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(54) **REFRIGERATION DEVICE**

(57) In a refrigeration apparatus that carries out a multistage compression refrigeration cycle, it is possible to prevent refrigerant drawn into a second-stage compression element from becoming wet, even under operation conditions in which the temperature of a heat source of the intercooler is low. An air-conditioning apparatus (1) has a two-stage compression mechanism (2); a heat source-side heat exchanger (4); a usage-side heat exchanger (6); an intercooler (7) which is provided to an intermediate refrigerant tube (8) for drawing refrigerant discharged from a first-stage compression element (2c) into a second-stage compression element (2d); and an intercooler bypass tube (9) connected to the intermediate refrigerant tube (8) so as to bypass the intercooler (7). In the air-conditioning apparatus (1), a wet prevention control is performed using the intercooler bypass tube (9) so that refrigerant does not flow to the intercooler (7) when the heat source temperature of the intercooler (7) or the outlet refrigerant temperature of the intercooler (7) is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element (2c) to the second-stage compression element (2d).

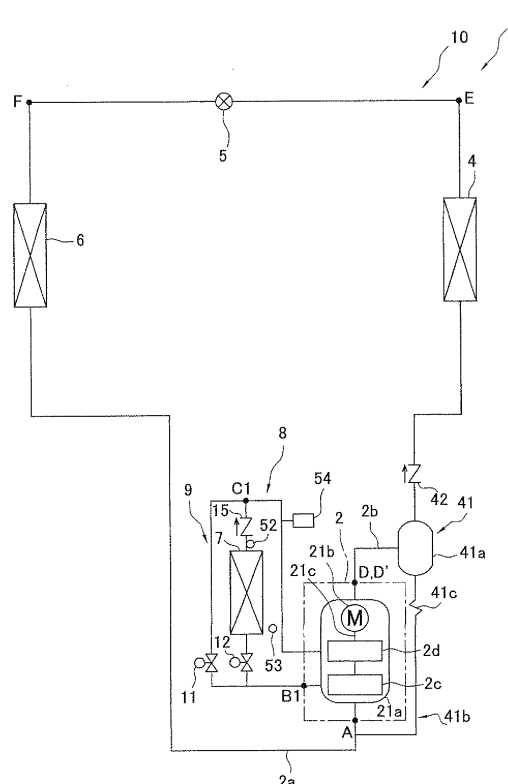


FIG. 1

Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus, and particularly relates to a refrigeration apparatus which performs a multistage compression refrigeration cycle.

BACKGROUND ART

[0002] As one conventional example of a refrigeration apparatus which performs a multistage compression refrigeration cycle, Patent Document 1 discloses an air-conditioning apparatus which performs a two-stage compression refrigeration cycle. This air-conditioning apparatus primarily has a compressor having two compression elements connected in series, an outdoor heat exchanger, an expansion valve, and an indoor heat exchanger.

<Patent Document 1>

Japanese Laid-open Patent Application No. 2007-232263

DISCLOSURE OF THE INVENTION

[0003] The refrigeration apparatus according to a first aspect of the present invention comprises a compression mechanism, a heat source-side heat exchanger, a usage-side heat exchanger, and an intercooler, and an intercooler bypass tube. The compression mechanism has a plurality of compression elements and is configured so that the refrigerant discharged from the first-stage compression element, which is one of a plurality of compression elements, is sequentially compressed by the second-stage compression element. As used herein, the term "compression mechanism" refers to a compressor in which a plurality of compression elements are integrally incorporated, or a configuration that includes a compressor in which a single compression element is incorporated and/or a plurality of compressors in which a plurality of compression elements have been incorporated are connected together. The phrase "the refrigerant discharged from a first-stage compression element, which is one of the plurality of compression elements, is sequentially compressed by a second-stage compression element" does not mean merely that two compression elements connected in series are included, namely, the "first-stage compression element" and the "second-stage compression element;" but means that a plurality of compression elements are connected in series and the relationship between the compression elements is the same as the relationship between the aforementioned "first-stage compression element" and "second-stage compression element." The intercooler is provided to an intermediate refrigerant tube for drawing refrigerant discharged from the first-stage compression element into

the second-stage compression element, and the intercooler functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element. The intercooler bypass tube is connected to the intermediate refrigerant tube so as to bypass the intercooler. In the refrigeration apparatus, a wet prevention control is performed using the intercooler bypass tube so that refrigerant does not flow to the intercooler when the heat source temperature of the intercooler or the outlet refrigerant temperature of the intercooler is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element.

[0004] In a conventional air-conditioning apparatus, since the refrigerant discharged from the first-stage compression element of the compressor is drawn into the second-stage compression element of the compressor and further compressed, the temperature of the refrigerant discharged from the second-stage compression element of the compressor is increased, there is a large difference in temperature between the refrigerant and the air and/or water as a heat source in, e.g., the outdoor heat exchanger functioning as a refrigerant cooler, and the outdoor heat exchanger has much heat radiation loss, which poses a problem in that it is difficult to achieve a high operating efficiency.

[0005] As a countermeasure to such problems, the intercooler which functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element is provided to the intermediate refrigerant tube for drawing refrigerant discharged from the first-stage compression element into the second-stage compression element, thereby lowering the temperature of the refrigerant drawn into the second-stage compression element. As a result, the temperature of the refrigerant discharged from the second-stage compression element is reduced, and a reduction in heat radiation loss in the outdoor heat exchanger is conceivable.

[0006] However, in such a configuration, the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element is liable to be excessively cooled under operating conditions in which the temperature of the water and/or air as the heat source of the intercooler is low. Therefore, the refrigerant drawn into the second-stage compression element becomes wet, and the reliability of the compressor is liable to be compromised.

[0007] In view of the above, this refrigeration apparatus uses the intercooler bypass tube as wet prevention control that does not allow refrigerant to flow to the intercooler when the heat source temperature of the intercooler or the outlet refrigerant temperature of the intercooler is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element.

[0008] Therefore, this refrigeration apparatus can pre-

vent the refrigerant drawn into the second-stage compression element from becoming wet even under operating conditions in which the heat source temperature of the intercooler is low.

[0009] The refrigeration apparatus according to a second aspect of the present invention is the refrigeration apparatus according to the first aspect of the present invention, wherein the intercooler is a heat exchanger in which air is used as a heat source.

[0010] The refrigeration apparatus prevents the refrigerant drawn into the second-stage compression element from becoming wet even under operating conditions in which the temperature of the air as the heat source of the intercooler is low.

[0011] The refrigeration apparatus according to a third aspect of the present invention is the refrigeration apparatus according to the first aspect of the present invention, wherein the intercooler is a heat exchanger in which water is used as a heat source; and water fed to the intercooler is stopped during wet prevention control.

[0012] The refrigeration apparatus can prevent the refrigerant drawn into the second-stage compression element from becoming wet even under operating conditions in which the temperature of the water as the heat source of the intercooler is low. Also, the refrigeration apparatus can prevent refrigerant inside the intercooler from liquefying and pooling because water fed to the intercooler is stopped during wet prevention control.

[0013] The refrigeration apparatus according to a fourth aspect of the present invention comprises a compression mechanism, a heat source-side heat exchanger, a usage-side heat exchanger, and an intercooler. The compression mechanism has a plurality of compression elements and is configured so that the refrigerant discharged from the first-stage compression element, which is one of a plurality of compression elements, is sequentially compressed by the second-stage compression element. As used herein, the term "compression mechanism" refers to a compressor in which a plurality of compression elements are integrally incorporated, or a configuration that includes a compressor in which a single compression element is incorporated and/or a plurality of compressors in which a plurality of compression elements have been incorporated are connected together. The phrase "the refrigerant discharged from a first-stage compression element, which is one of the plurality of compression elements, is sequentially compressed by a second-stage compression element" does not mean merely that two compression elements connected in series are included, namely, the "first-stage compression element" and the "second-stage compression element;" but means that a plurality of compression elements are connected in series and the relationship between the compression elements is the same as the relationship between the aforementioned "first-stage compression element" and "second-stage compression element." The intercooler is provided to an intermediate refrigerant tube for drawing refrigerant discharged from the first-stage

compression element into the second-stage compression element, and the intercooler functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element. The refrigeration apparatus carries out wet prevention control for reducing the flow rate of water that flows through the intercooler when the heat source temperature of the intercooler or the outlet refrigerant temperature of the intercooler is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element. As used herein, the phrase "for reducing the flow rate of water that flows through the intercooler" includes the meaning "water fed to the intercooler is stopped."

[0014] In a conventional air-conditioning apparatus, since the refrigerant discharged from the first-stage compression element of the compressor is drawn into the second-stage compression element of the compressor and further compressed, the temperature of the refrigerant discharged from the second-stage compression element of the compressor is increased, there is a large difference in temperature between the refrigerant and the air and/or water as a heat source in, e.g., the outdoor heat exchanger functioning as a refrigerant cooler, and the outdoor heat exchanger has much heat radiation loss, which poses a problem in that it is difficult to achieve a high operating efficiency.

[0015] As a countermeasure to such problems, the intercooler which functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element is provided to the intermediate refrigerant tube for drawing refrigerant discharged from the first-stage compression element into the second-stage compression element, thereby lowering the temperature of the refrigerant drawn into the second-stage compression element. As a result, the temperature of the refrigerant discharged from the second-stage compression element is reduced, and a reduction in heat radiation loss in the outdoor heat exchanger is conceivable.

[0016] However, in such a configuration, the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element is liable to be excessively cooled under operating conditions in which the temperature of the water and/or air as the heat source of the intercooler is low. Therefore, the refrigerant drawn into the second-stage compression element becomes wet, and the reliability of the compressor is liable to be compromised.

[0017] In view of the above, this refrigeration apparatus carries out wet prevention control for reducing the flow rate of water that flows through the intercooler when the heat source temperature of the intercooler or the outlet refrigerant temperature of the intercooler is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element.

[0018] The refrigeration apparatus thereby prevents the refrigerant drawn into the second-stage compression element from becoming wet even under operating conditions in which the temperature of the water as the heat source of the intercooler is low.

[0019] The refrigeration apparatus according to a fifth aspect of the present invention is the refrigeration apparatus according to the fourth aspect of the present invention, wherein, in the wet prevention control, the flow rate of water that flows through the intercooler is controlled so that the outlet refrigerant temperature of the intercooler is higher than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element.

[0020] The refrigeration apparatus controls the flow rate of water that flows through the intercooler so that the outlet refrigerant temperature of the intercooler is higher than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element in the wet prevention control. Therefore, the refrigerant drawn into the second-stage compression element can not only be prevented from becoming wet, but the temperature of the refrigerant drawn into the second-stage compression element can also be reduced, whereby the temperature of the refrigerant discharged from the second-stage compression element can be kept low, and the power consumption of the compression mechanism can be reduced.

[0021] The refrigeration apparatus according to a sixth aspect of the present invention is the refrigerant apparatus according to any of the first to fifth aspects of the present invention, further comprising a second-stage injection tubes for branching refrigerant that flows between the heat source-side heat exchanger and the usage-side heat exchanger after the refrigerant has been compressed by the compression mechanism, and returning the refrigerant to the second-stage compression element.

[0022] In addition to cooling the refrigerant drawn into the second-stage compression element by the intercooler, the refrigeration apparatus can reduce the temperature of the refrigerant drawn into the second-stage compression element by intermediate injection using a second-stage injection tube. Therefore, the temperature of the refrigerant discharged from the compression mechanism can be kept low, and the power consumption of the compression mechanism can be reduced.

BRIEF DESCRIPTION OF THE DRAWING

[0023]

FIG. 1 is a schematic structural diagram of an air-conditioning apparatus as an embodiment of the refrigeration apparatus according to the present invention.

FIG. 2 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation.

FIG. 3 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation.

FIG. 4 is a schematic structural diagram of an air-conditioning apparatus according to Modification 1.

FIG. 5 is a schematic structural diagram of an air-conditioning apparatus according to Modification 1.

FIG. 6 is a schematic structural diagram of an air-conditioning apparatus according to Modification 2.

FIG. 7 is a schematic structural diagram of an air-conditioning apparatus according to Modification 4.

FIG. 8 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 4.

FIG. 9 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 4.

FIG. 10 is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 4.

FIG. 11 is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 4.

FIG. 12 is a schematic structural diagram of an air-conditioning apparatus according to Modification 4.

FIG. 13 is a schematic structural diagram of an air-conditioning apparatus according to Modification 5.

FIG. 14 is a schematic structural diagram of an air-conditioning apparatus according to Modification 5.

EXPLANATION OF THE REFERENCE NUMERALS

[0024]

1	Air-conditioning apparatus (refrigeration apparatus)
2,102	Compression mechanisms
4	Heat source-side heat exchanger
6	Usage-side heat exchanger
7	Intercooler
8	Intermediate refrigerant tube
9	Intercooler bypass tube
18c	First second-stage injection tube
19	Second second-stage injection tube

BEST MODE FOR CARRYING OUT THE INVENTION

[0025] Embodiments of the refrigeration apparatus according to the present invention are described hereinbelow with reference to the drawings.

(1) Configuration of air-conditioning apparatus

[0026] FIG. 1 is a schematic structural diagram of an

air-conditioning apparatus 1 as an embodiment of the refrigeration apparatus according to the present invention. The air-conditioning apparatus 1 has a refrigerant circuit 10 configured so as to be capable of an air-cooling operation, and the apparatus performs a two-stage compression refrigeration cycle by using a refrigerant (carbon dioxide in this case) for operating in a supercritical range.

[0027] The refrigerant circuit 10 of the air-conditioning apparatus 1 has primarily a compression mechanism 2, a heat source-side heat exchanger 4, an expansion mechanism 5, a usage-side heat exchanger 6, and an intercooler 7.

[0028] In the present embodiment, the compression mechanism 2 is configured from a compressor 21 which uses two compression elements to subject a refrigerant to two-stage compression. The compressor 21 has a hermetic structure in which a compressor drive motor 21b, a drive shaft 21c, and compression elements 2c, 2d are housed within a casing 21a. The compressor drive motor 21b is linked to the drive shaft 21c. The drive shaft 21c is linked to the two compression elements 2c, 2d. Specifically, the compressor 21 has a so-called single-shaft, two-stage compression structure in which the two compression elements 2c, 2d are linked to a single drive shaft 21c and the two compression elements 2c, 2d are both rotatably driven by the compressor drive motor 21b. In the present embodiment, the compression elements 2c, 2d are rotary elements, scroll elements, or another type of positive displacement compression elements. The compressor 21 is configured so as to admit refrigerant through an intake tube 2a, to discharge this refrigerant to an intermediate refrigerant tube 8 after the refrigerant has been compressed by the compression element 2c, to admit the refrigerant discharged to the intermediate refrigerant tube 8 into the compression element 2d, and to discharge the refrigerant to a discharge tube 2b after the refrigerant has been further compressed. The intermediate refrigerant tube 8 is a refrigerant tube for taking refrigerant into the compression element 2d connected to the second-stage side of the compression element 2c after the refrigerant has been discharged from the compression element 2d connected to the first-stage side of the compression element 2c. The discharge tube 2b is a refrigerant tube for feeding refrigerant discharged from the compression mechanism 2 to the heat source-side heat exchanger 4, and the discharge tube 2b is provided with an oil separation mechanism 41 and a non-return mechanism 42. The oil separation mechanism 41 is a mechanism for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism 2 and returning the oil to the intake side of the compression mechanism 2, and the oil separation mechanism 41 has primarily an oil separator 41a for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism 2, and an oil return tube 41b connected to the oil separator 41a for returning the refrigerator oil separated from the refrigerant to the intake tube

2a of the compression mechanism 2. The oil return tube 41b is provided with a depressurizing mechanism 41c for depressurizing the refrigerator oil flowing through the oil return tube 41b. A capillary tube is used for the depressurizing mechanism 41c in the present embodiment. The non-return mechanism 42 is a mechanism for allowing the flow of refrigerant from the discharge side of the compression mechanism 2 to the heat source-side heat exchanger 4 and for blocking the flow of refrigerant from the heat source-side heat exchanger 4 to the discharge side of the compression mechanism 2, and a non-return valve is used in the present embodiment.

[0029] Thus, in the present embodiment, the compression mechanism 2 has two compression elements 2c, 2d and is configured so that among these compression elements 2c, 2d, refrigerant discharged from the first-stage compression element is compressed in sequence by the second-stage compression element.

[0030] The heat source-side heat exchanger 4 is a heat exchanger that functions as a refrigerant cooler. One end of the heat source-side heat exchanger 4 is connected to the compression mechanism 2, and the other end is connected to the expansion mechanism 5. The heat source-side heat exchanger is a heat exchanger having air as a heat source (i.e., cooling source). The air as the heat source is supplied to the heat source-side heat exchanger 4 by a heat source-side fan (not shown).

[0031] The expansion mechanism 5 is a mechanism for depressurizing the refrigerant, and an electric expansion valve is used in the present embodiment. One end of the expansion mechanism 5 is connected to the heat source-side heat exchanger 4, and the other end is connected to the usage-side heat exchanger 6. In the present embodiment, the expansion mechanism 5 depressurizes the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 before feeding the refrigerant to the usage-side heat exchanger 6.

[0032] The usage-side heat exchanger 6 is a heat exchanger that functions as a heater of refrigerant. One end of the usage-side heat exchanger 6 is connected to the expansion mechanism 5, and the other end is connected to the compression mechanism 2. The usage-side heat exchanger 6 is a heat exchanger having air and/or water as a heat source (i.e., a heating source).

[0033] The intercooler 7 is provided to the intermediate refrigerant tube 8, and is a heat exchanger which functions as a cooler of refrigerant discharged from the compression element 2c on the first-stage side and drawn into the compression element 2d. The intercooler 7 is a heat exchanger having air as a heat source (i.e., a cooling source). The air as the heat source is supplied to the intercooler 7 by a heat source-side fan (not shown). There are instances in which the intercooler 7 is integrated with the heat source-side heat exchanger 4, in which case there are configurations in which air used as a heat source is supplied by a heat source-side fan shared between the heat source-side heat exchanger 4 and the intercooler 7. Thus, it is acceptable to say that the inter-

cooler 7 is a cooler that uses an external heat source, meaning that the intercooler does not use the refrigerant that circulates through the refrigerant circuit 10.

[0034] An intercooler bypass tube 9 is connected to the intermediate refrigerant tube 8 so as to bypass the intercooler 7. This intercooler bypass tube 9 is a refrigerant tube for limiting the flow rate of refrigerant flowing through the intercooler 7. The intercooler bypass tube 9 is provided with an intercooler bypass on/off valve 11. The intercooler bypass on/off valve 11 is an electromagnetic valve in the present embodiment. The intercooler bypass on/off valve 11 is essentially closed in the present embodiment, except during temporary operation such as the later-described wet prevention control.

[0035] The intermediate refrigerant tube 8 is provided with a cooler on/off valve 12 in a position leading toward the intercooler 7 from the part connecting with the intercooler bypass tube 9 (i.e., in the portion leading from the part connecting with the intercooler bypass tube 9 nearer the inlet of the intercooler 7 to the connecting part nearer the outlet of the intercooler 7). The cooler on/off valve 12 is a mechanism for limiting the flow rate of refrigerant flowing through the intercooler 7. The cooler on/off valve 12 is an electromagnetic valve in the present embodiment. The cooler on/off valve 12 is essentially open in the present embodiment, except during temporary operation such as the later-described wet prevention control. In the present embodiment, the cooler on/off valve 12 is provided in a position nearer the inlet of the intercooler 7.

[0036] The intermediate refrigerant tube 8 is also provided with a non-return mechanism 15 for allowing refrigerant to flow from the discharge side of the first-stage compression element 2c to the intake side of the second-stage compression element 2d and for blocking the refrigerant from flowing from the discharge side of the second-stage compression element 2d to the first-stage compression element 2c. The non-return mechanism 15 is a non-return valve in the present embodiment. In the present embodiment, the non-return mechanism 15 is provided to the intermediate refrigerant tube 8 in the portion leading away from the outlet of the intercooler 7 toward the part connecting with the intercooler bypass tube 9.

[0037] Furthermore, the air-conditioning apparatus 1 is provided with various sensors. Specifically, the outlet of the intercooler 7 is provided with an intercooler outlet temperature sensor 52 for detecting the temperature of refrigerant at the outlet of the intercooler 7. The air-conditioning apparatus 1 is provided with an air temperature sensor 53 for detecting the temperature of the air as a heat source for the intercooler 7. An intermediate pressure sensor 54 for detecting the intermediate pressure of the compression mechanism, which is the pressure of the refrigerant that flows through the intermediate refrigerant tube 8, is provided to the intermediate refrigerant tube 8. Though not shown in the drawings, the air-conditioning apparatus 1 has a controller for controlling the actions of the compression mechanism 2, the expansion

mechanism 5, the intercooler bypass on/off valve 11, the cooler on/off valve 12, and the other components constituting the air-conditioning apparatus 1.

5 (2) Action of the air-conditioning apparatus

[0038] Next, the action of the air-conditioning apparatus 1 of the present embodiment will be described using FIGS. 1 through 3. FIG. 2 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, and FIG. 3 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation. Operation control during the cooling operation described below and wet prevention control for preventing refrigerant drawn into the second-stage compression element from becoming wet due to cooling in the intercooler 7 are carried out by the above-described controller (not shown). In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', and E in FIGS. 2 and 3), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A and F in FIGS. 2 and 3), and the term "intermediate pressure" and/or "intermediate pressure of the compression mechanisms" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B1 and C1 in FIGS. 2 and 3).

[0039] The opening degree of the expansion mechanism 5 is adjusted during the air-cooling operation. The cooler on/off valve 12 is opened and the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 is closed, thereby putting the intercooler 7 into a state of functioning as a cooler.

[0040] When the compression mechanism 2 is driven while the refrigerant circuit 10 is in this state, low-pressure refrigerant (refer to point A in FIGS. 1 through 3) is drawn into the compression mechanism 2 through the intake tube 2a, and after the refrigerant is first compressed to an intermediate pressure by the compression element 2c, the refrigerant is discharged to the intermediate refrigerant tube 8 (refer to point B1 in FIGS. 1 through 3). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled in the intercooler 7 by undergoing heat exchange with the air as a cooling source (refer to point C1 in FIGS. 1 through 3). The refrigerant cooled in the intercooler 7 is then led to and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is then discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 1 through 3). The high-pressure refrigerant discharged from the compression mechanism 2 is compressed to a pressure exceeding a critical pressure (i.e., the critical pressure P_{cp} at the critical point CP shown in FIG. 2) by the two-stage compression action of the compression elements 2c, 2d. The high-pressure refrigerant discharged from the compression mechanism 2 flows into the oil separator 41 constituting the oil sep-

aration mechanism 41, and the accompanying refrigeration oil is separated. The refrigeration oil separated from the high-pressure refrigerant in the oil separator 41a flows into the oil return tube 41b constituting the oil separation mechanism 41 wherein it is depressurized by the depressurization mechanism 41 c provided to the oil return tube 41b, and the oil is then returned to the intake tube 2a of the compression mechanism 2 and led back into the compression mechanism 2. Next, having been separated from the refrigeration oil in the oil separation mechanism 41, the high-pressure refrigerant is passed through the non-return mechanism 42 and fed to the heat source-side heat exchanger 4 functioning as a refrigerant cooler. The high-pressure refrigerant fed to the heat source-side heat exchanger 4 is cooled in the heat source-side heat exchanger 4 by heat exchange with air as a cooling source (refer to point E in FIGS. 1 through 3). The high-pressure refrigerant cooled in the heat source-side heat exchanger 4 is then depressurized by the expansion mechanism 5 to become a low-pressure gas-liquid two-phase refrigerant, which is fed to the usage-side heat exchanger 6 functioning as a refrigerant heater (refer to point F in FIGS. 1 through 3). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger 6 is heated by heat exchange with water or air as a heating source in the usage-side heat exchanger 6, and the refrigerant evaporates as a result (refer to point A in FIGS. 1 through 3). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is then led back into the compression mechanism 2. In this manner the air-cooling operation is performed.

[0041] Thus, in the air-conditioning apparatus 1, the intercooler 7 is provided to the intermediate refrigerant tube 8 for letting refrigerant discharged from the compression element 2c into the compression element 2d, and during the air-cooling operation, the cooler on/off valve 12 is opened and the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 is closed, thereby putting the intercooler 7 into a state of functioning as a cooler. Therefore, the refrigerant drawn into the compression element 2d on the second-stage side of the compression element 2c decreases in temperature (refer to points B1 and C1 in FIG. 3) and the refrigerant discharged from the compression element 2d also decreases in temperature (refer to points D and D' in FIG. 3), in comparison with cases in which no intercooler 7 is provided (in this case, the refrigeration cycle is performed in the sequence in FIGS. 2 and 3: point A → point B1 → point D' → point E → point F). Therefore, in the heat source-side heat exchanger 4 functioning as a cooler of high-pressure refrigerant in this air-conditioning apparatus 1, operating efficiency can be improved over cases in which no intercooler 7 is provided, because the temperature difference between the refrigerant and water or air as the cooling source can be reduced, and heat radiation loss can be reduced by an amount equivalent to the area enclosed by connecting points B1, D', D, and

C1 in FIG. 3.

<Wet Prevention Control>

[0042] In the cooling operation that accompanies cooling of the intermediate-pressure refrigerant by the intercooler 7 as described above, the refrigerant discharged from the first-stage compression element 2c and drawn into the second-stage compression element 2d is liable to be excessively cooled when under operating conditions in which the temperature of the air as the heat source of the intercooler 7 is low. Therefore, the refrigerant drawn into the second-stage compression element 2d becomes wet, and the reliability of the compressor 2 is liable to be compromised.

[0043] In view of the above, in the present embodiment, wet prevention control uses the intercooler bypass tube 9 so that refrigerant is not allowed to flow to the intercooler 7 when the heat source temperature of the intercooler 7 is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d. Specifically, in the present embodiment, when the temperature of air as the heat source of the intercooler 7 detected by the air temperature sensor 53 is equal to or less than the saturation temperature obtained by converting the intermediate pressure of the compression mechanism detected by the intermediate pressure sensor 54, the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 is opened and the cooler on/off valve 12 is closed, whereby the refrigerant discharged from the first-stage compression element 2c flows into the intake side of the second-stage compression element 2d by way of the intercooler bypass tube 9, and intermediate-pressure refrigerant does not flow into the intercooler 7. In the case a refrigerant that operates in the supercritical range is used such as in the present embodiment, the pressure of the refrigerant discharged from the first-stage compression element 2c is increased, and there may be cases in which the operating conditions are such that the intermediate pressure of the compression mechanism exceeds a critical pressure (i.e., the critical pressure P_{ep} at the critical point CP shown in FIG. 2). In such operating conditions, there is no longer the concept of a saturated state in not only high-pressure refrigerant, but also in intermediate-pressure refrigerant, and there is therefore no further need for the wet prevention control described above. Accordingly, in wet prevention control, it is determined whether the intermediate pressure of the compression mechanism is less than the critical pressure before a determination is made as to whether the temperature of the air as the heat source is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d. In the case that the intermediate pressure of the compression mechanism is equal to or greater than the critical pressure, the refrigerant is allowed to continue flowing to the

intercooler 7 to keep the temperature of the refrigerant drawn into the second-stage compression element 2d as low as possible. In the case that the intermediate pressure of the compression mechanism is less than the critical pressure, it is determined whether the temperature of the air as the heat source of the intercooler 7 detected by the air temperature sensor 53 is equal to or less than the saturation temperature obtained by converting the intermediate pressure of the compression mechanism detected by the intermediate pressure sensor 54. When the temperature of the air as the heat source of the intercooler 7 is equal to or less than the saturation temperature obtained by converting the intermediate pressure of the compression mechanism, the intermediate-pressure refrigerant is not allowed to flow to the intercooler 7; and when the temperature of the air as the heat source of the intercooler 7 is greater than the saturation temperature obtained by converting the intermediate pressure of the compression mechanism, the refrigerant is allowed to continue flowing to the intercooler 7.

[0044] In this manner, with the air-conditioning apparatus 1 of the present embodiment, when the temperature of the air as the heat source of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, wet prevention control that does not allow the refrigerant to flow to the intercooler 7 is carried out using the intercooler bypass tube 9. Therefore, the refrigerant drawn into the second-stage compression element 2d can be prevented from becoming wet, even under the operating conditions in which the temperature of the air as the heat source of the intercooler 7 is low.

[0045] With the air-conditioning apparatus 1, the cooler on/off valve 12 disposed in the inlet side of the intercooler 7 is closed when the temperature of the air as the heat source of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d. Therefore, all of the refrigerant discharged from the first-stage compression element 2c can be made to flow to the intercooler bypass tube 9, and the intermediate-pressure refrigerant that flows through the intermediate refrigerant tube 8 and the intercooler bypass tube 9 can be prevented from flowing from the inlet side of the intercooler 7 into the intercooler 7 and being retained inside the intercooler 7. Also, in the present embodiment, since a non-return mechanism 15 is provided to the outlet side of the intercooler 7, the intermediate-pressure refrigerant that flows through the intermediate refrigerant tube 8 and the intercooler bypass tube 9 can be prevented from flowing from the outlet side of the intercooler 7 to the intercooler 7 and being retained in the intercooler 7. In a particular configuration in which the intercooler 7 is integrally formed with the heat source-side heat exchanger 4 and air as the heat source is fed to both the heat source-side heat exchanger 4 and the intercooler 7 by a heat source-

side fan (not shown) shared by both the heat source-side heat exchanger 4 and the intercooler 7, air as the heat source is continuously fed to the intercooler 7 as well, as long as the air as the heat source is fed to the heat source-side heat exchanger 4. Therefore, it is effective to provide a cooler on/off valve 12 and a non-return mechanism 15 because the intermediate-pressure refrigerant is otherwise liable to flow into the intercooler 7 and be retained inside the intercooler 7.

[0046] Instead of determining the necessity of wet prevention control depending on whether the temperature of the air as the heat source of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, it is also possible to determine the necessity of wet prevention control depending on whether the temperature of the refrigerant (in this situation, the temperature of the refrigerant detected by the intercooler outlet temperature sensor 52) in the outlet of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d.

(3) Modification 1

[0047] In the embodiment described above, a heat exchanger is used as the intercooler 7 in which air is the heat source, but a heat exchanger may be used as the intercooler 7 in which water is used as the heat source.

[0048] For example, in a configuration that feeds water to the intercooler 7 via a water distribution tube 14 for intermediate cooling, as shown in FIG. 4, wet prevention control may be carried out so that a determination is made as to whether the temperature of the water (in this case, the temperature of the water fed to the intercooler 7 detected by a water temperature sensor 58 disposed in the water inlet side of the intercooler 7) as the heat source of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, or whether the temperature of the refrigerant (in this case, the temperature of the refrigerant detected by the intercooler outlet temperature sensor 52) in the outlet of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d. In the case that the temperature of the water as the heat source of the intercooler 7 or the temperature of the refrigerant in the outlet of the intercooler 7 is determined to be equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, the refrigerant discharged from the first-stage compression element 2c is allowed to flow to the intake side of the second-stage compression element 2d

via the intercooler bypass tube 9 by closing the cooler on/off valve 12 and opening the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 in the same manner as the embodiment described above, whereby the intermediate-pressure refrigerant is not allowed to flow to the intercooler 7.

[0049] The same operational effects as those of the embodiment described above can be achieved with the configuration of the present modification, except that the heat source of the intercooler 7 is water instead of air.

[0050] In a configuration that provides a water on/off valve 14a to the water distribution tube 14 for intermediate cooling, as shown in FIG. 5, control may be carried out so that the intermediate-pressure refrigerant does not flow to the intercooler 7 by making use of the intercooler bypass tube 9 described above, and control may be carried out for stopping the supply of water to the intercooler 7 by closing the water on/off valve 14a. In this case, the water on/off valve 14a is an electromagnetic valve capable of on/off control.

[0051] In this case, refrigerant inside the intercooler 7 can furthermore be prevented from being retained in a liquid state.

(4) Modification 2

[0052] Modification 1 described above is configured so that water is fed to the intercooler 7 via a water distribution tube 14 for intermediate cooling and so that a water on/off valve 14a is provided to the water distribution tube 14 for intermediate cooling; and in the case that it has been determined that the temperature of the water as the heat source of the intercooler 7 or temperature of the refrigerant in the outlet of the intercooler 7 is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, wet prevention control is carried out by allowing intermediate-pressure refrigerant not to flow to the intercooler 7 by using an intercooler bypass tube 9 and water fed to the intercooler 7 is stopped by closing the water on/off valve 14a (see FIG. 5). However, it is also possible to omit the intercooler bypass tube 9 including the intercooler bypass on/off valve 11, and/or a configuration such as the cooler on/off valve 12 for allowing intermediate-pressure refrigerant not to flow to the intercooler 7; and to instead use wet prevention control in which the only control that is performed is to stop the feeding of water to the intercooler 7.

[0053] In the configuration of the present modification, the refrigerant constantly flows to the intercooler 7 but the water fed to the intercooler 7 is stopped, which is different from Modification 1 described above. The same operational effects as those of Modification 1 described above can be achieved because, essentially, the refrigerant that flows to the intercooler 7 is no longer cooled by water.

(5) Modification 3

[0054] In the configuration of Modification 2 described above (see FIG. 6), it is also possible to use a configuration in which the water on/off valve 14a is composed of a valve whose degree of opening can be adjusted, and when it has been determined that the temperature of the refrigerant in the outlet of the intercooler 7 is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, wet prevention control is carried out so as to reduce the flow rate of water fed to the intercooler 7 by reducing the degree of opening of the water on/off valve 14a to prevent the refrigerant drawn into the second-stage compression element 2d from becoming wet, and furthermore so as to control the flow rate of the water that flows through the intercooler 7 so that the temperature of the refrigerant in the outlet of the intercooler 7 become greater than the saturation temperature of the refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d.

[0055] In the configuration of the present modification, not only can the refrigerant drawn into the second-stage compression element 2d be prevented from becoming wet, but the temperature of the refrigerant drawn into the second-stage compression element 2d can also be kept low, whereby the temperature of the refrigerant discharged from the second-stage compression element 2d can be kept low and the power consumption of the compression mechanism 2 can be reduced in the same manner as Modification 2 described above.

(6) Modification 4

[0056] In the refrigerant circuit 10 (see FIGS. 1, 4, 5, 6) in the embodiment described above and the modifications thereof, a single usage-side heat exchanger 6 is used and the configuration is capable of air-cooling operation. However, there are cases in which a configuration is provided with the aim of carrying out air cooling and/or air-warming in accordance with the air-conditioning load of a plurality of air-conditioning spaces, the configuration having a switching mechanism 3 for switching between air-cooling operation and air-warming operation, a plurality of usage-side heat exchangers 6 mutually connected in parallel, and a receiver 18 for temporarily retaining refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchangers 6. Also, usage-side expansion mechanisms 5c are provided between the usage-side heat exchangers 6 and the receiver 18 as a vapor-liquid separator, so as to correspond to the usage-side heat exchangers 6 and so that the rate at which the refrigerant flows through the usage-side heat exchangers 6 can be controlled and the required refrigeration load can be obtained in the usage-side heat exchangers 6 (e.g., a configuration that does not have second-stage injection tubes 18c, 19 and an

economizer heat exchanger 20 as in the later-described FIGS. 7 and 12). In such a configuration, intermediate pressure injection is carried out by returning the refrigerant to the second-stage compression element 2d from the receiver 18 as the vapor-liquid separator so as to merge with the intermediate-pressure refrigerant of the compression mechanism discharged from the first-stage compression element 2c of the compression mechanism 2 and drawn into the second-stage compression element 2d. Operating efficiency is thought to be improved because the temperature of the refrigerant discharged from the second-stage compression element 2d is reduced and power consumption of the compression mechanism 2 is reduced.

[0057] However, in such a configuration in which a plurality of usage-side heat exchangers 6 are connected to each other in parallel, in which usage-side expansion mechanisms 5c as a usage-side expansion valve are provided between the usage-side heat exchangers 6 and the receiver 18 as a vapor-liquid separator so as to correspond to the usage-side heat exchangers 6, and in which the usage-side expansion mechanisms 5c control the flow rate of the refrigerant that flows through the usage-side heat exchangers 6 so that a required refrigeration load can be obtained in the usage-side heat exchangers 6, the flow rate at which the refrigerant flows through the usage-side heat exchangers 6 in an air-warming operation is substantially determined by the degree of opening of the usage-side expansion mechanisms 5c provided in the downstream side of the usage-side heat exchangers 6 and in the upstream side of the receiver 18. However, in this case, the degree of opening of the usage-side expansion mechanisms 5c varies depending not only on the flow rate of the refrigerant that flows through the usage-side heat exchangers 6, but also on the state of the flow rate distribution between the plurality of usage-side heat exchangers 6. There are cases in which a state is produced in which the degree of opening considerably varies among the plurality of usage-side expansion mechanisms 5c, and a usage-side expansion mechanism 5c may have a relatively small degree of opening. Accordingly, there may be cases in which the vapor-liquid separator pressure, which is the pressure of the refrigerant in the receiver 18, may be excessively reduced when the degree of opening of the usage-side expansion mechanisms 5c is controlled during air-warming operation. Also, when such an air-conditioning apparatus 1 is configured as a separate-type air-conditioning apparatus in which a heat source unit mainly including a compression mechanism 2, a heat source-side heat exchanger 4, and a receiver 18, and a usage unit mainly including usage-side heat exchangers 6 are connected by an interconnecting pipe, the interconnecting pipe may become very long depending on the arrangement of the usage unit and the heat source unit. Due to the resulting pressure drop, this therefore adds to the reduced pressure of the vapor-liquid separator, and the pressure of the vapor-liquid separator is further reduced.

[0058] Accordingly, intermediate pressure injection by the receiver 18 as the vapor-liquid separator can be used even under conditions in which the pressure difference between the pressure of the vapor-liquid separator and the intermediate pressure of the compression mechanism is small. Therefore, this is advantageous in cases in which the pressure of the vapor-liquid separator is very likely to be excessively reduced such as in the air-warming operation in this configuration.

[0059] However, rather than carrying out an operation for considerably reducing the pressure using other than the first expansion mechanism 5a (e.g., see the first expansion mechanism 5a of the later-described FIGS. 7 and 12) as the heat source-side expansion mechanism between the time the refrigerant is cooled in the heat source-side heat exchanger 4 and flows into the receiver 18 as the vapor-liquid separator, as in air-cooling operation, there are preferably provided a second second-stage injection tube 19 for branching and returning the refrigerant that flows between the heat source-side heat exchanger 4 and the first expansion mechanism 5a to the second-stage compression element 2d, and an economizer heat exchanger 20 for carrying out heat exchange between the refrigerant that flows between the heat source-side heat exchanger 4 and the first expansion mechanism 5a and the refrigerant that flows through the second second-stage injection tube 19. In conditions in which it is possible to use the pressure difference between high pressure in the refrigeration cycle and near-intermediate pressure in the refrigeration cycle, the refrigerant that flows through the second second-stage injection tube 19 after being heated by heat exchange in the economizer heat exchanger 20 is returned (i.e., intermediate pressure injection is carried out by the economizer heat exchanger 20) to the second-stage compression element 2d (e.g., see the second second-stage injection tube 19 and the economizer heat exchanger 20 of the later-described FIGS. 7 and 12). This is due to the fact that intermediate pressure injection carried out by the economizer heat exchanger 20 causes the flow rate of the refrigerant that can be returned to the second-stage compression element 2d to fluctuate based on the amount of heat exchange in the economizer heat exchanger 20. Therefore, the amount of heat exchange in the economizer heat exchanger 20 is reduced and the flow rate of the refrigerant that can be returned to the second-stage compression element 2d is reduced in the case that the pressure difference between the pressure of the refrigerant in the inlet of the economizer heat exchanger 20 and the intermediate pressure of the compression mechanism is small, as in air-warming operation. While such application is difficult, it is effective when the pressure difference between the pressure of the refrigerant in the inlet of the economizer heat exchanger 20 and the intermediate pressure of the compression mechanism is large in that the amount of heat exchange in the economizer heat exchanger 20 is increased and the flow rate of the refrigerant that can be returned to the

second-stage compression element 2d is increased. In the particular case that refrigerant such as carbon dioxide for operating in a supercritical range is used, the pressure difference between the intermediate pressure and the high pressure in the refrigeration cycle is further increased because the high pressure in the refrigeration cycle exceeds the critical pressure. Therefore, intermediate pressure injection carried out by the economizer heat exchanger 20 is advantageous. Also, in the case that refrigerant such as carbon dioxide for operating in a supercritical range is used, the pressure of the vapor-liquid separator increases to a pressure that is greater than the critical pressure and the refrigerant inside the receiver 18 as the vapor-liquid separator is liable to enter a state in which gas refrigerant and liquid refrigerant are difficult to separate. Therefore, considering this point, intermediate pressure injection carried out by the economizer heat exchanger 20 is preferably used in conditions in which the pressure difference between the high pressure in the refrigeration cycle and the near-intermediate pressure in the refrigeration cycle can be used, as in air-cooling operation.

[0060] In view of the above, in the present modification, a configuration is provided having a plurality of usage-side heat exchangers 6 mutually connected in parallel and capable of switching between air-cooling operation and air-warming operation, as described above, and the usage-side expansion mechanisms 5c are provided between the usage-side heat exchangers 6 and the receiver 18 as the vapor-liquid separator so as to correspond to the usage-side heat exchangers 6 so that the flow rate of the refrigerant that flows through the usage-side heat exchangers 6 can be controlled and the required refrigeration load can be obtained in the usage-side heat exchangers 6. Furthermore, during air-warming operation, intermediate pressure injection carried out by the receiver 18 as the vapor-liquid separator is used with consideration given to the possibility that the pressure of the refrigerant in the downstream side of the usage-side expansion mechanisms 5c will be reduced; and during air-cooling operation, intermediate pressure injection carried out by the economizer heat exchanger 20 is used with consideration given to keeping the pressure of the refrigerant high in the downstream side of the heat source-side heat exchanger 4 and in the upstream side of the first expansion mechanism 5a as the heat source-side expansion mechanism.

[0061] For example, in the refrigerant circuit 10 (see FIG. 1) having the intercooler bypass tube 9 and the intercooler 7 in which air is used as a heat source in the embodiment described above, the configuration has a switching mechanism 3 for making it possible to switch between air-cooling operation and air-warming operation, and a plurality of usage-side heat exchangers 6 mutually connected in parallel, as shown in FIG. 7; and the first expansion mechanisms 5a, 5d as the heat source-side expansion mechanism and the usage-side expansion mechanisms 5c as the usage-side expansion valve

are provided in place of the expansion mechanism 5. Furthermore, it is possible to use a refrigerant circuit 610 provided with a bridge circuit 17, a receiver 18, a first second-stage injection tube 18c, a second second-stage injection tube 19, and an economizer heat exchanger 20.

[0062] The switching mechanism 3 is a mechanism for switching the direction of refrigerant flow in the refrigerant circuit 610. In order to allow the heat source-side heat exchanger 4 to function as a cooler of refrigerant compressed by the compression mechanism 2 and to allow the usage-side heat exchanger 6 to function as a heater of refrigerant cooled in the heat source-side heat exchanger 4 during the air-cooling operation, the switching mechanism 3 is capable of connecting the discharge side of the compression mechanism 2 and one end of the heat source-side heat exchanger 4 and also connecting the intake side of the compressor 21 and the usage-side heat exchanger 6 (refer to the solid lines of the switching mechanism 3 in FIG. 7, this state of the switching mechanism 3 is hereinbelow referred to as the "cooling operation state"). In order to allow the usage-side heat exchanger 6 to function as a cooler of refrigerant compressed by the compression mechanism 2 and to allow the heat source-side heat exchanger 4 to function as a heater of refrigerant cooled in the usage-side heat exchanger 6 during the air-warming operation, the switching mechanism 3 is capable of connecting the discharge side of the compression mechanism 2 and the usage-side heat exchanger 6 and also of connecting the intake side of the compression mechanism 2 and one end of the heat source-side heat exchanger 4 (refer to the dashed lines of the switching mechanism 3 in FIG. 7, this state of the switching mechanism 3 is hereinbelow referred to as the "heating operation state"). In the present modification, the switching mechanism 3 is a four-way switching valve connected to the intake side of the compression mechanism 2, the discharge side of the compression mechanism 2, the heat source-side heat exchanger 4, and the usage-side heat exchanger 6. The switching mechanism 3 is not limited to a four-way switching valve, and may be configured so as to have a function for switching the direction of the flow of the refrigerant in the same manner as described above by using, e.g., a combination of a plurality of electromagnetic valves.

[0063] Thus, in terms of only the compression mechanism 2, the heat source-side heat exchanger 4, the expansion mechanisms 5a, 5d, the receiver 18, the usage-side expansion mechanisms 5c, and the usage-side heat exchangers 6 that constitute the refrigerant circuit 610, the switching mechanism 3 is configured so as to be capable of switching between an air-cooling operation state and an air-warming operation state. In the cooling operation state, refrigerant is circulated in the sequence of the compression mechanism 2, the heat source-side heat exchanger 4, the first expansion mechanism 5a as the heat source-side expansion mechanism, the receiver 18, the usage-side expansion mechanisms 5c, and the usage-side heat exchangers 6. In the warming operation

state, the refrigerant is circulated in the sequence of the compression mechanism 2, the usage-side heat exchangers 6, the usage-side expansion mechanisms 5c as the usage-side expansion valve, the receiver 18, a third expansion mechanism 5d as the heat-source side expansion mechanism, and the heat source-side heat exchanger 4.

[0064] The bridge circuit 17 is provided between the heat source-side heat exchanger 4 and the usage-side heat exchanger 6, and is connected to a receiver inlet tube 18a connected to an inlet of the receiver 18, and to a receiver outlet tube 18b connected to an outlet of the receiver 18. The bridge circuit 17 has three non-return valves 17a, 17b, 17c and a third expansion mechanism 5d as a heat source-side expansion mechanism in the present modification. The inlet non-return valve 17a is a non-return valve for allowing refrigerant to flow only from the heat source-side heat exchanger 4 to the receiver inlet tube 18a. The inlet non-return valve 17b is a non-return valve for allowing refrigerant to flow only from the usage-side heat exchanger 6 to the receiver inlet tube 18a. In other words, the inlet non-return valves 17a, 17b have the function of allowing refrigerant to flow to the receiver inlet tube 18a from either the heat source-side heat exchanger 4 or the usage-side heat exchanger 6. The outlet non-return valve 17c is a non-return valve for allowing refrigerant to flow only from the receiver outlet tube 18b to the usage-side heat exchanger 6. The third expansion mechanism 5d is a mechanism for reducing the pressure of the refrigerant and constitutes a portion of the bridge circuit 17. In other words, the outlet non-return valves 17c and the third expansion mechanism 5d have the function of allowing refrigerant to flow from the receiver outlet tube 18b to the other of the heat source-side heat exchanger 4 and the usage-side heat exchanger 6. Accordingly, the third expansion mechanism 5d is fully closed during air-cooling operation in which the switching mechanism 3 is set in the air-cooling operation state, and is designed to reduce the pressure of the refrigerant fed from the receiver outlet tube 18b to the heat source-side heat exchanger 4 during air-warming operation in which the switching mechanism 3 is set in the air-warming operation state. The third expansion mechanism 5d is an electric expansion valve in the present modification.

[0065] The first expansion mechanism 5a is a refrigerant-depressurizing mechanism provided to the receiver inlet tube 18a, and an electric expansion valve is used in the present modification. One end of the first expansion mechanism 5a is connected to the heat source-side heat exchanger 4 via the bridge circuit 17, and the other end is connected to the receiver 18. In the present modification, the first expansion mechanism 5a depressurizes the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 before feeding the refrigerant to the usage-side heat exchanger 6 during the air-cooling operation, and depressurizes the high-pressure refrigerant cooled in the usage-side heat exchanger 6 before feeding

the refrigerant to the heat source-side heat exchanger 4 during the air-warming operation. An expansion mechanism bypass valve 5e is provided to the receiver inlet tube 18a so as to bypass the first expansion mechanism 5a. The expansion mechanism bypass valve 5e is an electromagnetic valve in the present modification.

[0066] The receiver 18 is a container capable of temporarily retaining refrigerant that has been depressurized in the first expansion mechanism 5a, the inlet thereof connected to the receiver inlet tube 18a, and the outlet thereof connected to the receiver outlet tube 18b. The first second-stage injection tube 18c and an intake return tube 18f is connected to the receiver 18. In this case, the portions of the first second-stage injection tube 18c and the intake return tube 18f that are on the receiver 18 side are integrally formed.

[0067] The first second-stage injection tube 18c is a refrigerant tube capable of carrying out intermediate pressure injection for withdrawing refrigerant from the receiver 18 and returning the refrigerant to the second-stage compression element 2d of the compression mechanism 2, and in the present modification, is provided so as to connect the upper portion of the receiver 18 and the intermediate refrigerant tube 8 (i.e., the intake side of the second-stage compression element 2d of the compression mechanism 2). A first second-stage injection on-off valve 18d and first second-stage injection non-return mechanism 18e are provided to the first second-stage injection tube 18c. The first second-stage injection on-off valve 18d is a valve capable of open-close operation, and is an electromagnetic valve in the present modification. The first second-stage injection non-return mechanism 18e is a mechanism for allowing refrigerant to flow from the receiver 18 to the second-stage compression element 2d, and blocking the flow of refrigerant from the second-stage compression element 2d to the receiver 18, and is a non-return valve in the present modification.

[0068] The intake return tube 18f is a refrigerant tube capable of withdrawing refrigerant from the receiver 18 and returning the refrigerant to the first-stage compression element 2c of the compression mechanism 2, and in the present modification, is provided so as to connect the upper portion of the receiver 18 and the intake tube 2a (i.e., the intake side of the first-stage compression element 2c of the compression mechanism 2). The intake return tube 18f is provided with an intake return on/off valve 18g. The intake return on/off valve 18g is a valve capable of open-close operation and is an electromagnetic valve in the present modification.

[0069] The receiver 18 thus functions as a vapor-liquid separator for separating the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchangers 6 into vapor and gas between the usage-side expansion mechanisms 5c and the expansion mechanisms 5a, 5d in the case that the first second-stage injection tube 18c and/or the intake return tube 18f are used by opening the first second-stage in-

jection on-off valve 18d and/or the intake return on/off valve 18g; and is mainly designed to be capable of returning the gas refrigerant obtained from the vapor-liquid separation in the receiver 18 from the upper portion of the receiver 18 to the first-stage compression element 2c and/or the second-stage compression element 2d of the compression mechanism 2.

[0070] The usage-side expansion mechanisms 5c are mechanisms for reducing the pressure of the refrigerant provided between the usage-side heat exchangers 6 and the receiver 18 (more specifically, the bridge circuit 17) as a vapor-liquid separator so as to correspond to the usage-side heat exchangers 6, and is electric expansion valve in the present modification. One end of the usage-side expansion mechanisms 5c are connected to the receiver 18 via the bridge circuit 17 and the other end is connected to the usage-side heat exchangers 6. In the present modification, the usage-side expansion mechanism 5c further depressurizes the refrigerant depressurized by the first expansion mechanism 5a to a low pressure before the refrigerant is fed to the usage-side heat exchanger 6 during the air-cooling operation, and during the air-warming operation, depressurizes the refrigerant that has passed through the usage-side heat exchanger 6 before the refrigerant is fed to the receiver 18.

[0071] The second second-stage injection tube 19 has a function for branching off and returning the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchanger 6 to the second-stage compression element 2d of the compression mechanism 2. In the present modification, the second second-stage injection tube 19 is provided so as to branch off refrigerant flowing through the receiver inlet tube 18a and return the refrigerant to the second-stage compression element 2d. More specifically, the second stage injection tube 19 is provided so as to branch off and return the refrigerant from a position (i.e., between the heat source-side heat exchanger 4 and the first expansion mechanism 5a when the switching mechanism 3 is in the cooling operation state) on the upstream side of the first expansion mechanism 5a of the receiver inlet tube 18a to a position on the downstream side of the intercooler 7 of the intermediate refrigerant tube 8. In this case, the portions of the first second-stage injection tube 18c and the second second-stage injection tube 19 that are on the intermediate refrigerant tube 8 side are integrally formed. The second second-stage injection tube 19 is provided with a second second-stage injection valve 19a whose opening degree can be controlled. The second second-stage injection valve 19a is an electric expansion valve in the present modification.

[0072] The economizer heat exchanger 20 is a heat exchanger for carrying out heat exchange between the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchanger 6 and the refrigerant that flows through the second second-stage injection tube 19 (more specifically, the refrigerant that has been depressurized to near intermediate pres-

sure in the second second-stage injection valve 19a). In the present modification, the economizer heat exchanger 20 is provided so that heat exchange is carried out between the refrigerant that flows in the upstream-side position of the first expansion mechanism 5a of the receiver inlet tube 18a (i.e., between the heat source-side heat exchanger 4 and the first expansion mechanism 5a when the switching mechanism 3 is set in the air-cooling operation state) and the refrigerant that flows through the second second-stage injection tube 19, and has flow channels through which both refrigerants flow so as to oppose each other. In the present modification, the economizer heat exchanger 20 is provided further downstream from the position in which the second second-stage injection tube 19 branches from the receiver inlet tube 18a. Therefore, the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchanger 6 is branched off in the receiver inlet tube 18a into the second second-stage injection tube 19 before undergoing heat exchange in the economizer heat exchanger 20, and heat exchange is then conducted in the economizer heat exchanger 20 with the refrigerant flowing through the second second-stage injection tube 19.

[0073] Thus, when the switching mechanism 3 is set in the cooling operation state by the bridge circuit 17, the receiver 18, the receiver inlet tube 18a, and the receiver outlet tube 18b, the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 can be fed to the usage-side heat exchangers 6 through the inlet non-return valve 17a of the bridge circuit 17, the first expansion mechanism 5a of the receiver inlet tube 18a, the receiver 18, the outlet non-return valve 17c of the bridge circuit 17, and the usage-side expansion mechanisms 5c. When the switching mechanism 3 is set in the heating operation state, the high-pressure refrigerant cooled in the usage-side heat exchangers 6 can be fed to the heat source-side heat exchanger 4 through the usage-side expansion mechanisms 5c, the non-return valve 17b of the bridge circuit 17, the expansion mechanism bypass valve 5e of the receiver inlet tube 18a, the receiver 18, and the third expansion mechanism 5d of the bridge circuit 17.

[0074] In the present modification, the outlet of the second second-stage injection tube 19 side of the economizer heat exchanger 20 is provided with an economizer outlet temperature sensor 55 for detecting the temperature of the refrigerant at the outlet of the second second-stage injection tube 19 side of the economizer heat exchanger 20. A vapor-liquid separator temperature sensor 57 for detecting the temperature of the refrigerant in the receiver 18 is provided to the receiver inlet tube 18a in a position nearer to the receiver 18 than the first expansion mechanism 5a. The vapor-liquid separator temperature sensor 57 may be provided to the receiver outlet tube 18b, or may be provided directly to the receiver 18, e.g., the bottom portion of the receiver 18.

[0075] Thus, in the present modification, it is possible to separately use intermediate pressure injection carried out by the receiver 18 for returning the refrigerant from

the receiver 18 as the vapor-liquid separator to the second-stage compression element 2d via the first second-stage injection tube 18c, and intermediate pressure injection carried out by the economizer heat exchanger 20 for returning the refrigerant heated in the economizer heat exchanger 20 to the second-stage compression element 2d via the second second-stage injection tube 19

[0076] Next, the action of the air-conditioning apparatus 1 will be described using FIGS. 7 through 11. FIG. 8 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the present modification, FIG. 9 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the present modification, FIG. 10 is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in the present modification, and FIG. 11 is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in present modification. Operation controls during the following air-cooling operation and air-warming operation, and control for limiting reduction in the pressure of the vapor-liquid separator are performed by the aforementioned controller (not shown). In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', E, and H in FIGS. 8 and 9, and the pressure at points D, D', F, and H in FIGS. 10 and 11), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A, F in FIGS. 8 and 9, and the pressure at points A and E in FIGS. 10 and 11), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B1, C1, and G in FIGS. 8 through 11).

<Air-cooling operation>

[0077] During the air-cooling operation, the switching mechanism 3 is brought to the cooling operation state shown by the solid lines in FIG. 7. The degree of opening of the first expansion mechanism 5a as the heat source-side expansion mechanism and the usage-side expansion mechanisms 5c as the usage-side expansion valves is adjusted. Also, the third expansion mechanism 5d and the expansion mechanism bypass valve 5e are in a fully closed state. When the switching mechanism 3 is set in an air-cooling operation state, intermediate pressure injection carried out by the economizer heat exchanger 20 for returning the refrigerant heated in the economizer heat exchanger 20 to the second-stage compression element 2d via the second second-stage injection tube 19 is performed without carrying out intermediate pressure injection by the receiver 18 as the vapor-liquid separator. More specifically, the first second-stage injection on-off valve 18d is set in a closed state and the degree of opening of the second second-stage injection valve 19a is adjusted. Here, a so-called superheat degree control is performed wherein the opening degree of the second

second-stage injection valve 19a is adjusted so that a target value is achieved in the degree of superheat of the refrigerant at the outlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20. In the present modification, the degree of superheat of the refrigerant at the outlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20 is obtained by converting the intermediate pressure detected by the intermediate pressure sensor 54 to a saturation temperature and subtracting this refrigerant saturation temperature value from the refrigerant temperature detected by the economizer outlet temperature sensor 55. Though not used in the present embodiment, another possible option is to provide a temperature sensor to the inlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20, and to obtain the degree of superheat of the refrigerant at the outlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20 by subtracting the refrigerant temperature detected by this temperature sensor from the refrigerant temperature detected by the economizer outlet temperature sensor 55. Furthermore, the cooler on/off valve 12 is opened and the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 is closed, thereby putting the intercooler 7 into a state of functioning as a cooler.

[0078] When the compression mechanism 2 is driven while the refrigerant circuit 610 is in this state, low-pressure refrigerant (refer to point A in FIGS. 7 through 9) is drawn into the compression mechanism 2 through the intake tube 2a, and after the refrigerant is first compressed to an intermediate pressure by the compression element 2c, the refrigerant is discharged to the intermediate refrigerant tube 8 (refer to point B1 in FIGS. 7 through 9). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled by heat exchange with air and/or water as a cooling source (refer to point C1 in FIGS. 7 to 9). The refrigerant cooled in the intercooler 7 is further cooled (refer to point G in FIGS. 7 to 9) by being mixed with refrigerant being returned from the second second-stage injection tube 19 to the second-stage compression element 2d (refer to point K in FIGS. 7 to 9). Next, having been mixed with the refrigerant returned from the second second-stage injection tube 19 (i.e., intermediate pressure injection carried out by the economizer heat exchanger 20), the intermediate-pressure refrigerant is drawn into and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is then discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 7 to 9). The high-pressure refrigerant discharged from the compression mechanism 2 is compressed by the two-stage compression action of the compression elements 2c, 2d to a pressure exceeding a critical pressure (i.e., the critical pressure P_{cp} at the critical point CP shown in FIG. 8). The high-pressure refrigerant discharged from the compression mechanism 2 is

fed via the switching mechanism 3 to the heat source-side heat exchanger 4 functioning as a refrigerant cooler, and the refrigerant is cooled by heat exchange with air and/or water as a cooling source (refer to point E in FIGS. 7 to 9). The high-pressure refrigerant cooled in the heat source-side heat exchanger 4 flows through the inlet non-return valve 17a of the bridge circuit 17 into the receiver inlet tube 18a, and some of the refrigerant is branched off into the second second-stage injection tube 19. The refrigerant flowing through the second second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the second second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 7 to 9). The refrigerant flowing through the receiver inlet tube 18a after being branched off to the second second-stage injection tube 19 then flows into the economizer heat exchanger 20, where it is cooled by heat exchange with the refrigerant flowing through the second second-stage injection tube 19 (refer to point H in FIGS. 7 to 9). The refrigerant flowing through the second second-stage injection tube 19 is heated by heat exchange with the refrigerant flowing through the receiver inlet tube 18a (refer to point K in FIGS. 7 to 9), and this refrigerant is mixed with the refrigerant cooled in the intercooler 7 as described above. The high-pressure refrigerant cooled in the economizer heat exchanger 20 is depressurized to a nearly saturated pressure by the first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 7 to 9). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b, is fed to the usage-side expansion mechanisms 5c via the receiver outlet tube 18b and the outlet non-return valve 17c of the bridge circuit 17, and is depressurized by the usage-side expansion mechanism 5c to become a low-pressure gas-liquid two-phase refrigerant (refer to point F in FIGS. 7 to 9). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger 6 is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. 7 to 9). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is then led back into the compression mechanism 2 via the switching mechanism 3. In this manner the air-cooling operation is performed.

[0079] In the configuration of the present modification, in addition to the cooling of the refrigerant drawn into the second-stage compression element 2d by the intercooler 7, the temperature of the refrigerant drawn into the second-stage compression element 2d can be kept low by intermediate pressure injection using the second second-stage injection tube 19 and the economizer heat exchanger 20. Therefore, the temperature of the refrigerant discharged from the compression mechanism 2 can be even further reduced (refer to points D and D' in FIG. 9). The power consumption of the compression mechanism 2 is thereby reduced and operating efficiency can be improved.

<Air-warming operation>

[0080] During the air-warming operation, the switching mechanism 3 is brought to the heating operation state shown by the dashed lines in FIG. 7. The degree of opening of the third expansion mechanism 5d as the heat source-side expansion mechanism and the usage-side expansion mechanisms 5c as usage-side expansion valves is adjusted. The expansion mechanism bypass valve 5e is set in a fully opened state, and depressurization is not performed by the first expansion mechanism 5a. When the switching mechanism 3 is set in a heating operation state, intermediate pressure injection is not carried out by the economizer heat exchanger 20, and intermediate pressure injection is carried out by the receiver 18 as the vapor-liquid separator to the second-stage compression element 2d via the first second-stage injection tube 18c. More specifically, the first second-stage injection on-off valve 18d is set in an open state, and the second second-stage injection valve 19a is set in a fully closed state. Furthermore, the cooler on/off valve 12 is closed and the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 is opened, thereby putting the intercooler 7 into a state of not functioning as a cooler.

[0081] When the compression mechanism 2 is driven while the refrigerant circuit 610 is in this state, low-pressure refrigerant (refer to point A in FIGS. 7, 10, and 11) is drawn into the compression mechanism 2 through the intake tube 2a, and after the refrigerant is first compressed by the compression element 2c to an intermediate pressure, the refrigerant is discharged to the intermediate refrigerant tube 8 (refer to point B1 in FIGS. 7, 10 and 11). Unlike the air-cooling operation, the intermediate-pressure refrigerant discharged from the first-stage compression element 2c passes through the intercooler bypass tube 9 (refer to point C1 in FIG. 7) without passing through the intercooler 7 (i.e. without being cooled), and the refrigerant is cooled (refer to point G in FIGS. 7, 10, and 11) by being mixed with refrigerant being returned from the receiver 18 to the second-stage compression element 2d via the first second-stage injection tube 18c (refer to point M in FIGS. 7, 10, and 11). Next, having been mixed with the refrigerant returning from the first second-stage injection tube 18c (i.e., intermediate pressure injection is carried out by the receiver 18 which acts as a gas-liquid separator), the intermediate-pressure refrigerant is led to and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 7, 10, and 11). The high-pressure refrigerant discharged from the compression mechanism 2 is compressed by the two-stage compression action of the compression elements 2c, 2d to a pressure exceeding a critical pressure (i.e., the critical pressure P_{ep} at the critical point CP shown in FIG. 10), similar to the air-cooling operation. The high-pres-

sure refrigerant discharged from the compression mechanism 2 is fed via the switching mechanism 3 to the usage-side heat exchanger 6 functioning as a refrigerant cooler, and the refrigerant is cooled by heat exchange with air or water as a cooling source (refer to point F in FIGS. 7, 10, and 11). The high-pressure refrigerant cooled in the usage-side heat exchanger 6 is depressurized by the usage-side expansion mechanisms 5c to approximately intermediate pressure, is allowed to flow into the receiver inlet tube 18a via the inlet non-return valve 17b of the bridge circuit 17, and passes through the expansion mechanism bypass valve 5e and temporarily retained and made to undergo vapor-liquid separation inside the receiver 18 (refer to points I, L, M in FIGS. 7, 10, 11). The gas refrigerant separated in vapor-liquid separation in the receiver 18 is withdrawn by the first second-stage injection tube 18c from the upper portion of the receiver 18, and is mixed with the intermediate-pressure refrigerant discharged from the first-stage compression element 2c, as described above. The liquid refrigerant retained in the receiver 18 is fed to the bridge circuit 17 via the receiver outlet tube 18b, is depressurized by the third expansion mechanism 5d to become low-pressure gas-liquid two-phase refrigerant, and is fed to the heat source-side heat exchanger 4 that functions as a refrigerant heater (refer to point E in FIGS. 7, 10, 11). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger 4 is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. 7, 10, and 11). The low-pressure refrigerant heated in the heat source-side heat exchanger 4 is then led back into the compression mechanism 2 via the switching mechanism 3. In this manner the air-warming operation is performed.

[0082] In the configuration of the present modification, the temperature of the refrigerant discharged from the compression mechanism 2 can be kept low because the temperature of the refrigerant drawn into the second-stage compression element 2d can be kept low by intermediate pressure injection using the receiver 18 and the first second-stage injection tube 18c (refer to points D and D' in FIG. 11). The power consumption of the compression mechanism 2 is thereby reduced and operating efficiency can be improved. However, the intercooler 7 is not allowed to function as a cooler, which is different from that during air-cooling operation; and heat radiation loss by the intercooler 7 to the exterior is suppressed and a reduction in heating ability in the usage-side heat exchangers 6 is suppressed in comparison with the case in which the intercooler 7 is made to function as a cooler in the same manner as the air-cooling operation.

<Superheat degree control of refrigerant drawn into the second-stage compression element>

[0083] In the present modification, the air-warming operation, which is accompanied by intermediate pressure

injection by the receiver 18 as the vapor-liquid separator, produces operating conditions in which a large amount of liquid refrigerant is retained in the receiver 18 as the vapor-liquid separator, the cause of which is unknown. When vapor-liquid separation becomes difficult, liquid refrigerant is liable to become mixed with the refrigerant that returns from the receiver 18 to the second-stage compression element 2d via the first second-stage injection tube 18c, whereby the intermediate-pressure refrigerant drawn into the second-stage compression element 2d becomes wet after intermediate pressure injection has been carried out, and the reliability of the compression mechanism 2 is liable to be compromised.

[0084] In view of the above, in the present modification, the degree of superheat of the refrigerant drawn into the second-stage compression element 2d is controlled by the open-close operation of the first second-stage injection on-off valve 18d. Specifically, in the present modification, the first second-stage injection on-off valve 18d is opened and closed so that the degree of superheat of the refrigerant drawn into the second-stage compression element 2d after intermediate pressure injection has been carried out by the receiver 18 does not become less than a predetermined value. Here, the degree of superheat of the refrigerant drawn into the second-stage compression element 2d is obtained by converting the compression mechanism intermediate pressure detected by the intermediate pressure sensor 54 to a saturation temperature and subtracting the saturation temperature of the refrigerant that corresponds to the compression mechanism intermediate pressure from the temperature of the refrigerant detected by the intermediate temperature sensor 56. The predetermined value of the degree of superheat used in this control process is set to a value that is greater than at least 0°, e.g., several °C to several tens of °C, so that the intermediate-pressure refrigerant drawn into the second-stage compression element 2d does not become wet. The open-close operation of the first second-stage injection on-off valve 18d can be carried out by varying the time ratio between time t1 in which the first second-stage injection on-off valve 18d is set in an open-state and the time t2 at which the closed-state is set. In the present modification, the first second-stage injection on-off valve 18d is kept in an open-state by setting the time ratio of time t2 in relation to time t1 to 0 in order to positively carry out intermediate pressure injection by the receiver 18 in the case that the degree of superheat of the refrigerant drawn into the second-stage compression element 2d is at a predetermined value or greater; and the time ratio of time t2 with respect to time t1 is changed in the increase direction (i.e., the time that the first second-stage injection on-off valve 18d is in a closed state) in order to reduce the flow rate of the refrigerant returning from the receiver 18 to the second-stage compression element 2d in the case that the degree of superheat of the refrigerant drawn into the second-stage compression element 2d is less than a predetermined value. After the degree of superheat of the re-

refrigerant drawn into the second-stage compression element 2d has recovered to a predetermined value or higher, the time ratio of time t2 with respect to time t1 is changed in the decrease direction in order to cause the flow rate of the refrigerant returned from the receiver 18 to the second-stage compression element 2d to increase again.

[0085] Thus, in the present modification, the degree of superheat of the refrigerant discharged from the first-stage compression element 2c and drawn into the second-stage compression element 2d is controlled by the open-close operation of the first second-stage injection on-off valve 18d. Therefore, the refrigerant drawn into the second-stage compression element 2d can be prevented from becoming wet by reducing the flow rate of the refrigerant returned from the receiver 18 to the second-stage compression element 2d, even under operating conditions in which a large quantity of the liquid refrigerant is retained in the receiver 18 as the vapor-liquid separator and the liquid refrigerant mixes with the refrigerant returned from the receiver 18 to the second-stage compression element 2d. The reliability of the compression mechanism 2 during air-warming operation is thereby improved in the present modification.

[0086] In the present modification, intermediate pressure injection carried out by the economizer heat exchanger 20 is performed during air-cooling operation, and the degree of superheat of the refrigerant returned from the second second-stage injection tube 19 to the second-stage compression element 2d is controlled by adjusting the degree of opening of the second second-stage injection valve 19a so as to achieve a target value. Accordingly, in the present modification, the refrigerant drawn into the second-stage compression element 2d can be prevented from becoming wet due to the effect of the refrigerant returned to the second-stage compression element 2d by intermediate pressure injection carried out by the economizer heat exchanger 20 in the air-cooling operation, whereby the reliability of the compression mechanism 2 is improved.

[0087] Furthermore, in the present modification, wet prevention control is carried out using the intercooler bypass tube 9 so that refrigerant does not flow to the intercooler 7 when the temperature of the air as the heat source of the intercooler 7 is equal to or less than the saturation temperature of the intermediate-pressure refrigerant fed from the first-stage compression element 2c to the second-stage compression element 2d, as in the embodiment described above. Therefore, the refrigerant drawn into the second-stage compression element 2d can be prevented from becoming wet even under operating conditions in which the temperature of the air as the heat source of the intercooler 7 is low, whereby the reliability of the compression mechanism 2 is improved.

[0088] Thus, in the present modification, the refrigerant drawn into the second-stage compression element 2d can be prevented from becoming wet due to the cooling operation of the intercooler 7 and/or the effect of the

refrigerant returned to the second-stage compression element 2d by intermediate pressure injection, whereby the reliability of the compression mechanism 2 is improved in the air-cooling operation and the air-warming operation.

[0089] In the refrigerant circuit 610 described above (see FIG. 7), the first expansion mechanism 5a and the receiver 18 are connected between the heat source-side heat exchanger 4 and the usage-side heat exchangers 6 via the bridge circuit 17 (including the third expansion mechanism 5d), but it is possible to use a refrigerant circuit 710 configured so that the bridge circuit 17 is omitted and the first expansion mechanism 5a is connected between the heat source-side heat exchanger 4 and the receiver 18, as shown in FIG. 12, whereby the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchangers 6 flows in sequence through the first expansion mechanism 5a, the receiver 18, and the usage-side expansion mechanisms 5c when the switching mechanism 3 is set in the air-cooling operation state; and the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchangers 6 flows in sequence through the usage-side expansion mechanisms 5c, the receiver 18, and the first expansion mechanism 5a when the switching mechanism 3 is set in the heating operation state.

[0090] In this configuration, the differing points are that the bridge circuit 17 is omitted and that the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchanger 6 does so in the sequence of the usage-side expansion mechanisms 5c, the receiver 18, and the first expansion mechanism 5a when the switching mechanism 3 is set in the heating operation state (accordingly, the points I and L in FIGS. 10 and 11 change places); however, the same operational effects as those described above can also be achieved.

[0091] The configuration of the intercooler 7 and the like in the embodiment described above is used as the configuration of the intercooler 7 and the like in the refrigerant circuits 610, 710 described above (see FIGS. 7 and 12), but no limitation is imposed thereby; it also being possible to use the configuration of Modifications 1 to 3.

(7) Modification 5

[0092] In the above-described embodiment and modifications thereof, a two-stage compression-type compression mechanism 2 is configured from the single compressor 21 having a single-shaft two-stage compression structure, wherein two compression elements 2c, 2d are provided and refrigerant discharged from the first-stage compression element is sequentially compressed in the second-stage compression element, but another possible option is to use a multistage compression mechanism such as three-stage compression or the like having more than two compression stages. Another possible option

is to configure a multistage compression mechanism by connecting in series a plurality of compressors having a single compression element and/or a plurality of compressors having a plurality of compression elements. Yet another possible option is to use a parallel multistage compression mechanism in which two or more multistage compression mechanisms are connected in parallel in the case that there is a need to increase the capacity of the compression mechanism, such as the case in which several usage-side heat exchangers 6 are connected.

[0093] For example, in a refrigerant circuit 610 (see FIG. 7) that does not have the bridge circuit 17 of Modification 4 described above, in place of the two-stage compression mechanism 2, it is also possible to use a refrigerant circuit 810 having a compression mechanism 102 in which two two-stage compression mechanisms 103, 104 are connected in parallel, as shown in FIG. 13.

[0094] In the present modification, the first compression mechanism 103 is configured using a compressor 29 for subjecting the refrigerant to two-stage compression through two compression elements 103c, 103d, and is connected to a first intake branch tube 103a which branches off from an intake header tube 102a of the compression mechanism 102, and also to a first discharge branch tube 103b whose flow merges with a discharge header tube 102b of the compression mechanism 102. In the present modification, the second compression mechanism 104 is configured using a compressor 30 for subjecting the refrigerant to two-stage compression through two compression elements 104c, 104d, and is connected to a second intake branch tube 104a which branches off from the intake header tube 102a of the compression mechanism 102, and also to a second discharge branch tube 104b whose flow merges with the discharge header tube 102b of the compression mechanism 102. Since the compressors 29, 30 have the same configuration as the compressor 21 in the embodiment and modifications thereof described above, symbols indicating components other than the compression elements 103c, 103d, 104c, 104d are replaced with symbols beginning with 29 or 30, and these components are not described. The compressor 29 is configured so that refrigerant is drawn from the first intake branch tube 103a, the refrigerant thus drawn in is compressed by the compression element 103c and then discharged to a first inlet-side intermediate branch tube 81 that constitutes the intermediate refrigerant tube 8, the refrigerant discharged to the first inlet-side intermediate branch tube 81 is caused to be drawn into the compression element 103d by way of an intermediate header tube 82 and a first outlet-side intermediate branch tube 83 constituting the intermediate refrigerant tube 8, and the refrigerant is further compressed and then discharged to the first discharge branch tube 103b. The compressor 30 is configured so that refrigerant is drawn in through the first intake branch tube 104a, the drawn-in refrigerant is compressed by the compression element 104c and then discharged to a second inlet-side intermediate branch tube 84 con-

stituting the intermediate refrigerant tube 8, the refrigerant discharged to the second inlet-side intermediate branch tube 84 is drawn in into the compression element 104d via the intermediate header tube 82 and a second outlet-side intermediate branch tube 85 constituting the intermediate refrigerant tube 8, and the refrigerant is further compressed and then discharged to the second discharge branch tube 104b. In the present modification, the intermediate refrigerant tube 8 is a refrigerant tube for admitting refrigerant discharged from the compression elements 103c, 104c connected to the first-stage sides of the compression elements 103d, 104d into the compression elements 103d, 104d connected to the second-stage sides of the compression elements 103c, 104c, and the intermediate refrigerant tube 8 primarily comprises the first inlet-side intermediate branch tube 81 connected to the discharge side of the first-stage compression element 103c of the first compression mechanism 103, the second inlet-side intermediate branch tube 84 connected to the discharge side of the first-stage compression element 104c of the second compression mechanism 104, the intermediate header tube 82 whose flow merges with both inlet-side intermediate branch tubes 81, 84, the first discharge-side intermediate branch tube 83 branching off from the intermediate header tube 82 and connected to the intake side of the second-stage compression element 103d of the first compression mechanism 103, and the second outlet-side intermediate branch tube 85 branching off from the intermediate header tube 82 and connected to the intake side of the second-stage compression element 104d of the second compression mechanism 104. The discharge header tube 102b is a refrigerant tube for feeding refrigerant discharged from the compression mechanism 102 to the switching mechanism 3. A first oil separation mechanism 141 and a first non-return mechanism 142 are provided to the first discharge branch tube 103b connected to the discharge header tube 102b. A second oil separation mechanism 143 and a second non-return mechanism 144 are provided to the second discharge branch tube 104b connected to the discharge header tube 102b. The first oil separation mechanism 141 is a mechanism whereby refrigeration oil that accompanies the refrigerant discharged from the first compression mechanism 103 is separated from the refrigerant and returned to the intake side of the compression mechanism 102. The first oil separation mechanism mainly has a first oil separator 141a for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first compression mechanism 103, and a first oil return tube 141b that is connected to the first oil separator 141a and that is used for returning the refrigeration oil separated from the refrigerant to the intake side of the compression mechanism 102. The second oil separation mechanism 143 is a mechanism whereby refrigeration oil that accompanies the refrigerant discharged from the second compression mechanism 104 is separated from the refrigerant and returned to the intake side of the com-

pression mechanism 102. The second oil separation mechanism 143 mainly has a second oil separator 143a for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the second compression mechanism 104, and a second oil return tube 143b that is connected to the second oil separator 143a and that is used for returning the refrigeration oil separated from the refrigerant to the intake side of the compression mechanism 102. In the present modification, the first oil return tube 141b is connected to the second intake branch tube 104a, and the second oil return tube 143c is connected to the first intake branch tube 103a. Accordingly, a greater amount of refrigeration oil returns to the compression mechanism 103, 104 that has the lesser amount of refrigeration oil even when there is an imbalance between the amount of refrigeration oil that accompanies the refrigerant discharged from the first compression mechanism 103 and the amount of refrigeration oil that accompanies the refrigerant discharged from the second compression mechanism 104, which is due to the imbalance in the amount of refrigeration oil retained in the first compression mechanism 103 and the amount of refrigeration oil retained in the second compression mechanism 104. The imbalance between the amount of refrigeration oil retained in the first compression mechanism 103 and the amount of refrigeration oil retained in the second compression mechanism 104 is therefore resolved. In the present modification, the first intake branch tube 103a is configured so that the portion leading from the flow juncture with the second oil return tube 143b to the flow juncture with the intake header tube 102a slopes downward toward the flow juncture with the intake header tube 102a, while the second intake branch tube 104a is configured so that the portion leading from the flow juncture with the first oil return tube 141b to the flow juncture with the intake header tube 102a slopes downward toward the flow juncture with the intake header tube 102a. Therefore, even if either one of the compression mechanisms 103, 104 is stopped, refrigeration oil being returned from the oil return tube corresponding to the operating compression mechanism to the intake branch tube corresponding to the stopped compression mechanism is returned to the intake header tube 102a, and there will be little likelihood of a shortage of oil supplied to the operating compression mechanism. The oil return tubes 141b, 143b are provided with depressurizing mechanisms 141c, 143c for depressurizing the refrigeration oil that flows through the oil return tubes 141b, 143b. The non-return mechanism 142, 144 are mechanisms for allowing refrigerant to flow from the discharge side of the compression mechanisms 103, 104 to the switching mechanism 3, and for cutting off the flow of refrigerant from the switching mechanism 3 to the discharge side of the compression mechanism 103, 104.

[0095] Thus, in the present modification, the compression mechanism 102 is configured by connecting two compression mechanisms in parallel; namely, the first compression mechanism 103 having two compression

elements 103c, 103d and configured so that refrigerant discharged from the first-stage compression element of these compression elements 103c, 103d is sequentially compressed by the second-stage compression element, and the second compression mechanism 104 having two compression elements 104c, 104d and configured so that refrigerant discharged from the first-stage compression element of these compression elements 104c, 104d is sequentially compressed by the second-stage compression element.

[0096] In the present modification, the intercooler 7 is provided to the intermediate header tube 82 constituting the intermediate refrigerant tube 8, and the intercooler 7 is a heat exchanger for cooling the conjoined flow of the refrigerant discharged from the first-stage compression element 103c of the first compression mechanism 103 and the refrigerant discharged from the first-stage compression element 104c of the second compression mechanism 104. Specifically, the intercooler 7 functions as a shared cooler for two compression mechanisms 103, 104. Accordingly, the circuit configuration is simplified around the compression mechanism 102 when the intercooler 7 is provided to the parallel-multistage-compression-type compression mechanism 102 in which a plurality of multistage-compression-type compression mechanisms 103, 104 are connected in parallel.

[0097] The first inlet-side intermediate branch tube 81 constituting the intermediate refrigerant tube 8 is provided with a non-return mechanism 81a for allowing the flow of refrigerant from the discharge side of the first-stage compression element 103c of the first compression mechanism 103 toward the intermediate header tube 82 and for blocking the flow of refrigerant from the intermediate header tube 82 toward the discharge side of the first-stage compression element 103c, while the second inlet-side intermediate branch tube 84 constituting the intermediate refrigerant tube 8 is provided with a non-return mechanism 84a for allowing the flow of refrigerant from the discharge side of the first-stage compression element 104c of the second compression mechanism 104 toward the intermediate header tube 82 and for blocking the flow of refrigerant from the intermediate header tube 82 toward the discharge side of the first-stage compression element 104c. In the present modification, non-return valves are used as the non-return mechanisms 81 a, 84a. Therefore, even if either one of the compression mechanisms 103, 104 has stopped, there are no instances in which refrigerant discharged from the first-stage compression element of the operating compression mechanism passes through the intermediate refrigerant tube 8 and travels to the discharge side of the first-stage compression element of the stopped compression mechanism. Therefore, there are no instances in which refrigerant discharged from the first-stage compression element of the operating compression mechanism passes through the interior of the first-stage compression element of the stopped compression mechanism and exits out through the intake side of the

compression mechanism 102, which would cause the refrigeration oil of the stopped compression mechanism to flow out, and it is thus unlikely that there will be insufficient refrigeration oil for starting up the stopped compression mechanism. In the case that the compression mechanisms 103, 104 are operated in order of priority (for example, in the case of a compression mechanism in which priority is given to operating the first compression mechanism 103), the stopped compression mechanism described above will always be the second compression mechanism 104, and therefore in this case only the non-return mechanism 84a corresponding to the second compression mechanism 104 need be provided.

[0098] In cases of a compression mechanism which prioritizes operating the first compression mechanism 103 as described above, since a shared intermediate refrigerant tube 8 is provided for both compression mechanisms 103, 104, the refrigerant discharged from the first-stage compression element 103c corresponding to the operating first compression mechanism 103 passes through the second outlet-side intermediate branch tube 85 of the intermediate refrigerant tube 8 and travels to the intake side of the second-stage compression element 104d of the stopped second compression mechanism 104, whereby there is a danger that refrigerant discharged from the first-stage compression element 103c of the operating first compression mechanism 103 will pass through the interior of the second-stage compression element 104d of the stopped second compression mechanism 104 and exit out through the discharge side of the compression mechanism 102, causing the refrigeration oil of the stopped second compression mechanism 104 to flow out, resulting in insufficient refrigeration oil for starting up the stopped second compression mechanism 104. In view of this, an on/off valve 85a is provided to the second outlet-side intermediate branch tube 85 in the present modification, and when the second compression mechanism 104 has stopped, the flow of refrigerant through the second outlet-side intermediate branch tube 85 is blocked by the on/off valve 85a. The refrigerant discharged from the first-stage compression element 103c of the operating first compression mechanism 103 thereby no longer passes through the second outlet-side intermediate branch tube 85 of the intermediate refrigerant tube 8 and travels to the intake side of the second-stage compression element 104d of the stopped second compression mechanism 104; therefore, there are no longer any instances in which the refrigerant discharged from the first-stage compression element 103c of the operating first compression mechanism 103 passes through the interior of the second-stage compression element 104d of the stopped second compression mechanism 104 and exits out through the discharge side of the compression mechanism 102 which causes the refrigeration oil of the stopped second compression mechanism 104 to flow out, and it is thereby even more unlikely that there will be insufficient refrigeration oil for starting up the stopped second compression mechanism 104. An

electromagnetic valve is used as the on/off valve 85a in the present modification.

[0099] In the case of a compression mechanism which prioritizes operating the first compression mechanism 103, the second compression mechanism 104 is started up in continuation from the starting up of the first compression mechanism 103, but at this time, since a shared intermediate refrigerant tube 8 is provided for both compression mechanisms 103, 104, the starting up takes place from a state in which the pressure in the discharge side of the first-stage compression element 103c of the second compression mechanism 104 and the pressure in the intake side of the second-stage compression element 103d are greater than the pressure in the intake side of the first-stage compression element 103c and the pressure in the discharge side of the second-stage compression element 103d, and it is difficult to start up the second compression mechanism 104 in a stable manner. In view of this, in the present modification, there is provided a startup bypass tube 86 for connecting the discharge side of the first-stage compression element 104c of the second compression mechanism 104 and the intake side of the second-stage compression element 104d, and an on/off valve 86a is provided to this startup bypass tube 86. In cases in which the second compression mechanism 104 has stopped, the flow of refrigerant through the startup bypass tube 86 is blocked by the on/off valve 86a and the flow of refrigerant through the second outlet-side intermediate branch tube 85 is blocked by the on/off valve 85a. When the second compression mechanism 104 is started up, a state in which refrigerant is allowed to flow through the startup bypass tube 86 can be restored via the on/off valve 86a, whereby the refrigerant discharged from the first-stage compression element 104c of the second compression mechanism 104 is drawn into the second-stage compression element 104d via the startup bypass tube 86 without being mixed with the refrigerant discharged from the first-stage compression element 103c of the first compression mechanism 103, a state of allowing refrigerant to flow through the second outlet-side intermediate branch tube 85 can be restored via the on/off valve 85a at a point in time when the operating state of the compression mechanism 102 has been stabilized (e.g., a point in time when the intake pressure, discharge pressure, and intermediate pressure of the compression mechanism 102 have been stabilized), the flow of refrigerant through the startup bypass tube 86 can be blocked by the on/off valve 86a, and operation can transition to the normal air-cooling operation. In the present modification, one end of the startup bypass tube 86 is connected between the on/off valve 85a of the second outlet-side intermediate branch tube 85 and the intake side of the second-stage compression element 104d of the second compression mechanism 104, while the other end is connected between the discharge side of the first-stage compression element 104c of the second compression mechanism 104 and the non-return mechanism 84a of the second inlet-side

intermediate branch tube 84, and when the second compression mechanism 104 is started up, the startup bypass tube 86 can be kept in a state of being substantially unaffected by the intermediate pressure portion of the first compression mechanism 103. An electromagnetic valve is used as the on/off valve 86a in the present modification.

[0100] The actions of the air-conditioning apparatus 1 of the present modification during the air-cooling operation, the air-warming operation, the wet prevention control, and the like are essentially the same as the actions in the above-described embodiment and modifications thereof (FIGS. 1 through 12 and the relevant descriptions), except that the points modified by the circuit configuration surrounding the compression mechanism 102 are somewhat more complex due to the compression mechanism 102 being provided instead of the compression mechanism 2, for which reason the actions are not described herein.

[0101] The same operational effects as those of the above-described embodiment and modifications thereof can also be achieved with the configuration of the present modification.

[0102] In a refrigerant circuit 710 (see FIG. 12) that does not have the bridge circuit 17 of Modification 4 described above, in place of the two-stage compression-type compression mechanism 2, it is also possible to use a refrigerant circuit 910 having a compression mechanism 102 in which two two-stage compression-type compression mechanisms 103, 104 are connected in parallel, as shown in FIG. 14.

[0103] Since the bridge circuit 17 is omitted in this configuration, the configuration is different from that of the refrigerant circuit 810 (see FIG. 13) in that the refrigerant that flows between the heat source-side heat exchanger 4 and the usage-side heat exchanger 6 flows in the sequence of the usage-side expansion mechanisms 5c, the receiver 18, and the first expansion mechanism 5a when the switching mechanism 3 is set in the heating operation state, but the same operational effects as those described above can be achieved.

(8) Other embodiments

[0104] Embodiments of the present invention and modifications thereof are described above with reference to the drawings, but the specific configuration is not limited to these embodiments or their modifications, and can be changed within a range that does not deviate from the scope of the invention.

[0105] For example, in the above-described embodiment and modifications thereof, the present invention may be applied to a so-called chiller-type air-conditioning apparatus in which water or brine is used as a heating source or cooling source for conducting heat exchange with the refrigerant flowing through the usage-side heat exchanger 6, and a secondary heat exchanger is provided for conducting heat exchange between indoor air and

the water or brine that has undergone heat exchange in the usage-side heat exchanger 6.

[0106] The present invention can also be applied to other types of refrigeration apparatuses besides the above-described chiller-type air-conditioning apparatus, as long as the apparatus performs a multistage compression refrigeration cycle by using a refrigerant that operates in a supercritical range as its refrigerant.

[0107] The refrigerant that operates in a supercritical range is not limited to carbon dioxide; ethylene, ethane, nitric oxide, and other gases may also be used.

INDUSTRIAL APPLICABILITY

[0108] If the present invention is used, it is possible to prevent the refrigerant drawn into the second-stage compression element from becoming wet in a refrigeration apparatus that carries out a multistage compression refrigeration cycle, even under operation conditions in which the temperature of the heat source of the intercooler is low.

Claims

1. A refrigeration apparatus (1), the refrigeration apparatus comprising:

a compression mechanism (2, 102) having a plurality of compression elements and configured so that refrigerant discharged from a first-stage compression element of the plurality of compression elements is sequentially compressed by a second-stage compression element;
a heat source-side heat exchanger (4);
a usage-side heat exchanger (6);
an intercooler (7) which is provided to an intermediate refrigerant tube (18) for drawing refrigerant discharged from the first-stage compression element into the second-stage compression element, and which functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element; and
an intercooler bypass tube (9) connected to the intermediate refrigerant tube so as to bypass the intercooler; wherein
a wet prevention control is performed using the intercooler bypass tube so that refrigerant does not flow to the intercooler when the heat source temperature of the intercooler or the outlet refrigerant temperature of the intercooler is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element.

2. The refrigeration apparatus (1) according to claim 1,

wherein the intercooler (7) is a heat exchanger in which air is used as a heat source.

3. The refrigeration apparatus (1) according to claim 1, wherein
the intercooler (7) is a heat exchanger in which water is used as a heat source; and water fed to the intercooler is stopped during wet prevention control. 5

4. A refrigeration apparatus (1), the refrigeration apparatus comprising: 10
 - a compression mechanism (2, 102) having a plurality of compression elements and configured so that refrigerant discharged from a first-stage compression element of the plurality of compression elements is sequentially compressed by a second-stage compression element; 15
 - a heat source-side heat exchanger (4);
 - a usage-side heat exchanger (6); and 20
 - an intercooler (7) which is a heat exchanger having water as a heat source, and which is provided to an intermediate refrigerant tube (8) for drawing refrigerant discharged from the first-stage compression element into the second-stage compression element, and which functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element; wherein 25
 - a wet prevention control for reducing the flow rate of water that flows through the intercooler is carried out when the heat source temperature of the intercooler or the outlet refrigerant temperature of the intercooler is equal to or less than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element. 30

5. The refrigeration apparatus (1) according to claim 4, wherein, in the wet prevention control, the flow rate of water that flows through the intercooler is controlled so that the outlet refrigerant temperature of the intercooler (7) is higher than the saturation temperature of the refrigerant fed from the first-stage compression element to the second-stage compression element. 35

6. The refrigeration apparatus (1) according to any of claims 1 to 5, further comprising a second-stage injection tube (18c, 19) for branching refrigerant that flows between the heat source-side heat exchanger (4) and the usage-side heat exchanger (6), and returning the refrigerant to the second-stage compression element. 40 45 50 55

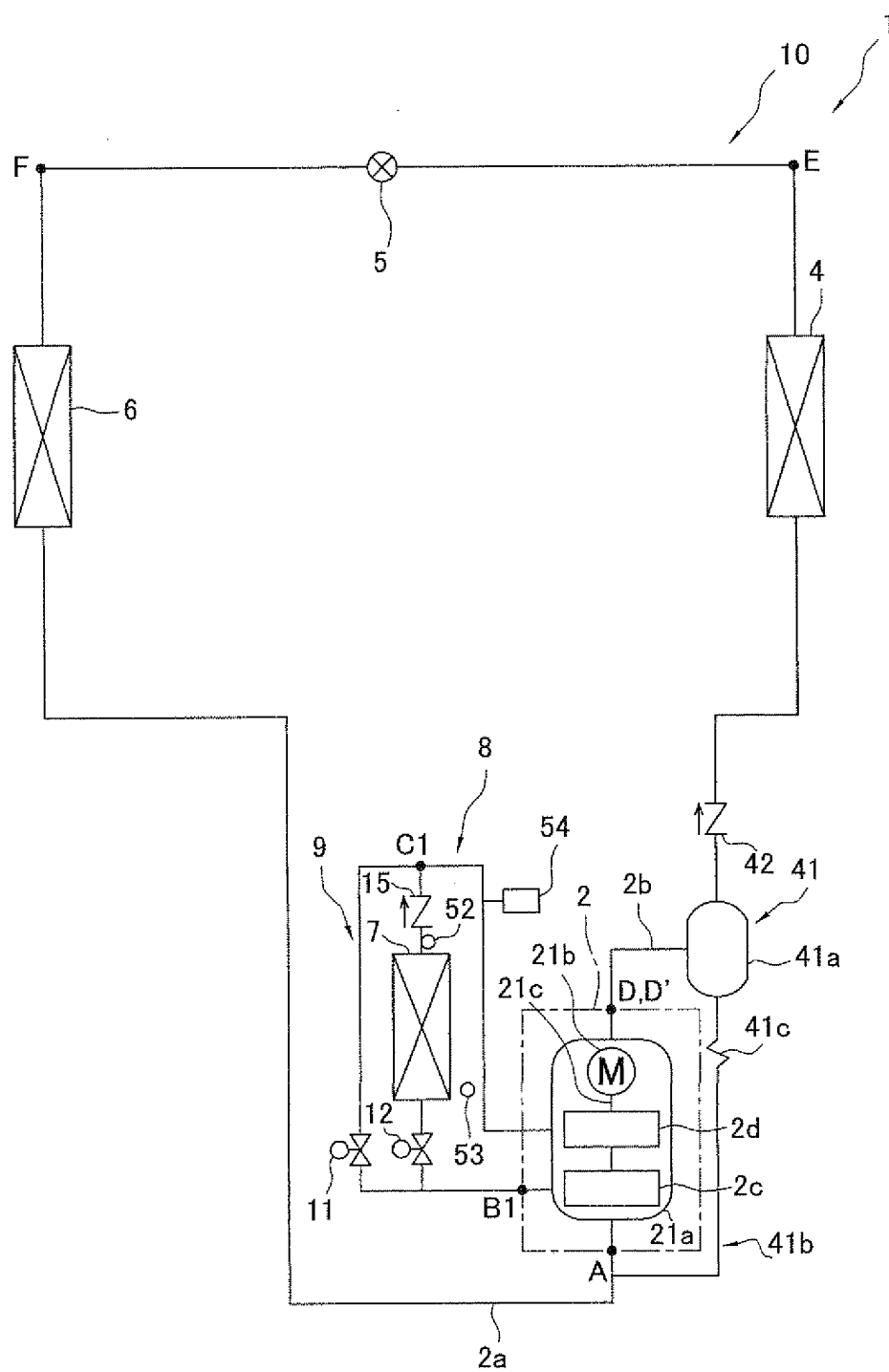


FIG. 1

FIG. 2

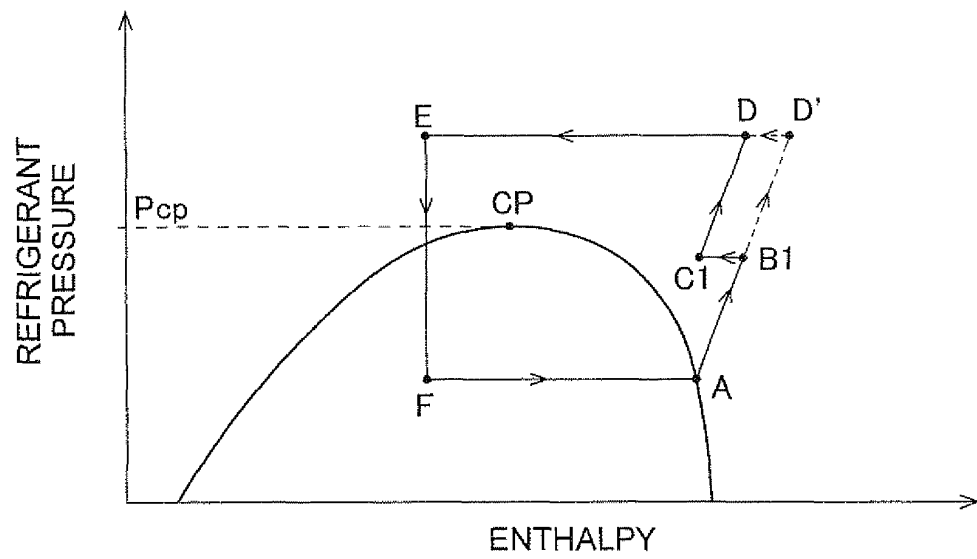
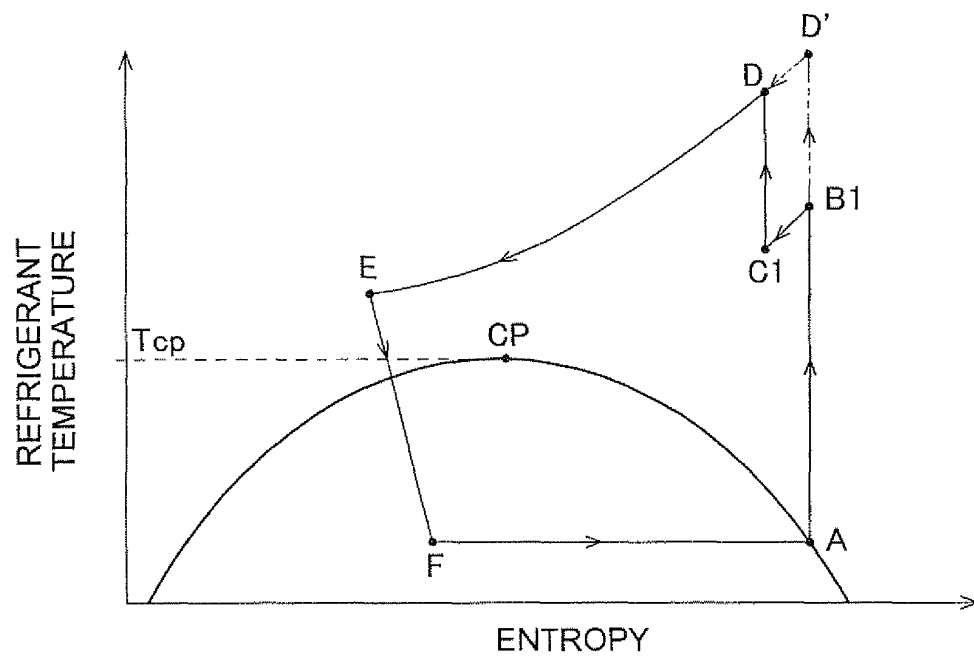


FIG. 3



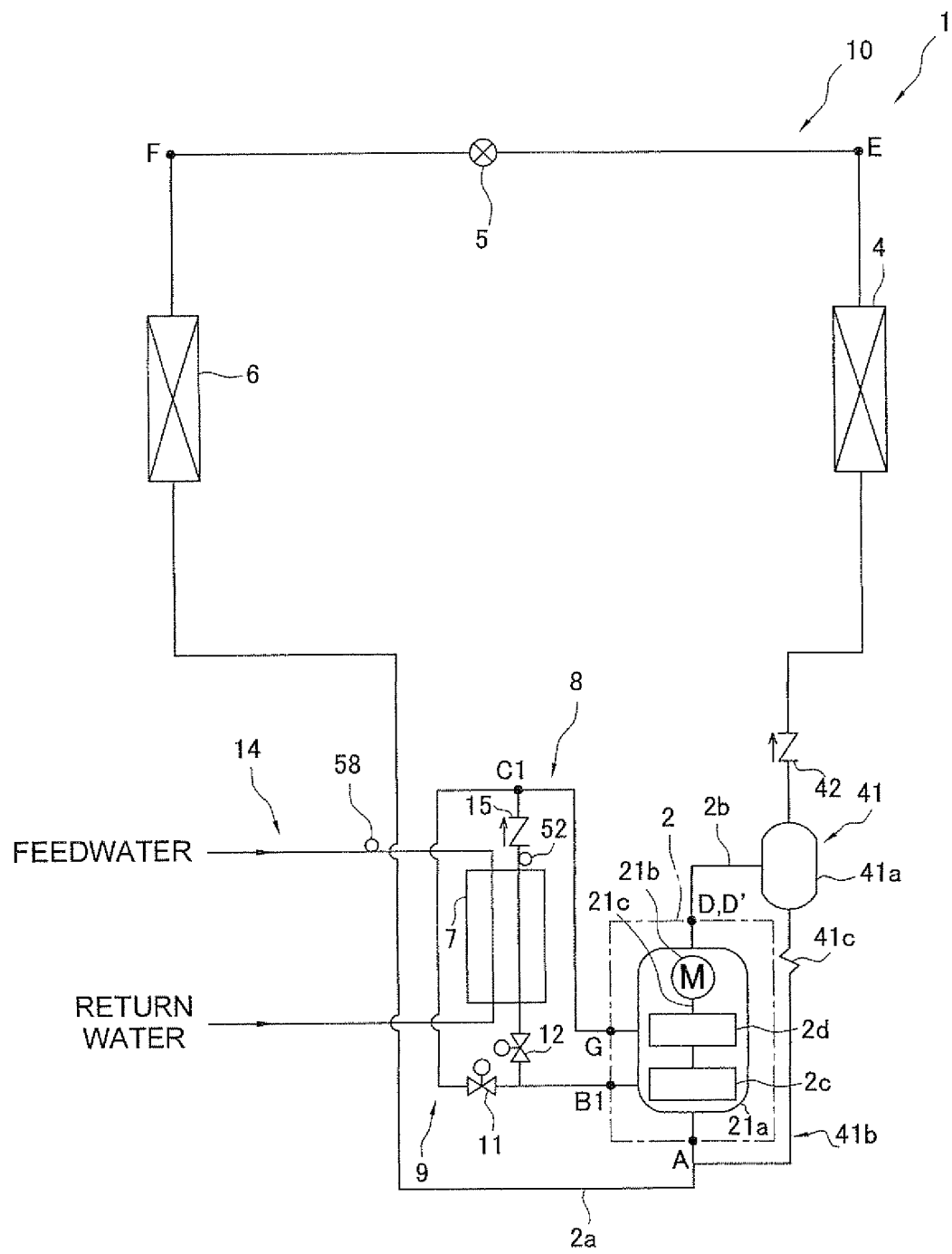


FIG. 4

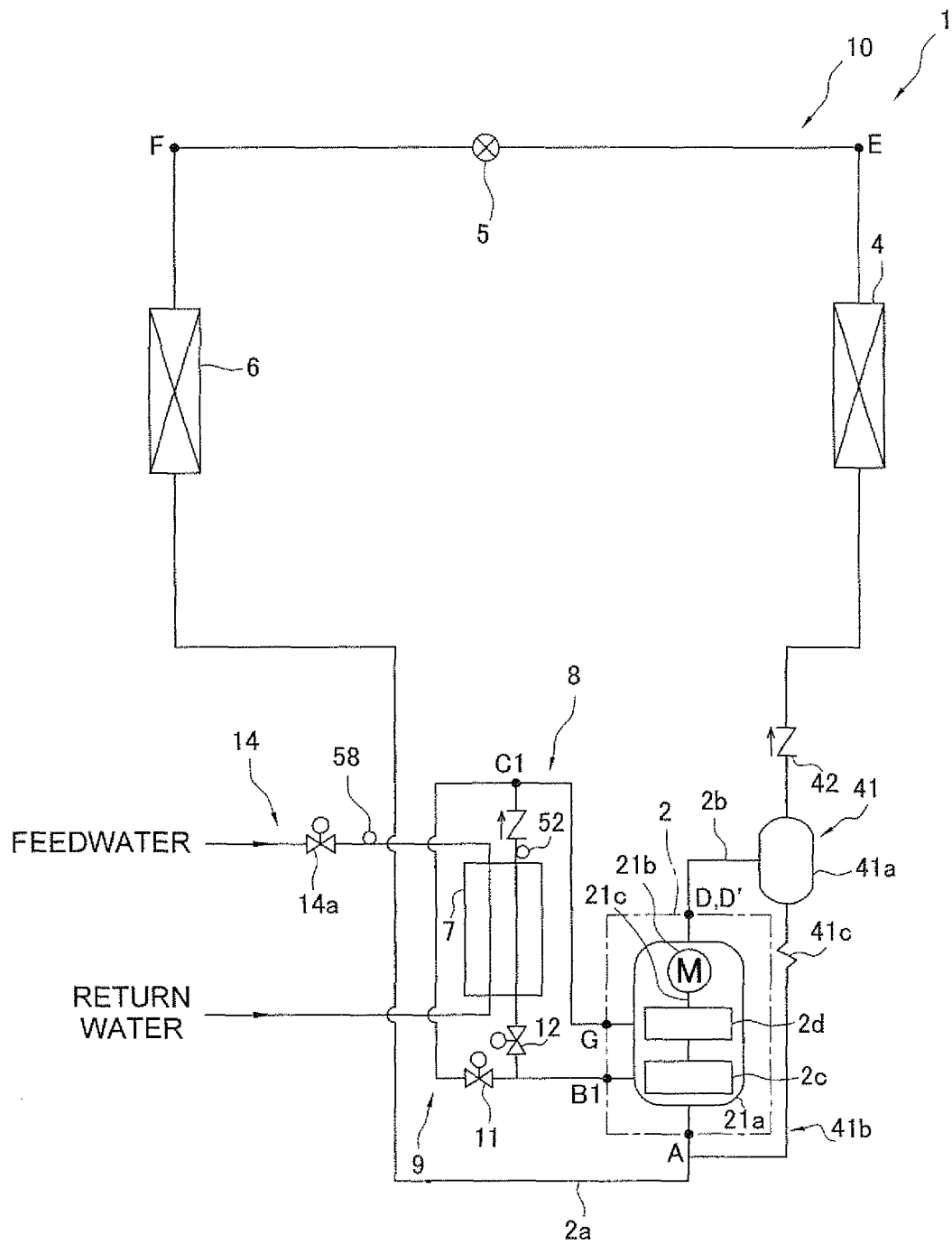


FIG. 5

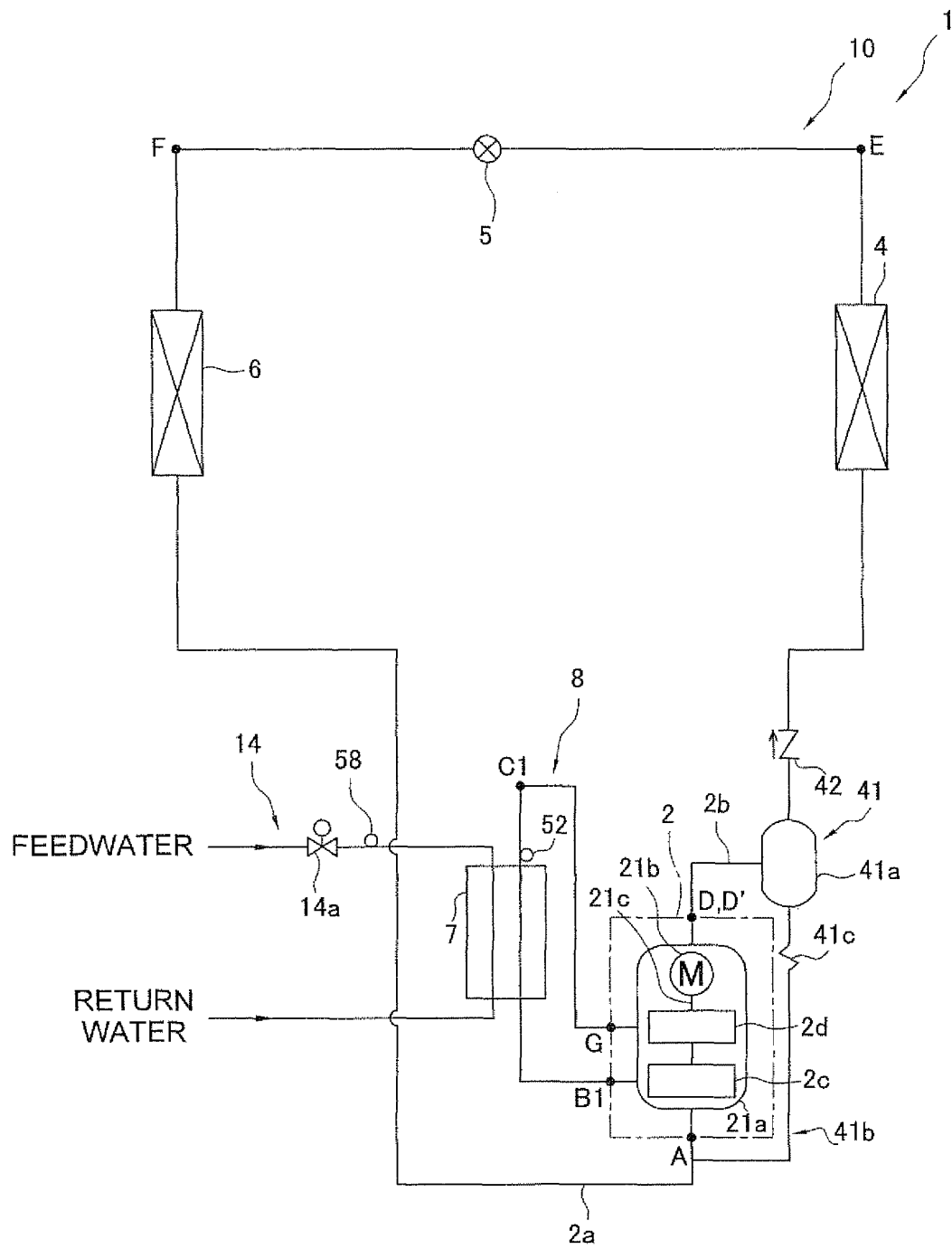


FIG. 6

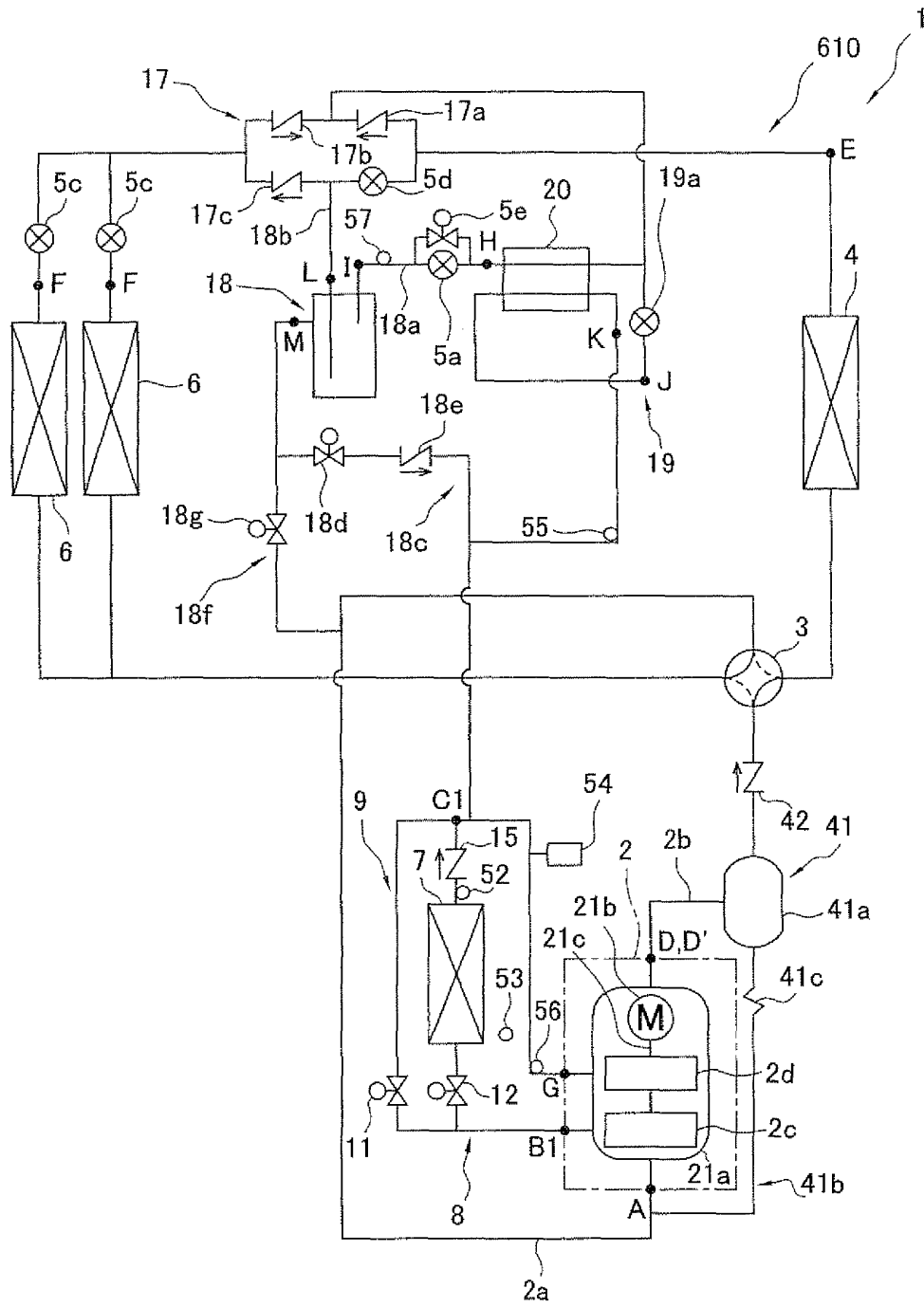


FIG. 7

FIG. 8

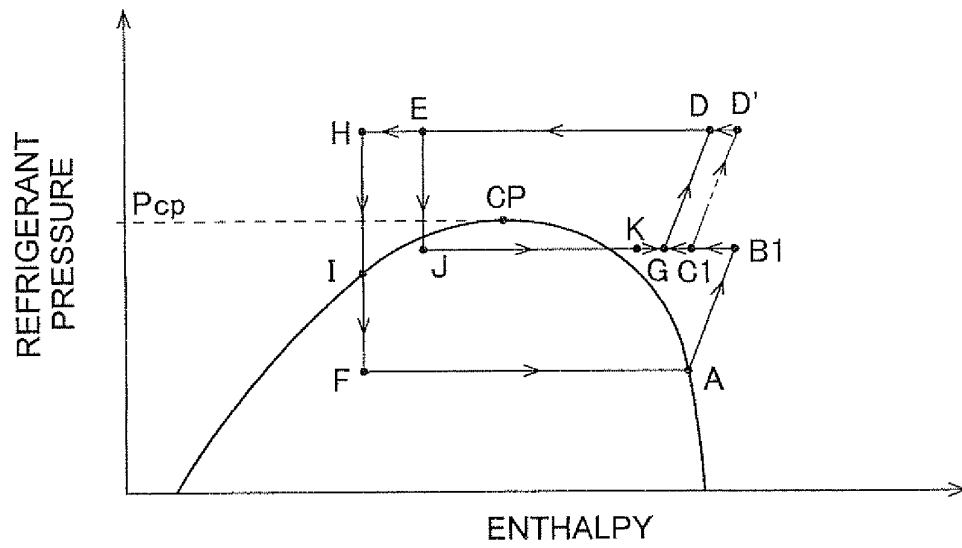


FIG. 9

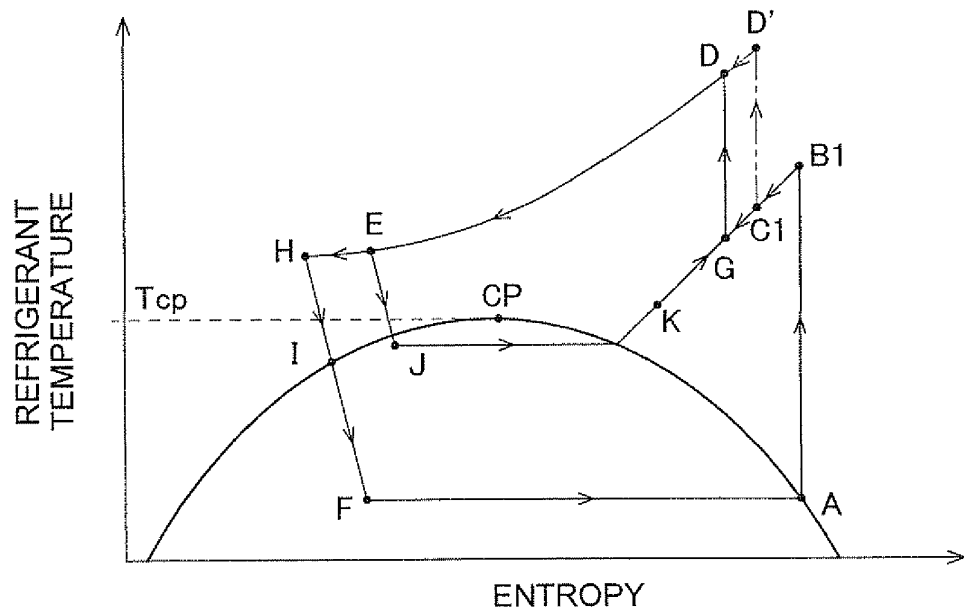


FIG. 10

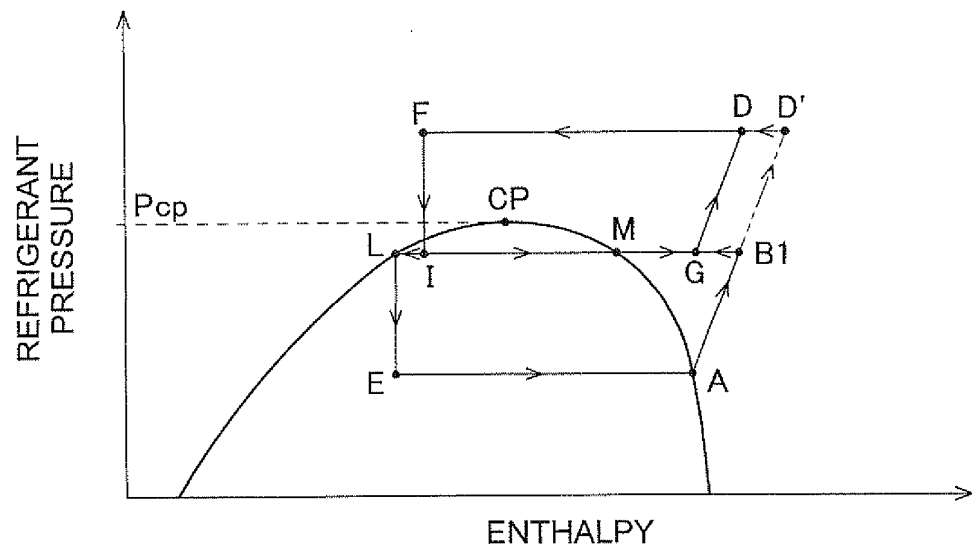
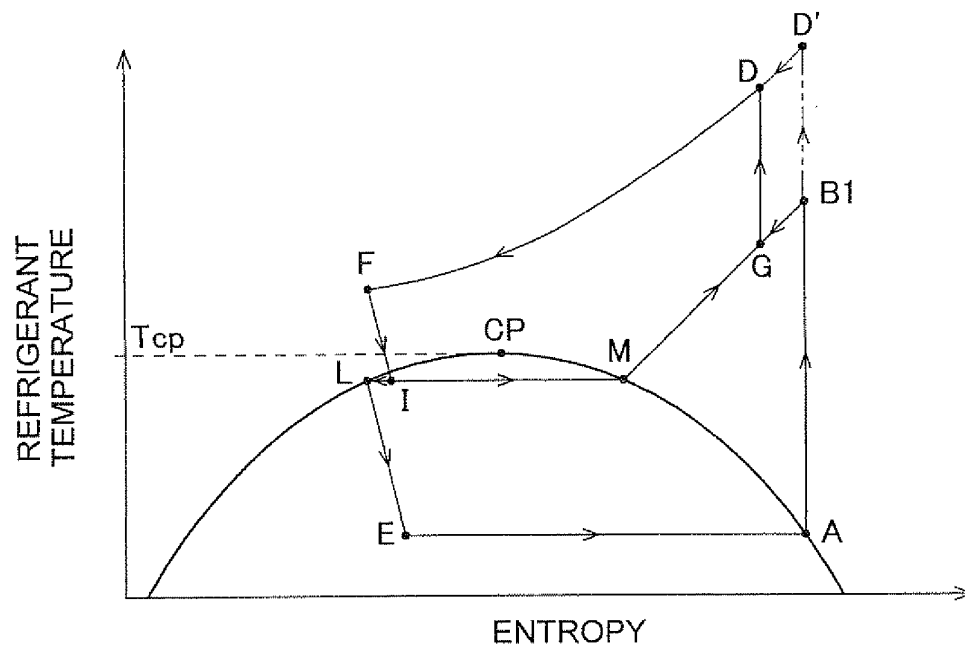


FIG. 11



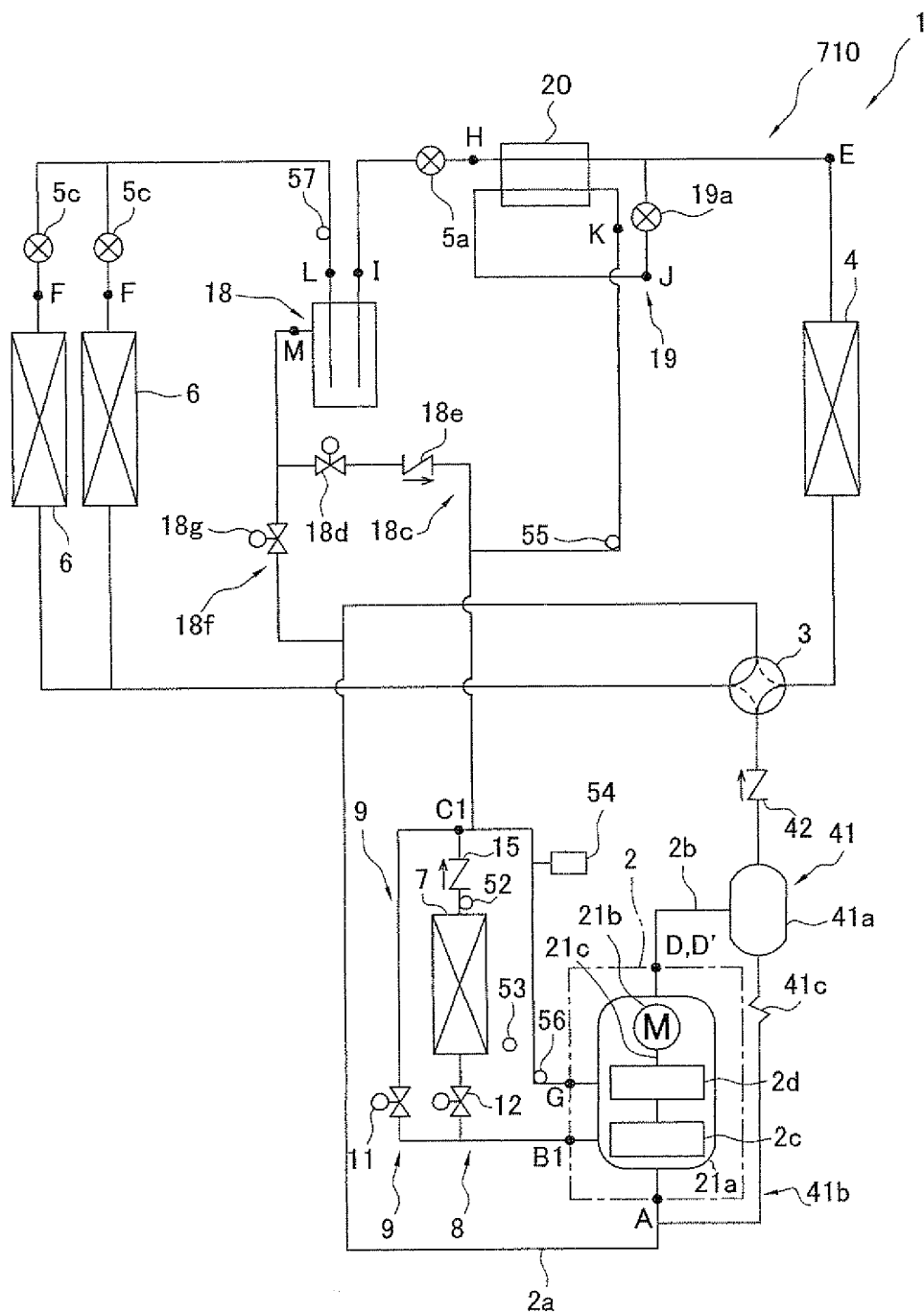


FIG. 12

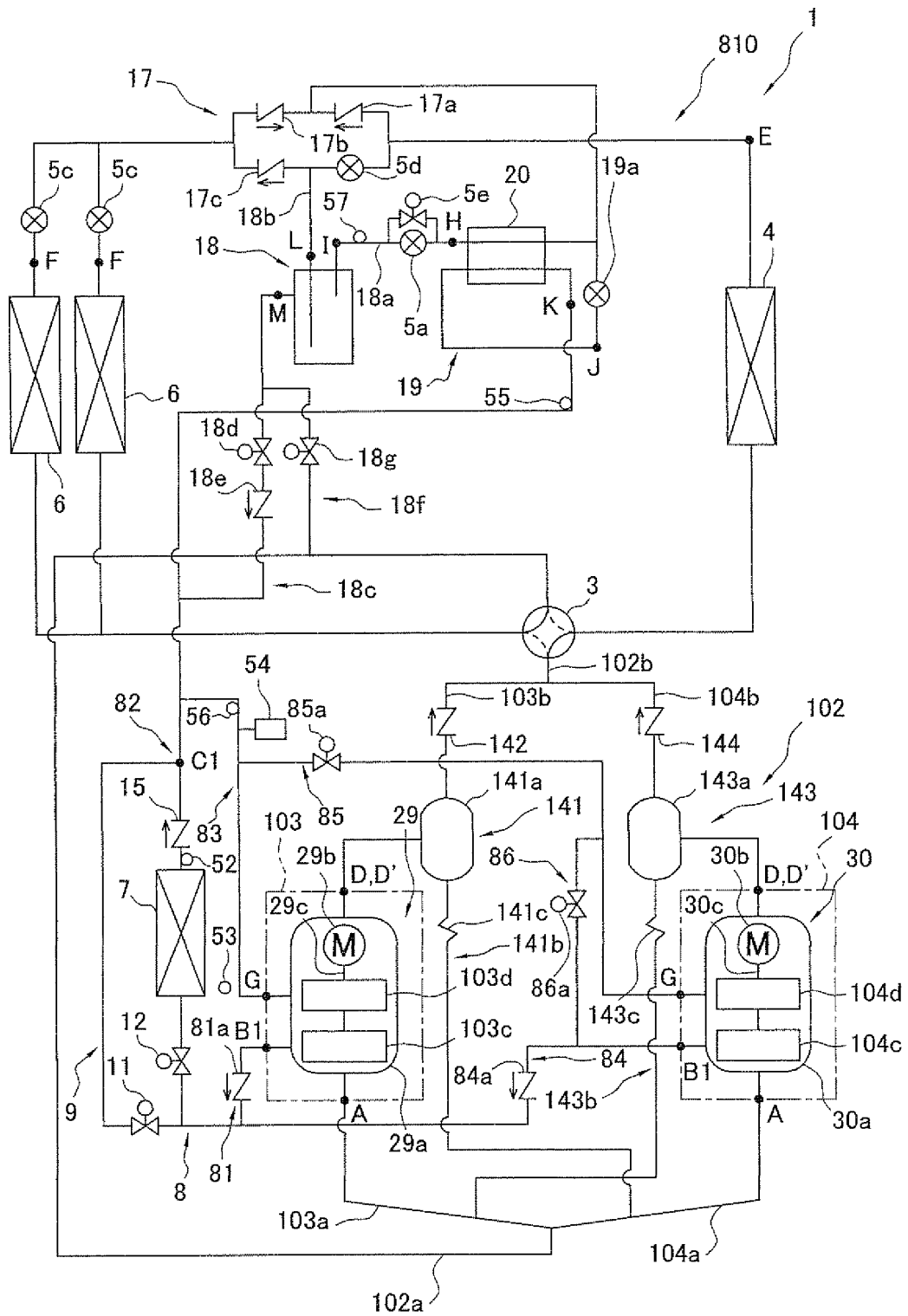


FIG. 13

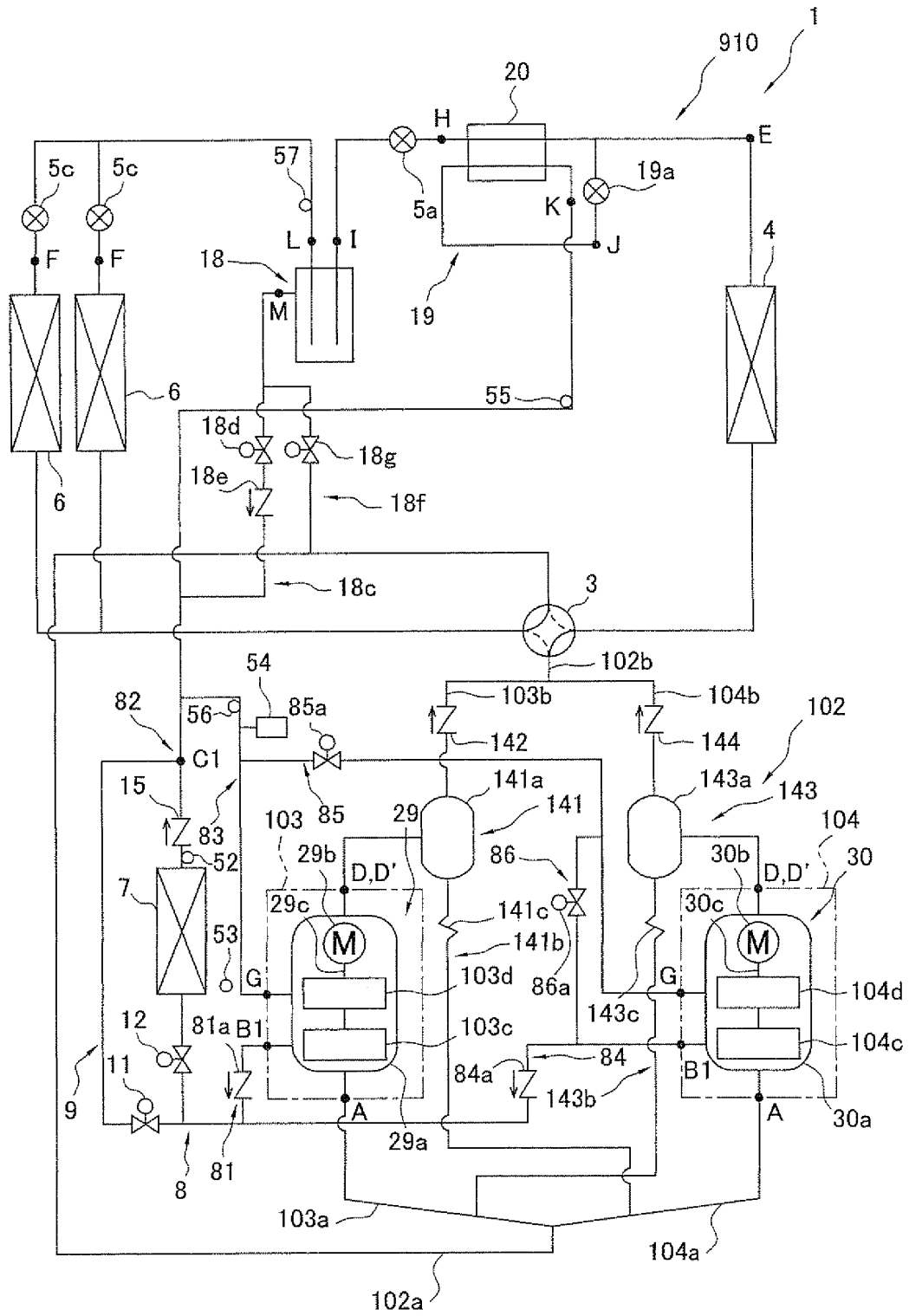


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/051235

A. CLASSIFICATION OF SUBJECT MATTER F25B1/10(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) F25B1/10, F25B1/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2009 Kokai Jitsuyo Shinan Koho 1971-2009 Toroku Jitsuyo Shinan Koho 1994-2009		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2007-190256 A (Sanyo Electric Co., Ltd.), 02 August, 2007 (02.08.07), Figs. 1 to 4; Par. Nos. [0030] to [0052] & US 2007/0169366 A1 & EP 1811076 A1 & CN 101012618 A	1-6
Y A	JP 2004-301453 A (Sanyo Electric Co., Ltd.), 28 October, 2004 (28.10.04), Fig. 11; Claim 1; Par. Nos. [0102] to [0118] (Family: none)	1, 2, 6 3-5
☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 16 March, 2009 (16.03.09)		Date of mailing of the international search report 24 March, 2009 (24.03.09)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/051235

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2004-116957 A (Sanyo Electric Co., Ltd.), 15 April, 2004 (15.04.04), Fig. 2; Par. No. [0026] & US 2004/0040339 A1 & US 2005/0144964 A1 & US 2005/0144972 A1 & US 2005/0144973 A1 & US 2005/0144977 A1 & US 2005/0172661 A1 & US 2005/0172662 A1 & US 2005/0183447 A1 & EP 1394479 A2 & EP 1970644 A1 & EP 1970645 A1 & EP 1970646 A1 & EP 1972870 A2 & KR 10-2004-0020013 A & CN 1485584 A	1, 2, 6 3-5
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Y A	JP 2001-133058 A (Matsushita Electric Industrial Co., Ltd.), 18 May, 2001 (18.05.01), Full text; all drawings (Family: none)	6 1-5

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REFERENCES CITED IN THE DESCRIPTION

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