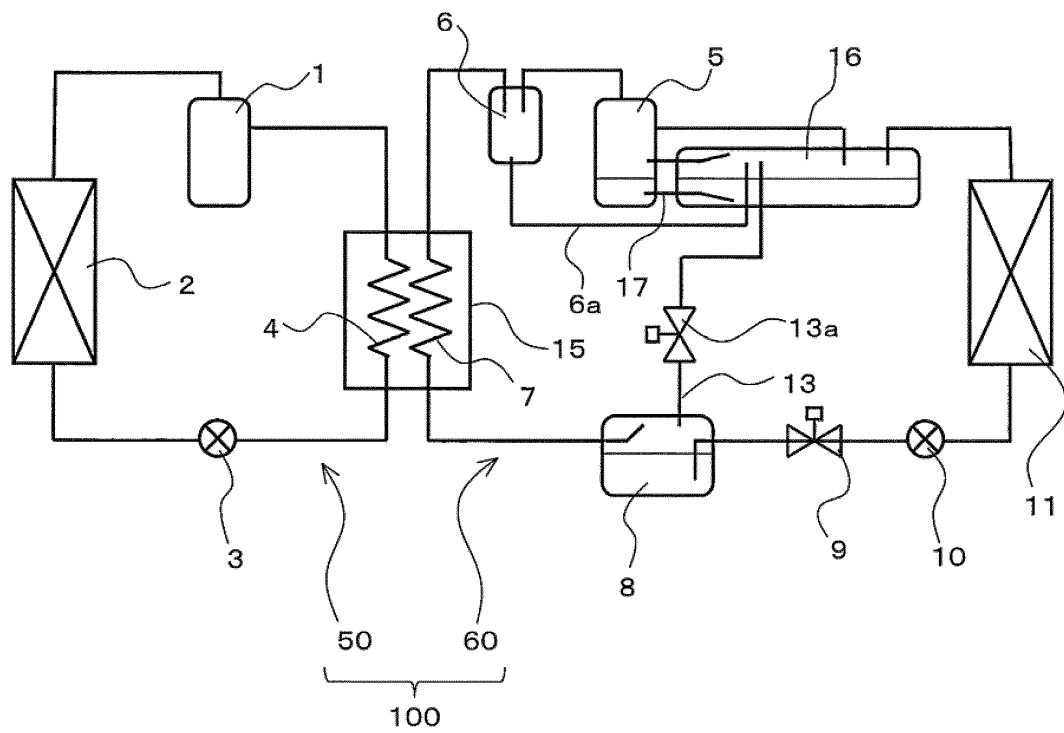


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/074197

A. CLASSIFICATION OF SUBJECT MATTER

F25B7/00(2006.01) i, 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)

F25B7/00, 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 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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 8-14673 A (Daikin Industries, Ltd.), 19 January 1996 (19.01.1996), fig. 1; paragraphs [0026] to [0034] (Family: none)	1-6
A	JP 2006-275440 A (Mitsubishi Electric Corp.), 12 October 2006 (12.10.2006), fig. 1, 2; paragraphs [0009] to [0014] (Family: none)	1-6
A	JP 6-82107 A (Daikin Industries, Ltd.), 22 March 1994 (22.03.1994), entire text; all drawings (Family: none)	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search
12 October, 2012 (12.10.12)Date of mailing of the international search report
23 October, 2012 (23.10.12)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/074197

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2004/076945 A1 (Toshiba Carrier Corp.), 10 September 2004 (10.09.2004), entire text; all drawings & JP 4323484 B & EP 1605211 A1 & EP 2397793 A1 & KR 10-2005-0107451 A & CN 1751213 A & RU 2005126948 A & ES 2382736 T	1-6
A	JP 2006-38290 A (Chubu Electric Power Co., Inc.), 09 February 2006 (09.02.2006), entire text; all drawings (Family: none)	1-6
A	JP 2004-301461 A (Hitachi, Ltd.), 28 October 2004 (28.10.2004), entire text; all drawings (Family: none)	1-6
A	JP 4-39574 A (Mitsubishi Electric Corp.), 10 February 1992 (10.02.1992), entire text; all drawings (Family: none)	1-6

REFERENCES CITED IN THE DESCRIPTION

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