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(54) **REFRIGERATION DEVICE**

(57) An air-conditioning apparatus (1) uses carbon dioxide as a refrigerant, and has a two-stage compression-type compression mechanism (2), a heat source-side heat exchanger (4), an expansion mechanism (5), 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 into a second-stage compression element and which functions as a cooler of refrigerant discharged from the first-stage compression element and drawn into a second-stage compression element, and an intermediate oil separation mechanism (16) for separating from the refrigerant a refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element and for returning the refrigeration oil to the intake side of the compression mechanism (2), the intermediate oil separation mechanism being provided to a section of the intermediate refrigerant tube (8) between the first-stage compression element and an inlet of the intercooler (7).

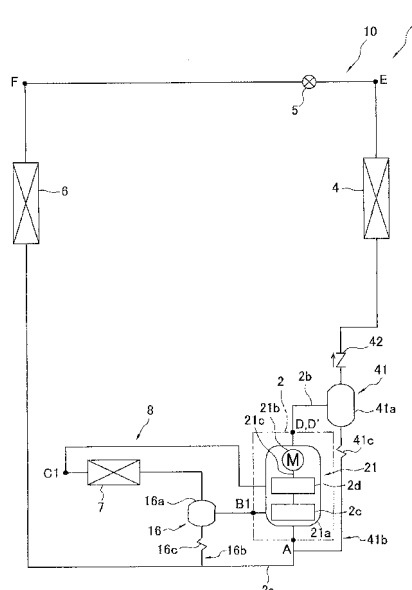


FIG. 1

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 by using a refrigerant that operates in a supercritical range.

BACKGROUND ART

[0002] As one conventional example of a refrigeration apparatus which performs a multistage compression refrigeration cycle by using a refrigerant that operates in a supercritical range, Patent Document 1 discloses an air-conditioning apparatus performs a two-stage compression refrigeration cycle by using carbon dioxide as a refrigerant. This air-conditioning apparatus has primarily a compressor having two compression elements connected in series, an outdoor heat exchanger as a heat source-side 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] A refrigeration apparatus according to a first aspect of the present invention is a refrigeration apparatus which a refrigerant that operates in a supercritical range is used, comprising a compression mechanism, a heat source-side heat exchanger, an expansion mechanism for depressurizing the refrigerant, a usage-side heat exchanger, an intercooler, and an intermediate oil separation mechanism. 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. The term "compression mechanism" herein means a compressor in which a plurality of compression elements are integrally incorporated, or a configuration including a compressor in which a single compression element is incorporated and/or a plurality of connected compressors in which a plurality of compression elements are incorporated in each. 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 com-

pression 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 functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element. The intermediate oil separation mechanism is provided to a section of the intermediate refrigerant tube between the first-stage compression element and an inlet of the intercooler, and is a mechanism for separating from the refrigerant a refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element and for returning the refrigeration oil to the intake side of the compression mechanism.

[0004] In cases in which a heat exchanger that uses air as a heat source is used as the outdoor heat exchanger in a conventional air-conditioning apparatus, the critical temperature (about 31°C) of carbon dioxide used as the refrigerant is about the same as the temperature of water or air as the cooling source of an outdoor heat exchanger or indoor heat exchanger functioning as a cooler of the refrigerant, which is low compared to R22, R410A, and other refrigerants, and the apparatus therefore operates in a state in which the high pressure of the refrigeration cycle is higher than the critical pressure of the refrigerant so that the refrigerant can be cooled by the air in the outdoor heat exchanger during an air-cooling operation as the cooling operation. As a result, since the refrigerant discharged from the second-stage compression element of the compressor has a high temperature, there is a large difference in temperature between the refrigerant and the air as a heat source in the outdoor heat exchanger functioning as a refrigerant cooler, and the outdoor heat exchanger has much heat radiation loss, which poses a problem in making it difficult to achieve a high operating efficiency.

[0005] As a countermeasure to this problem, in this refrigeration apparatus, 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 of the compressor is reduced, and heat radiation loss in the outdoor heat exchanger is reduced.

[0006] Since the refrigeration oil in the compressor herein accompanies the refrigerant discharged from the first-stage compression element of the compressor, the refrigeration oil in the compressor is moved out of the compressor by the intermediate refrigerant tube. There is a danger of a shortage of oil to the compressor because

merely providing an intercooler as described above causes refrigeration oil to accumulate in the intercooler and to cease returning to the compressor.

[0007] However, in this refrigeration apparatus, since the intermediate oil separation mechanism is provided and the refrigeration oil accompanying the refrigerant discharged from the first-stage compression element can be suppressed from flowing into the intercooler, the accumulation of refrigeration oil in the intercooler can be prevented, and oil shortages to the compression mechanism can be prevented. It is also possible to prevent loss of heat transfer performance and increases in pressure drop in the intercooler due to accumulation of refrigeration oil in the intercooler, and the performance of the refrigeration apparatus can be improved.

[0008] Particularly in cases in which the compression mechanism includes a high-pressure dome-type compressor in which a plurality of compression elements connected in series are housed within the same casing, since the refrigerant discharged from the second-stage compression element is discharged out of the casing after being discharged into the space in the casing where refrigeration oil accumulates, there is not a large amount of refrigeration oil accompanying this refrigerant. Meanwhile, since the refrigerant discharged from the first-stage compression element is discharged directly out of the casing, there is a large amount of refrigeration oil accompanying this refrigerant and there is a high danger that a large amount of refrigeration oil will accumulate in the intercooler. Therefore, it is extremely beneficial to provide the intermediate oil separation mechanism according to the present invention.

[0009] A 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 intermediate oil separation mechanism has an intermediate oil separator for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element, and an intermediate oil return tube for returning the refrigeration oil separated from the refrigerant to the compression mechanism, the intermediate oil return tube being connected to the intermediate oil separator.

[0010] In this refrigeration apparatus, since providing the intermediate oil separator in the vicinity of the first-stage compression element makes it possible to separate refrigeration oil from the refrigerant in the vicinity of the first-stage compression element, the accumulation of refrigeration oil can be prevented not only in the intercooler but in the intermediate refrigerant tube as well.

[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 intermediate oil separation mechanism has a header provided to the inlet of the intercooler, and an intermediate oil return tube for connecting a lower end of the header with the compression mechanism.

[0012] In this refrigeration apparatus, the increase in

the number of components can be minimized because the header provided to the inlet of the intercooler functions as an oil separator.

[0013] A refrigeration apparatus according to a fourth aspect of the present invention is the refrigeration apparatus according to any of the first through third aspects of the present invention, wherein the refrigerant that operates in the supercritical range is carbon dioxide.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

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 drawing of an intercooler and an intermediate oil separation mechanism in an air-conditioning apparatus according to Modification 1.

FIG. 5 is a schematic structural drawing of an air-conditioning apparatus according to Modification 2.

FIG. 6 is a schematic structural drawing of an air-conditioning apparatus according to Modification 3.

FIG. 7 is a schematic structural drawing of an air-conditioning apparatus according to Modification 3.

FIG. 8 is a schematic structural drawing of an air-conditioning apparatus according to Modification 3.

FIG. 9 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 3.

FIG. 10 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 3.

FIG. 11 is a schematic structural drawing of an air-conditioning apparatus according to Modification 4.

FIG. 12 is a schematic structural drawing of an air-conditioning apparatus according to Modification 5.

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

FIG. 14 is a schematic structural drawing of an air-conditioning apparatus according to Modification 6.

FIG. 15 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 6.

FIG. 16 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 6.

FIG. 17 is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 6.

FIG. 18 is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 6.

FIG. 19 is a schematic structural drawing of an air-conditioning apparatus according to Modification 6.

FIG. 20 is a schematic structural drawing of an air-conditioning apparatus according to Modification 7.

FIG. 21 is a schematic structural drawing of an air-conditioning apparatus according to Modification 7.

EXPLANATION OF THE REFERENCE NUMERALS

[0015]

1	Air-conditioning apparatus (refrigeration apparatus)
2, 102, 202	Compression mechanisms
4	Heat source-side heat exchanger
5	Expansion mechanism
6	Usage-side heat exchanger
7	Intercooler
8	Intermediate refrigerant tube
16	Intermediate oil separation mechanism
16a	Intermediate oil separator
16b	Intermediate oil return tube
16d	Header

BEST MODE FOR CARRYING OUT THE INVENTION

[0016] Embodiments of the refrigeration apparatus according to the present invention are described hereinbelow with reference to the drawings.

(1) Configuration of air-conditioning apparatus

[0017] 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.

[0018] 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.

[0019] 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 2c connected to the first-stage side of the compression element 2c.

[0020] 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 41 a for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism 2, and an oil return tube 41 b connected to the oil separator 41 a 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 decompression mechanism 41 c for depressurizing the refrigerator oil flowing through the oil return tube 41b. A capillary tube is used for the decompression 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 switching mechanism 3 and for blocking the flow of refrigerant from the switching mechanism 3 to the discharge side of the compression mechanism 2, and a non-return valve is used in the present embodiment.

[0021] 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.

[0022] 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. Though not shown in the drawings, the heat source-side heat exchanger 4 is supplied with water or air as a cooling source for conducting heat exchange with the refrigerant flowing through the heat source-side heat exchanger 4.

[0023] 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.

[0024] 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. Though not shown in the drawings, the usage-side heat exchanger 6 is supplied with water or air as a heat source for conducting heat exchange with the refrigerant flowing through the usage-side heat exchanger 6.

[0025] 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. Though not illustrated herein, the intercooler 7 is supplied with water or air as a cooling source for conducting heat exchange with the refrigerant flowing through the intercooler 7. Thus, it is acceptable to say that the intercooler 7 is a cooler that uses the external heat source, meaning that the intercooler does not use the refrigerant that circulates through the refrigerant circuit 10.

[0026] An intermediate oil separation mechanism 16 is provided in a section of the intermediate refrigerant tube 8 between the first-stage compression element 2c and the inlet of the intercooler 7. The intermediate oil separation mechanism 16 is a mechanism for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element 2c and for returning the refrigeration oil to the compression mechanism 2. The intermediate oil separation mechanism 16 has primarily an intermediate oil separator 16a for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element 2c, and an intermediate oil return tube 16b for returning the refrigeration oil separated from the refrigerant to the compression mechanism 2, the intermediate oil return tube

being connected to the intermediate oil separator 16a. In the present embodiment, the intermediate oil return tube 16b is connected between an oil outlet of the intermediate oil separator 16a and the intake side of the compression mechanism 2 (the intake tube 2a in this case), and is provided with a depressurizing mechanism 16c for depressurizing the refrigeration oil flowing through the intermediate oil return tube 16b. A capillary tube is used as the depressurizing mechanism 16c in the present embodiment.

[0027] Furthermore, though not illustrated herein, the air-conditioning apparatus 1 has a controller for controlling the actions of the compression mechanism 2, the expansion mechanism 5, and the other components constituting the air-conditioning apparatus 1.

(2) Action of the air-conditioning apparatus

[0028] 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 controls during the following air-cooling operation 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', 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" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B1 and C1 in FIGS. 2 and 3).

[0029] When the compression mechanism 2 is driven while the refrigerant circuit 310 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). As in the embodiment described above, the intermediate-pressure discharged from the first-stage compression element 2c flows into the intermediate oil separator 16a constituting the intermediate oil separation mechanism 16, and after the accompanying refrigeration oil is separated, the refrigerant is fed to the intercooler 7. The refrigeration oil separated from the intermediate-pressure refrigerant in the intermediate oil separator 16a flows into the intermediate oil return tube 16b constituting the intermediate oil separation mechanism 16, and after being depressurized by the depressurizing mechanism 16c provided to the intermediate oil return tube 16b, the refrigerant is returned to the compression mechanism 2 (the intake tube 2a in this case) and led back into the compression mechanism 2. After the refrigeration oil has

been separated in the intermediate oil separation mechanism 16, the intermediate-pressure refrigerant is then cooled in the intercooler 7 by undergoing heat exchange with water or 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 41a constituting the oil separation 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 41c 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 is 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 water or 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, 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.

[0030] 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. 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.

[0031] In the air-conditioning apparatus 1, since the section of the intermediate refrigerant tube 8 between the first-stage compression element 2c and the inlet of the intercooler 7 is provided with the intermediate oil separation mechanism 16 for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element 2c and returning the refrigerant to the compression mechanism 2, the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element 2c can be suppressed from flowing into the intercooler 7, the accumulation of refrigeration oil in the intercooler 7 can be prevented, and oil shortages to the compression mechanism 2 can be prevented, in comparison with cases in which no intermediate oil separation mechanism 16 is provided.

[0032] In cases in which no intermediate oil separation mechanism 16 is provided, since the heat transfer performance of the intercooler 7 decreases and the amount of heat exchanged in the intercooler 7 (i.e. the enthalpy difference between points B1 and C1 in FIG. 2) decreases due to the accumulation of refrigeration oil in the intercooler 7, it may not be possible to reduce the heat radiation loss in the heat source-side heat exchanger 4. The accumulation of refrigeration oil in the intercooler 7 may also cause greater pressure drop in the intercooler 7, a pressure drop (specifically, point C1 in FIG. 2) in the refrigerant drawn into the second-stage compression element 2d, and an increase in power consumption in the second-stage compression element 2d. However, since the intermediate oil separation mechanism 16 is provided, it is possible to prevent the loss of heat transfer performance and the increase in pressure drop in the intercooler 7 as caused by the accumulation of refrigeration oil in the intercooler 7, and the performance of the air-conditioning apparatus 1 can be improved.

[0033] Furthermore, since the intermediate oil separation mechanism 16 in the present embodiment has the intermediate oil separator 16a for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element 2c, and the intermediate oil return tube 16b connected to the intermediate oil separator 16a for returning the refrigeration oil separated from the refrigerant to the compression mechanism 2; providing the intermediate

oil separator 16a in the vicinity of the first-stage compression element 2c makes it possible to separate the refrigeration oil from the refrigerant in the vicinity of the first-stage compression element 2c, whereby the accumulation of refrigeration oil can be prevented not only in the intercooler 7 but in the intermediate refrigerant tube 8 as well.

[0034] In any case where the compressor 21 constituting the compression mechanism 2 is a low-pressure dome-type compressor in which the refrigerant drawn into the first-stage compression element 2c fills the space in the casing 21a where refrigeration oil accumulates, an intermediate-pressure dome-type compressor in which the refrigerant discharged from the first-stage compression element 2c fills the space in the casing 21a where refrigeration oil accumulates, or a high-pressure dome-type compressor in which the refrigerant discharged from the second-stage compression element 2d fills the space in the casing 21a where refrigeration oil accumulates; the effect of preventing oil shortages to the compression mechanism 2 as well as other effects can be achieved by providing the intermediate oil separation mechanism 16. Particularly in cases in which a high-pressure dome-type compressor is used as the compressor 21 constituting the compression mechanism 2, the refrigerant discharged from the second-stage compression element 2d is discharged out of the casing 21a after being first discharged into the space in the casing 21a where refrigeration oil accumulates and the amount of refrigeration oil accompanying this refrigerant is therefore not large, whereas since the refrigerant discharged from the first-stage compression element 2c is discharged directly out of the casing 21a, a large amount of refrigeration oil accompanies this refrigerant and there is a danger of a large amount of refrigeration oil accumulating in the intercooler 7. It is therefore extremely beneficial to provide the intermediate oil separation mechanism 16.

(3) Modification 1

[0035] In the embodiment described above, the intermediate oil separation mechanism 16 is configured from the intermediate oil separator 16a and the intermediate oil return tube 16b, but the intermediate oil separation mechanism 16 may also be configured such that the intermediate oil return tube 16b is connected to a lower end of a header 16d provided to the inlet of the intercooler 7, as shown in FIG. 4. In the case that the intercooler 7 is structured having a plurality of heat transfer channels, the header 16d is a tube member located between the intermediate refrigerant tube 8 and a branching tube for branching off to the heat transfer channels. Aside from being connected to the lower end of the header 16d rather than to the oil outlet of the intermediate oil separator 16a, the intermediate oil return tube 16b has the same configuration as the intermediate oil return tube 16b in the embodiment described above.

[0036] In the configuration of Modification 1, since the

header 16d provided to the inlet of the intercooler 7 functions as an oil separator, the increase in the number of components can be minimized in comparison with the embodiment described above.

[0037] In the modifications described hereinafter, examples are described in which the intermediate oil separation mechanism 16 has the intermediate oil separator 16a and the intermediate oil return tube 16b, but a configuration may also be used in which the intermediate oil return tube 16b is connected to the lower end of the header 16d provided in the inlet of the intercooler 7, as is the case in the present modification.

(4) Modification 2

[0038] In the above-described embodiment and modifications thereof, the compression mechanism 2 was a two-stage compression-type compression mechanism 2 configured from a 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 configure a compression mechanism 2 having a two-stage compression structure by connecting two compressors in series, each of which compressors having a single-stage compression structure in which one compression element is rotatably driven by one compressor drive motor.

[0039] For example, in the embodiment described above, the compression mechanism 2 can be configured by connecting two compressors in series, one being a compressor 22 housing the compression element 2c and the other being a compressor 23 housing the compression element 2d as shown in FIG. 5, and the configuration can have an intermediate oil separation mechanism 16 identical to that of the previous embodiment (i.e. an intermediate oil separation mechanism 16 having an intermediate oil separator 16a and an intermediate oil return tube 16b) provided to the section of the intermediate refrigerant tube 8 between the first-stage compression element 2c (i.e. the compressor 22) and the inlet of the intercooler 7. The compression mechanism 2 has a compressor 22 and a compressor 23. The compressor 22 has a hermetic structure in which a casing 22a houses a compressor drive motor 22b, a drive shaft 22c, and a compression element 2c. The compressor drive motor 22b is coupled with the drive shaft 22c, and the drive shaft 22c is coupled with the compression element 2c. The compressor 23 has a hermetic structure in which a casing 23a houses a compressor drive motor 23b, a drive shaft 23c, and a compression element 2d. The compressor drive motor 23b is coupled with the drive shaft 23c, and the drive shaft 23c is coupled with the compression element 2d. As in the above-described embodiment and modifications thereof, the compression mechanism 2 is configured so as to admit refrigerant through an intake

tube 2a, discharge the drawn-in refrigerant to an intermediate refrigerant tube 8 after the refrigerant has been compressed by the compression element 2c, and discharge the refrigerant discharged to a discharge tube 2b after the refrigerant has been drawn into the compression element 2d and further compressed.

[0040] Since it is possible in the configuration of Modification 2 as well to suppress the refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 2c housed in the compressor 22 from flowing into the intercooler 7, the accumulation of refrigeration oil in the intercooler 7 can be prevented, and oil shortages to the compression mechanism 2 can be prevented. It is also possible to prevent loss of heat transfer performance and the increase of pressure drop in the intercooler 7 caused by the accumulation of refrigeration oil in the intercooler 7, and the performance of the air-conditioning apparatus 1 can be improved.

(5) Modification 3

[0041] In the above-described embodiment and the modifications thereof, the two-stage compression-type compression mechanism 2 was used in which refrigerant discharged from the first-stage compression element of two compression elements 2c, 2d was sequentially compressed by the second-stage compression element, but another possible option is to use a three-stage compression-type compression mechanism 102 in which refrigerant discharged from the first-stage compression element of three compression elements is sequentially compressed by the second-stage compression elements.

[0042] For example, in the embodiment described above, the compression mechanism 102 can be configured by connecting two compressors in series, one being a compressor 24 housing a compression element 102c and the other being a compressor 25 housing compression elements 102d, 102e as shown in FIG. 6, wherein an intermediate oil separation mechanism 16 identical to that of the previous embodiment (i.e. the intermediate oil separation mechanism 16 having the intermediate oil separator 16a and the intermediate oil return tube 16b) is provided in the section of an intermediate refrigerant tube 8 (the one connecting the compression element 102c and the compression element 102d) between the first-stage compression element 102c and the inlet of the intercooler 7, and another intermediate oil separation mechanism 16 is provided in the section of another intermediate refrigerant tube 8 (the one connecting the compression element 102d and the compression element 102e) between the first-stage compression element 102d and the inlet of the intercooler 7. The compression mechanism 102 herein is configured by establishing a serial connection between the compressor 24 which compresses refrigerant in one stage with a single compression element, and the compressor 25 which compresses refrigerant in two stages with two compression elements. The compressor 24 has a hermetic structure

in which a casing 24a houses a compressor drive motor 24b, a drive shaft 24c, and the compression element 102c, similar to the compressors 22, 23 having single-stage compression structures in Modification 3 described above. The compressor drive motor 24b is coupled with the drive shaft 24c, and the drive shaft 24c is coupled with the compression element 102c. The compressor 25 also has a hermetic structure in which a casing 25a houses a compressor drive motor 25b, a drive shaft 25c, and the compression elements 102d, 102e, similar to the compressor 21 having a two-stage compression structure in the embodiment described above. The compressor drive motor 25b is coupled with the drive shaft 25c, and the drive shaft 25c is coupled with the two compression elements 102d, 102e. The compressor 24 is configured so that refrigerant is drawn in through an intake tube 102a, compressed by the compression element 102c, and then discharged to an intermediate refrigerant tube 8 for taking refrigerant into the compression element 102d connected to the second-stage side of the compression element 102c. The compressor 25 is configured so that refrigerant discharged to this intermediate refrigerant tube 8 is drawn into the compression element 102d and further compressed, after which the refrigerant is discharged to the intermediate refrigerant tube 8 for taking refrigerant into the compression element 102e connected to the second-stage side of the compression element 102d, the refrigerant discharged to this intermediate refrigerant tube 8 is drawn into the compression element 102e and further compressed, and the refrigerant is then discharged to a discharge tube 102b.

[0043] Instead of the configuration shown in FIG. 6 (specifically, a configuration in which the single-stage compression-type compressor 24 and the two-stage compression-type compressor 25 are connected in series), another possible option is a configuration in which a two-stage compression-type compressor 26 and a single-stage compression-type compressor 27 are connected in series as shown in FIG. 7. In this case, the compressor 26 has compression elements 102c, 102d and the compressor 27 has a compression element 102e, and a configuration is therefore obtained in which three compression elements 102c, 102d, 102e are connected in series, similar to the configuration shown in FIG. 6. Since the compressor 26 has the same configuration as the compressor 21 in the previous embodiment and the compressor 27 has the same configuration as the compressors 22, 23 in Modification 3 described above, the symbols indicating components other than the compression elements 102c, 102d, 102e are replaced by symbols beginning with the numbers 26 and 27, and descriptions of these components are omitted.

[0044] Furthermore, instead of the configuration shown in FIG. 6 (specifically, a configuration in which a single-stage compression-type compressor 24 and a two-stage compression-type compressor 25 are connected in series), another possible option is a configuration in which three single-stage compression-type com-

pressors 26, 28, 27 are connected in series as shown in FIG. 8. In this case, the compressor 26 has a compression element 102c, the compressor 28 has a compression element 102d, and the compressor 27 has a compression element 102e, and a configuration is therefore obtained in which three compression elements 102c, 102d, 102e are connected in series, similar to the configurations shown in FIGS. 6 and 7. Since the compressors 26, 28 have the same structure as the compressors 22, 23 in Modification 3 described above, the symbols indicating components other than the compression elements 102c, 102d are replaced by symbols beginning with the numbers 26 and 28, and descriptions of these components are omitted.

[0045] Thus, in the present modification, the compression mechanism 102 has three compression elements 102c, 102d, 102e, and this compression mechanism is configured so that refrigerant discharged from the first-stage compression element of these compression elements 102c, 102d, 102e is sequentially compressed by the second-stage compression elements. The refrigerant circuit 110 in the present modification is configured from a compression mechanism 102, intermediate refrigerant tubes 8, intercoolers 7, intermediate oil separation mechanisms 16, and other components.

[0046] Next, the action of the air-conditioning apparatus 1 of the present modification will be described using FIGS. 6 through 10. FIG. 9 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in Modification 3, and FIG. 10 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in Modification 3. Operation control in the following air-cooling operation is 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', and E in FIGS. 9 and 10), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A and F in FIGS. 9 and 10), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B1, B2, B2', C1, C2, and C2' in FIGS. 9 and 10).

[0047] When the compression mechanism 102 is driven, low-pressure refrigerant (refer to point A in FIGS. 6 through 10) is drawn into the compression mechanism 102 through the intake tube 102a, and after being first compressed to an intermediate pressure by the compression element 102c, the refrigerant is discharged to the intermediate refrigerant tube 8 for drawing refrigerant discharged from the first-stage compression element 102c into the second-stage compression element 102d (refer to point B1 in FIGS. 6 through 10). The intermediate-pressure refrigerant discharged from the first-stage compression element 102c flows into the intermediate oil separator 16a constituting the intermediate oil separation mechanism 16 provided to a section of the intermediate refrigerant tube 8 between the first-stage compression

element 102c and an inlet of an intercooler 7, and after the accompanying refrigeration oil is separated, the refrigerant is fed to the intercooler 7. The refrigeration oil separated from the intermediate-pressure refrigerant in the intermediate oil separator 16a flows into the intermediate oil return tube 16b constituting the intermediate oil separation mechanism 16, and after being depressurized by a depressurizing mechanism 16c provided to the intermediate oil return tube 16b, the refrigeration oil is returned to the compression mechanism 102 (the intake tube 102a in this case) and drawn back into the compression mechanism 102. Next, the intermediate-pressure refrigerant separated from the refrigeration oil in the intermediate oil separation mechanism 16 is cooled in the intercooler 7 by heat exchange with water or air as a cooling source (refer to point C1 in FIGS. 6 through 10). The refrigerant cooled in the intercooler 7 is drawn into the compression element 102d connected to the second-stage side of the compression element 102c and further compressed to a higher intermediate pressure, and is then discharged to the intermediate refrigerant tube 8 for drawing refrigerant discharged from the first-stage compression element 102d into the second-stage compression element 102e (refer to point B2 in FIGS. 6 through 10). The intermediate-pressure refrigerant discharged from the first-stage compression element 102d flows into the intermediate oil separator 16a constituting the intermediate oil separation mechanism 16 provided in the section of the intermediate refrigerant tube 8 between the first-stage compression element 102d and the inlet of the intercooler 7, and after the accompanying refrigeration oil is separated, the refrigerant is fed to the intercooler 7. The refrigeration oil separated from the intermediate-pressure refrigerant in the intermediate oil separator 16a flows into the intermediate oil return tube 16b constituting the intermediate oil separation mechanism 16, and after being depressurized by the depressurizing mechanism 16c provided to the intermediate oil return tube 16b, the refrigeration oil is returned to the intake tube 102a of the compression mechanism 102 and drawn back into the compression mechanism 102. Next, the intermediate-pressure refrigerant separated from the refrigeration oil in the intermediate oil separation mechanism 16 is cooled in the intercooler 7 by heat exchange with water or air as a cooling source (refer to point C2 in FIGS. 6 through 10). The refrigerant cooled in the intercooler 7 is drawn into the compression element 102e connected to the second-stage side of the compression element 102d and further compressed, and is then discharged from the compression mechanism 102 to the discharge tube 102b (refer to point D in FIGS. 6 through 10). The high-pressure refrigerant discharged from the compression mechanism 102 is herein compressed to a pressure exceeding a critical pressure (i.e. the critical pressure P_{cp} at the critical point CP shown in FIG. 9) by the three-stage compression action of the compression elements 102c, 102d, 102e. The high-pressure refrigerant discharged from the compression mechanism 102

flows into the oil separator 41a constituting the oil separation 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 where it is depressurized by the depressurizing mechanism 41c provided to the oil return tube 41b, after which the refrigeration oil is returned to the compression mechanism 102 (the intake tube 102a in this case) and drawn back into the compression mechanism 102. 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 by heat exchange with water or air as a cooling source (refer to point E in FIGS. 6 through 10). The high-pressure refrigerant cooled in the heat source-side heat exchanger 4 is 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. 6 through 10). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger 6 is heated in the usage-side heat exchanger 6 by heat exchange with water or air as a heating source, and the refrigerant evaporates as a result (refer to point A in FIGS. 6 through 10). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is drawn back into the compression mechanism 102. In this manner the air-cooling operation is performed.

[0048] Thus, in the configuration of the present modification, since the intercooler 7 is provided to the intermediate refrigerant tube 8 for drawing refrigerant discharged from the compression element 102c into the compression element 102d and the intercooler 7 is also provided to the intermediate refrigerant tube 8 for drawing refrigerant discharged from the compression element 102d into the compression element 102e, the temperature of the refrigerant drawn into the compression element 102d on the second-stage side of the compression element 102c and the temperature of the refrigerant drawn into the compression element 102e on the second-stage side of the compression element 102d are both reduced (refer to points B1, C1, B2, and C2 in FIG. 10), and the temperature of the refrigerant discharged from the compression element 102e is also reduced (refer to points D and D' in FIG. 10), in comparison with cases in which no intercoolers 7 are provided (in this case, the refrigeration cycle is performed in the sequence in FIGS. 9 and 10: point A → point B1 → point B2' (C2') → point D' → point E → point F). Therefore, in the configuration of the present modification, it is possible to reduce the temperature difference between the refrigerant and the water or air as a cooling source in the heat source-side heat exchanger 4 functioning as a cooler of high-pressure refrigerant in comparison with cases in which no inter-

coolers 7 are provided, the heat radiation loss can be reduced in proportion to the area enclosed by points B1, B2' (C2'), D', D, C2, B2, and C1 in FIG. 10, and operating efficiency can therefore be improved. Moreover, since this area is greater than the area in a two-stage compression refrigeration cycle such as those of the above-described embodiment and the modifications thereof, the operating efficiency can be further improved over the above-described embodiment and the modifications thereof.

[0049] In the configuration of the present modification, oil shortages to the compression mechanism 102 can be prevented as in the above-described embodiment and the modifications thereof, because the intermediate oil separation mechanism 16 for separating from the refrigerant the refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 102c and returning the refrigeration oil to the intake side of the compression mechanism 102 is provided to the section in the intermediate refrigerant tube 8 between the first-stage compression element 102c and the inlet of the intercooler 7, and another intermediate oil separation mechanism 16 for separating from the refrigerant the refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 102d and returning the refrigeration oil to the intake side of the compression mechanism 102 is provided to the section of the other intermediate refrigerant tube 8 between the first-stage compression element 102d and the inlet of the intercooler 7.

[0050] In cases in which no intermediate oil separation mechanisms 16 are provided, the intercoolers 7 suffer a loss of heat transfer performance and the amount of heat exchanged in the intercoolers 7 (i.e. the enthalpy difference between points B1 and C1 and the enthalpy difference between points B2 and C2 in FIG. 9) decreases due to the accumulation of refrigeration oil in the intercoolers 7. Therefore, it may no longer be possible to reduce heat radiation loss in the heat source-side heat exchanger 4, and the accumulation of refrigeration oil in the intercoolers 7 may cause greater pressure drop in the intercoolers 7, lower pressure in the refrigerant (i.e. points C1 and C2 in FIG. 9) drawn into the second-stage compression element 102d and compression element 102e, and increased power consumption in the second-stage compression element 102d and compression element 102e. However, since the intermediate oil separation mechanisms 16 are provided, the performance of the air-conditioning apparatus 1 can be improved as with the above-described embodiment and the modifications thereof.

[0051] In any case where the two-stage compression-type compressor 25 (see FIG. 6) constituting the compression mechanism 102 is a low-pressure dome-type compressor in which the refrigerant drawn into the first-stage compression element 102d fills the space in the casing 25a where refrigeration oil accumulates, an intermediate-pressure dome-type compressor in which the

refrigerant discharged from the first-stage compression element 102d fills the space in the casing 25a where refrigeration oil accumulates, or a high-pressure dome-type compressor in which the refrigerant discharged from the second-stage compression element 102e fills the space in the casing 25a where refrigeration oil accumulates; the effect of preventing oil shortages to the compression mechanism 102 as well as other effects can be achieved by providing the intermediate oil separation mechanisms 16. Particularly in cases in which a high-pressure dome-type compressor is used as the compressor 25 constituting the compression mechanism 102, the refrigerant discharged from the second-stage compression element 102e is discharged out of the casing 25a after being first discharged into the space in the casing 25a where refrigeration oil accumulates and the amount of refrigeration oil accompanying this refrigerant is therefore not large, whereas since the refrigerant discharged from the first-stage compression element 102d is discharged directly out of the casing 25a, a large amount of refrigeration oil accompanies this refrigerant and there is a danger of a large amount of refrigeration oil accumulating in the intercooler 7. It is therefore extremely beneficial to provide the intermediate oil separation mechanism 16. As with the compressor 25, it is also extremely beneficial to provide the intermediate oil separation mechanism 16 in cases in which a high-pressure dome-type compressor is used as the two-stage compression-type compressor 26 (see FIG. 7) constituting the compression mechanism 102.

[0052] Though not described in detail herein, another possible option instead of the three-stage compression-type compression mechanism 102 is to use a compression mechanism having more stages than a three-stage compression system, such as a four-stage compression system, and the same effects as the present modification can be achieved in this case as well.

(6) Modification 4

[0053] In the above-described embodiment and the modifications thereof, the configuration had the multi-stage compression-type compression mechanism 2 or compression mechanism 102 in which compression was performed sequentially by a plurality of compression elements, but another possible option for cases in which a high-capacity usage-side heat exchanger 6 is connected or a plurality of usage-side heat exchangers 6 are connected, for example, is to use a parallel multistage compression-type compression mechanism in which a plurality of multistage compression-type compression mechanisms 2 or compression mechanisms 102 are connected in parallel.

[0054] For example, a refrigerant circuit 210 can be used, which uses a compression mechanism 202 having a configuration wherein a parallel connection is established between a two-stage compression-type first compression mechanism 203 having compression elements

203c, 203d, and a two-stage compression-type second compression mechanism 204 having compression elements 204c, 204d, as shown in FIG. 11.

[0055] In the present modification, the first compression mechanism 203 is configured using a compressor 29 for subjecting the refrigerant to two-stage compression through two compression elements 203c, 203d, and is connected to a first intake branch tube 203a which branches off from an intake header tube 202a of the compression mechanism 202, and also to a first discharge branch tube 203b whose flow merges with a discharge header tube 202b of the compression mechanism 202. In the present modification, the second compression mechanism 204 is configured using a compressor 30 for subjecting the refrigerant to two-stage compression through two compression elements 204c, 204d, and is connected to a second intake branch tube 204a which branches off from the intake header tube 202a of the compression mechanism 202, and also to a second discharge branch tube 204b whose flow merges with the discharge header tube 202b of the compression mechanism 202. Since the compressors 29, 30 have the same configuration as the compressor 21 in the embodiment described above, symbols indicating components other than the compression elements 203c, 203d, 204c, 204d 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 in through the first intake branch tube 203a, the drawn-in refrigerant is compressed by the compression element 203c and then discharged to a first inlet-side intermediate branch tube 81 constituting the intermediate refrigerant tube 8, the refrigerant discharged to the first inlet-side intermediate branch tube 81 is drawn in into the compression element 203d via an intermediate header tube 82 and a first discharge-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 203b. The compressor 30 is configured so that refrigerant is drawn in through the second intake branch tube 204a, the drawn-in refrigerant is compressed by the compression element 204c and then discharged to a second inlet-side intermediate branch tube 84 constituting the intermediate refrigerant tube 8, the refrigerant discharged to the second inlet-side intermediate branch tube 84 is drawn in into the compression element 204d 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 204b. In the present modification, the intermediate refrigerant tube 8 is a refrigerant tube for admitting refrigerant discharged from the compression elements 203c, 204c connected to the first-stage sides of the compression elements 203d, 204d into the compression elements 203d, 204d connected to the second-stage sides of the compression elements 203c, 204c, 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 203c of the first compression mechanism 203, the second inlet-side intermediate branch tube 84 connected to the discharge side of the first-stage compression element 204c of the second compression mechanism 204, 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 203d of the first compression mechanism 203, 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 204d of the second compression mechanism 204. The discharge header tube 202b is a refrigerant tube for feeding the refrigerant discharged from the compression mechanism 202 to the heat source-side heat exchanger 4, and the first discharge branch tube 203b connected to the discharge header tube 202b is provided with a first oil separation mechanism 241 and a first non-return mechanism 242, while the second discharge branch tube 204b connected to the discharge header tube 202b is provided with a second oil separation mechanism 243 and a second non-return mechanism 244. The first oil separation mechanism 241 is a mechanism for separating from the refrigerant the refrigeration oil accompanying the refrigerant discharged from the first compression mechanism 203 and returning the oil to the intake side of the compression mechanism 202. The first oil separation mechanism 241 primarily comprises a first oil separator 241a for separating from the refrigerant the refrigeration oil accompanying the refrigerant discharged from the first compression mechanism 203, and a first oil return tube 241 b connected to the first oil separator 241 a for returning the refrigeration oil separated from the refrigerant to the intake side of the compression mechanism 202. The second oil separation mechanism 243 is a mechanism for separating from the refrigerant the refrigeration oil accompanying the refrigerant discharged from the second compression mechanism 204 and returning the oil to the intake side of the compression mechanism 202. The second oil separation mechanism 243 primarily comprises a second oil separator 243a for separating from the refrigerant the refrigeration oil accompanying the refrigerant discharged from the second compression mechanism 204, and a second oil return tube 243b connected to the second oil separator 243a for returning the refrigeration oil separated from the refrigerant to the intake side of the compression mechanism 202. In the present modification, the first oil return tube 241b is connected to the second intake branch tube 204a, and the second oil return tube 243b is connected to the first intake branch tube 203a. Therefore, even if there is a disparity between the amount of refrigeration oil accompanying the refrigerant discharged from the first compression mechanism 203 and the

amount of refrigeration oil accompanying the refrigerant discharged from the second compression mechanism 204, which occurs as a result of a disparity between the amount of refrigeration oil retained in the first compression mechanism 203 and the amount of refrigeration oil retained in the second compression mechanism 204, more refrigeration oil returns to whichever of the compression mechanisms 203, 204 has the smaller amount of refrigeration oil, thus resolving the disparity between the amount of refrigeration oil retained in the first compression mechanism 203 and the amount of refrigeration oil retained in the second compression mechanism 204. In the present modification, the first intake branch tube 203a is configured so that the portion leading from the flow juncture with the second oil return tube 243b to the flow juncture with the intake header tube 202a slopes downward toward the flow juncture with the intake header tube 202a, while the second intake branch tube 204a is configured so that the portion leading from the flow juncture with the first oil return tube 241 b to the flow juncture with the intake header tube 202a slopes downward toward the flow juncture with the intake header tube 202a. Therefore, even if either one of the two-stage compression-type compression mechanisms 203, 204 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 202a, and there will be little likelihood of a shortage of oil supplied to the operating compression mechanism. The oil return tubes 241b, 243b are provided with depressurizing mechanisms 241c, 243c for depressurizing the refrigeration oil flowing through the oil return tubes 241b, 243b. The non-return mechanisms 242, 244 are mechanisms for allowing refrigerant to flow from the discharge sides of the compression mechanisms 203, 204 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 sides of the compression mechanisms 203, 204.

[0056] Thus, in the present modification, the compression mechanism 202 is configured by connecting two compression mechanisms in parallel; namely, the first compression mechanism 203 having two compression elements 203c, 203d and configured so that refrigerant discharged from the first-stage compression element of these compression elements 203c, 203d is sequentially compressed by the second-stage compression element, and the second compression mechanism 204 having two compression elements 204c, 204d and configured so that refrigerant discharged from the first-stage compression element of these compression elements 204c, 204d is sequentially compressed by the second-stage compression element.

[0057] 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 203c of the first compression mechanism 203 and the refrigerant discharged from the first-stage compression element 204c of the second compression mechanism 204. In other words, the intercooler 7 functions as a cooler shared by the two compression mechanisms 203, 204. Therefore, it is possible to simplify the circuit configuration surrounding the compression mechanism 202 when the intercooler 7 is provided to a parallel multistage compression-type compression mechanism 202 in which a plurality of multistage compression-type compression mechanisms 203, 204 is connected in parallel.

[0058] In the present modification, the intermediate oil separation mechanism 16 is provided in the section between the inlet of the intercooler 7 and the flow juncture between the inlet-side intermediate branch tubes 81, 84 of the intermediate header tube 82 constituting the intermediate refrigerant tube 8, and the intermediate oil separation mechanism 16 is provided to be shared by the two compression mechanisms 203, 204, similar to the intercooler 7. In the present modification, the intermediate oil return tube 16b connects the oil outlet of the intermediate oil separator 16a with the intake header tube 202a of the compression mechanism 202.

[0059] 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 203c of the first compression mechanism 203 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 203c, 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 204c of the second compression mechanism 204 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 204c. In the present modification, non-return valves are used as the non-return mechanisms 81a, 84a. Therefore, even if either one of the compression mechanisms 203, 204 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 202, 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 203, 204 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 203), the stopped compression mechanism described above will always be the second compression mechanism 204, and therefore in this case only the non-return mechanism 84a corresponding to the second compression mechanism 204 need be provided.

[0060] In cases of a compression mechanism which prioritizes operating the first compression mechanism 203 as described above, since a shared intermediate refrigerant tube 8 is provided for both compression mechanisms 203, 204, the refrigerant discharged from the first-stage compression element 203c corresponding to the operating first compression mechanism 203 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 204d of the stopped second compression mechanism 204, whereby there is a danger that refrigerant discharged from the first-stage compression element 203c of the operating first compression mechanism 203 will pass through the interior of the second-stage compression element 204d of the stopped second compression mechanism 204 and exit out through the discharge side of the compression mechanism 202, causing the refrigeration oil of the stopped second compression mechanism 204 to flow out, resulting in insufficient refrigeration oil for starting up the stopped second compression mechanism 204. 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 204 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 203c of the operating first compression mechanism 203 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 204d of the stopped second compression mechanism 204; therefore, there are no longer any instances in which the refrigerant discharged from the first-stage compression element 203c of the operating first compression mechanism 203 passes through the interior of the second-stage compression element 204d of the stopped second compression mechanism 204 and exits out through the discharge side of the compression mechanism 202 which causes the refrigeration oil of the stopped second compression mechanism 204 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 204. An electromagnetic valve is used as the on/off valve 85a in the present modification.

[0061] In the case of a compression mechanism which prioritizes operating the first compression mechanism 203, the second compression mechanism 204 is started up in continuation from the starting up of the first compression mechanism 203, but at this time, since a shared intermediate refrigerant tube 8 is provided for both compression mechanisms 203, 204, the starting up takes place from a state in which the pressure in the discharge side of the first-stage compression element 203c of the second compression mechanism 204 and the pressure in the intake side of the second-stage compression element 203d are greater than the pressure in the intake side of the first-stage compression element 203c and the pressure in the discharge side of the second-stage compression element 203d, and it is difficult to start up the second compression mechanism 204 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 204c of the second compression mechanism 204 and the intake side of the second-stage compression element 204d, and an on/off valve 86a is provided to this startup bypass tube 86. In cases in which the second compression mechanism 204 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 204 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 204c of the second compression mechanism 204 is drawn into the second-stage compression element 204d via the startup bypass tube 86 without being mixed with the refrigerant discharged from the first-stage compression element 203c of the first compression mechanism 203, 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 point in time when the operating state of the compression mechanism 202 has been stabilized (e.g., a point in time when the intake pressure, discharge pressure, and intermediate pressure of the compression mechanism 202 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 204d of the second compression mechanism 204, while the other end is connected between the discharge side of the first-stage compression element 204c of the second compression mechanism 204 and the non-return mechanism 84a of the second inlet-side intermediate branch tube 84, and when the second compression mechanism 204 is started up, the startup by-

pass tube 86 can be kept in a state of being substantially unaffected by the intermediate pressure portion of the first compression mechanism 203. An electromagnetic valve is used as the on/off valve 86a in the present modification.

[0062] The actions of the air-conditioning apparatus 1 of the present modification during the air-cooling operation are essentially the same as the actions in the above-described embodiment (FIGS. 1 through 3 and the relevant descriptions), except for the points modified by the circuit configuration surrounding the compression mechanism 202 are somewhat more complex due to the compression mechanism 202 being provided instead of the compression mechanism 2, and these actions are therefore not described herein.

[0063] The accumulation of refrigeration oil in the intercooler 7 can be prevented and oil shortages to the compression mechanism 202 can be prevented with this configuration of Modification 4 as well, because the refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 203c of the first compression mechanism 203 and the first-stage compression element 204c of the second compression mechanism 204 can be suppressed from flowing into the intercooler 7. It is also possible to prevent the loss of heat transfer performance and the increase of pressure drop in the intercooler 7 caused by the accumulation of refrigeration oil in the intercooler 7, and the performance of the air-conditioning apparatus 1 can be improved. In the configuration of the present modification, although a parallel multistage compression-type compression mechanism 202 is used in which a plurality of multistage compression-type compression mechanisms 203, 204 are connected in parallel, it is possible to simplify the circuit configuration surrounding the compression mechanism 202 because the intermediate oil separation mechanism 16 is provided to be shared by the two compression mechanisms 203, 204. In the present modification, since the intermediate oil return tube 16b connects the oil outlet of the intermediate oil separator 16a with the intake header tube 202a of the compression mechanism 202, refrigeration oil can be reliably returned to both compression mechanisms 203, 204.

[0064] Though not described in detail herein, other possible options instead of the two-stage compression-type compression mechanisms 203, 204 are to use a compression mechanism having more stages than a two-stage compression system, such as a three-stage compression system (e.g. the compression mechanism 102 in Modification 3) or the like, or a parallel multistage compression-type compression mechanism in which three or more multistage compression-type compression mechanisms are connected in parallel. In this case, the same effects as those of the present modification can be achieved.

(7) Modification 5

[0065] In Modification 4 described above, the intermediate oil separation mechanism 16 was provided to be shared by the two compression mechanisms 203, 204 as shown in FIG. 11, but another possible option is to provide an intermediate oil separation mechanism 16 corresponding for each of the compression mechanisms 203, 204 as shown in FIG. 12. For example, for the first compression mechanism 203, an intermediate oil separation mechanism 16 can be provided in a first inlet-side intermediate branch tube 81 connected to the discharge side of a first-stage compression element 203c, and for the second compression mechanism 204, another intermediate oil separation mechanism 16 can be provided to a second inlet-side intermediate branch tube 84 connected to the discharge side of a first-stage compression element 204c.

[0066] The accumulation of refrigeration oil in the intercooler 7 can be prevented and oil shortages to the compression mechanism 202 can be prevented with this configuration of Modification 5 as well, because the refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 203c of the first compression mechanism 203 and the first-stage compression element 204c of the second compression mechanism 204 can be suppressed from flowing into the intercooler 7. It is also possible to prevent the loss of heat transfer performance and the increase of pressure drop in the intercooler 7 caused by the accumulation of refrigeration oil in the intercooler 7, and the performance of the air-conditioning apparatus 1 can be improved. In the configuration of the present modification, since an intermediate oil separation mechanism 16 is provided so as to correspond to each of the compression mechanisms 203, 204, providing intermediate oil separators 16a in the vicinities of the first-stage compression elements 203c, 204c makes it possible to separate refrigeration oil from the refrigerant in the vicinities of the first-stage compression elements 203c, 204c, whereby it is possible to prevent the accumulation of refrigeration oil not only in the intercooler 7 but also in the intermediate header tube 82, the inlet-side intermediate branch tubes 81, 84, and other locations in the intermediate refrigerant tube 8.

[0067] In the configuration shown in FIG. 12, the intermediate oil return tube 16b of the intermediate oil separation mechanism 16 provided for the first compression mechanism 203 may be connected to the portion of the second intake branch tube 204a configured so as to slope downward toward the flow juncture with the intake header tube 202a, and the intermediate oil return tube 16b of the intermediate oil separation mechanism 16 provided for the second compression mechanism 204 may be connected to the portion of the first intake branch tube 203a configured so as to slope downward toward the flow juncture with the intake header tube 202a (see FIG. 13).

[0068] In this configuration, in addition to the effects described above, even in cases of a disparity between

the amount of refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 203c of the first compression mechanism 203 and the amount of refrigeration oil accompanying the refrigerant discharged from the first-stage compression element 204c of the second compression mechanism 204, which occurs as a result of a disparity between the amount of refrigeration oil retained in the first compression mechanism 203 and the amount of refrigeration oil retained in the second compression mechanism 204; more refrigeration oil returns to whichever of the compression mechanisms 203, 204 having the least amount of refrigeration oil, thus resolving the disparity between the amount of refrigeration oil retained in the first compression mechanism 203 and the amount of refrigeration oil retained in the second compression mechanism 204. Moreover, even if either one of the compression mechanisms 203, 204 has stopped, the refrigeration oil being returned from the intermediate 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 202a, and oil shortages to the operating compression mechanism can be impeded.

(8) Modification 6

[0069] In the above-described embodiment and the modifications thereof, in the air-conditioning apparatus 1 configured to be capable of the air-cooling operation, the intercooler 7 was provided to the intermediate refrigerant tube 8 and the intermediate oil separation mechanism 16 was provided between the first-stage compression element of the intermediate refrigerant tube 8 and the inlet of the intercooler 7, thereby achieving the effects of reducing heat radiation loss in the heat source-side heat exchanger 4 functioning as a refrigerant cooler, improving operating efficiency, preventing oil shortages in the operating compression mechanism, and other effects. However, in addition to this configuration, another possibility is to enable switching between an air-cooling operation and an air-warming operation, and to further provide a second-stage injection tube for branching off the refrigerant cooled in the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 and returning the refrigerant to the second-stage compression element 2d.

[0070] For example, in the above-described embodiment in which a two-stage compression-type compression mechanism 2 is used, a refrigerant circuit 310 can be used in which a switching mechanism 3 is provided for switching between an air-cooling operation and an air-warming operation, a receiver inlet expansion mechanism 5a and a receiver outlet expansion mechanism 5b are provided instead of the expansion mechanism 5, and a bridge circuit 17, a receiver 18, a second-stage injection tube 19, and an economizer heat exchanger 20 are provided as shown in FIG. 14.

[0071] The switching mechanism 3 is a mechanism for

switching the direction of refrigerant flow in the refrigerant circuit 310. 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. 14, 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. 14, 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 also be configured by combining a plurality of electromagnetic valves, for example, so as to provide the same function of switching the direction of refrigerant flow as described above.

[0072] Thus, the switching mechanism 3 is configured so as to be capable of switching between the cooling operation state in which refrigerant is circulated in sequence through the compression mechanism 2, the heat source-side heat exchanger 4, the expansion mechanisms 5a, 5b, and the usage-side heat exchanger 6; and the heating operation state in which refrigerant is circulated in sequence through the compression mechanism 2, the usage-side heat exchanger 6, the expansion mechanisms 5a, 5b, and the heat source-side heat exchanger 4.

[0073] 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 functions as an intercooler limiting mechanism 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 modification. The intercooler bypass on/off valve 11 is closed

when the switching mechanism 3 is set to the cooling operation state and opened when the switching mechanism 3 is set to the heating operation state.

[0074] 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 functions as an intercooler limiting 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 modification. The cooler on/off valve 12 is controlled so as to open when the switching mechanism 3 is set to the cooling operation state and close when the switching mechanism 3 is set to the heating operation state.

[0075] 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 four non-return valves 17a, 17b, 17c and 17d 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 outlet non-return valve 17d is a non-return valve for allowing refrigerant to flow only from the receiver outlet tube 18b to the heat source-side heat exchanger 4. In other words, the outlet non-return valves 17c, 17d have the function of allowing the 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.

[0076] The receiver inlet 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. In the present modification, the receiver inlet 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.

[0077] The receiver 18 is a container provided in order

to temporarily retain refrigerant after it is depressurized by the receiver inlet expansion mechanism 5a, wherein the inlet of the receiver is connected to the receiver inlet tube 18a and the outlet is connected to the receiver outlet tube 18b. Also connected to the receiver 18 is an intake return tube 18c capable of withdrawing refrigerant from inside the receiver 18 and returning the refrigerant to the intake tube 2a of the compression mechanism 2 (i.e., to the intake side of the compression element 2c on the first-stage side of the compression mechanism 2). The intake return tube 18c is provided with an intake return on/off valve 18d. The intake return on/off valve 18d is an electromagnetic valve in the present modification.

[0078] The receiver outlet expansion mechanism 5b is a refrigerant-depressurizing mechanism provided to the receiver outlet tube 18b, and an electric expansion valve is used in the present modification. In the present modification, the receiver outlet expansion mechanism 5b further depressurizes refrigerant depressurized by the receiver inlet expansion mechanism 5a to an even lower pressure before feeding the refrigerant to the usage-side heat exchanger 6 during the air-cooling operation, and further depressurizes refrigerant depressurized by the receiver inlet expansion mechanism 5a to an even lower pressure before feeding the refrigerant to the heat source-side heat exchanger 4.

[0079] Thus, when the switching mechanism 3 is brought to 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 exchanger 6 through the inlet non-return valve 17a of the bridge circuit 17, the receiver inlet expansion mechanism 5a of the receiver inlet tube 18a, the receiver 18, the receiver outlet expansion mechanism 5b of the receiver outlet tube 18b, and the outlet non-return valve 17c of the bridge circuit 17. When the switching mechanism 3 is brought to the heating operation state, the high-pressure refrigerant cooled in the usage-side heat exchanger 6 can be fed to the heat source-side heat exchanger 4 through the inlet non-return valve 17b of the bridge circuit 17, the receiver inlet expansion mechanism 5a of the receiver inlet tube 18a, the receiver 18, the receiver outlet expansion mechanism 5b of the receiver outlet tube 18b, and the outlet non-return valve 17d of the bridge circuit 17.

[0080] The second-stage injection tube 19 has the function of branching off the refrigerant cooled in the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 and returning the refrigerant to the compression element 2d on the second-stage side of the compression mechanism 2. In the present modification, the 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 refrigerant from a position upstream of the receiver inlet

expansion mechanism 5a of the receiver inlet tube 18a (specifically, between the heat source-side heat exchanger 4 and the receiver inlet expansion mechanism 5a when the switching mechanism 3 is in the cooling operation state, and between the usage-side heat exchanger 6 and the receiver inlet expansion mechanism 5a when the switching mechanism 3 is in the heating operation state) and return the refrigerant to a position downstream of the intercooler 7 of the intermediate refrigerant tube 8. The second-stage injection tube 19 is provided with a second-stage injection valve 19a whose opening degree can be controlled. The second-stage injection valve 19a is an electric expansion valve in the present modification.

[0081] The economizer heat exchanger 20 is a heat exchanger for conducting heat exchange between the refrigerant cooled in the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 and the refrigerant flowing through the second-stage injection tube 19 (more specifically, the refrigerant that has been depressurized nearly to an intermediate pressure in the second-stage injection valve 19a). In the present modification, the economizer heat exchanger 20 is provided so as to conduct heat exchange between the refrigerant flowing through a position upstream (specifically, between the heat source-side heat exchanger 4 and the receiver inlet expansion mechanism 5a when the switching mechanism 3 is in the cooling operation state, and between the usage-side heat exchanger 6 and the receiver inlet expansion mechanism 5a when the switching mechanism 3 is in the heating operation state) of the receiver inlet expansion mechanism 5a of the receiver inlet tube 18a and the refrigerant flowing through the second-stage injection tube 19, and the economizer heat exchanger 20 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 upstream of the second-stage injection tube 19 of the receiver inlet tube 18a. Therefore, the refrigerant cooled in the heat source-side heat exchanger 4 or usage-side heat exchanger 6 is branched off in the receiver inlet tube 18a to the 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-stage injection tube 19.

[0082] Furthermore, the air-conditioning apparatus 1 of the present modification is provided with various sensors. Specifically, an intermediate pressure sensor 54 for detecting the pressure of refrigerant flowing through the intermediate refrigerant tube 8 is provided to the intermediate refrigerant tube 8 or the compression mechanism 2. The outlet on the 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 refrigerant at the outlet on the second-stage injection tube 19 side of the economizer heat exchanger 20.

[0083] Next, the action of the air-conditioning apparatus 1 of the present modification will be described using FIGS. 14 through 18. FIG. 15 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in Modification 6, FIG. 16 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in Modification 6, FIG. 17 is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in Modification 6, and FIG. 18 is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in Modification 6. Operation control in the air-cooling operation and the air-warming operation described hereinbelow is 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. 15 and 16, and the pressure at points D, D', F, and H in FIGS. 17 and 18), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A, F, and F' in FIGS. 15 and 16, and the pressure at points A, E, and E' in FIGS. 17 and 18), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B1, C1, G, J, and K in FIGS. 15 through 18).

<Air-Cooling Operation>

[0084] During the air-cooling operation, the switching mechanism 3 is brought to the cooling operation state shown by the solid lines in FIG. 14. The opening degrees of the receiver inlet expansion mechanism 5a and the receiver outlet expansion mechanism 5b are adjusted. Since the switching mechanism 3 is in the cooling operation state, 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. Furthermore, the opening degree of the second-stage injection valve 19a is also adjusted. More specifically, in the present modification, so-called superheat degree control is performed wherein the opening degree of the 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-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-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 modification, another possible option is to provide a temperature sensor to the inlet in the 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-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.

[0085] When the compression mechanism 2 is driven while the refrigerant circuit 310 is in this state, low-pressure refrigerant (refer to point A in FIGS. 14 to 16) 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. 14 to 16). As in the embodiment described above, the intermediate-pressure refrigerant discharged from the first-stage compression element 2c flows into the intermediate oil separator 16a constituting the intermediate oil separation mechanism 16, and after the accompanying refrigeration oil is separated, the refrigerant is fed to the intercooler 7.

The refrigeration oil separated from the intermediate-pressure refrigerant in the intermediate oil separator 16a flows into the intermediate oil return tube 16b constituting the intermediate oil separation mechanism 16, and after being depressurized by the depressurizing mechanism 16c provided to the intermediate oil return tube 16b, the refrigerant is returned to the compression mechanism 2 (the intake tube 2a in this case) and led back into the compression mechanism 2. After the refrigeration oil has been separated in the intermediate oil separation mechanism 16, the intermediate-pressure refrigerant is then cooled in the intercooler 7 by undergoing heat exchange with water or air as a cooling source (refer to point C1 in FIGS. 14 to 16). The refrigerant cooled in the intercooler 7 is further cooled (refer to point G in FIGS. 14 to 16) by mixing with refrigerant being returned from the second-stage injection tube 19 to the second-stage side compression element 2d (refer to point K in FIGS. 14 to 16). Next, having been mixed with the refrigerant returned from the second-stage injection tube 19, 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. 14 to 16). 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. 15). 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 water or air as a cooling source (refer to point E in FIGS. 14 to 16). 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 to the second-stage injection tube 19. The refrigerant flowing through the second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 14 to 16). The refrigerant flowing through the receiver inlet tube 18a after being branched off to the 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-stage injection tube 19 (refer to point H in FIGS. 14 to 16). The refrigerant flowing through the 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. 14 to 16), and this refrigerant mixes 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 receiver inlet expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 14 to 16). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b and is depressurized by the receiver outlet expansion mechanism 5b to become a low-pressure gas-liquid two-phase refrigerant, and is then fed through the outlet non-return valve 17c of the bridge circuit 17 to the usage-side heat exchanger 6 functioning as a refrigerant heater (refer to point F in FIGS. 14 to 16). 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. 14 to 16). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is led once again into the compression mechanism 2 via the switching mechanism 3. In this manner the air-cooling operation is performed.

[0086] In the configuration of the present modification, as in the embodiment described above, since the intercooler 7 is in a state of functioning as a cooler during the air-cooling operation in which the switching mechanism 3 is brought to the cooling operation state, heat radiation loss in the heat source-side heat exchanger 4 can be reduced in comparison with cases in which no intercooler 7 is provided.

[0087] In the configuration of the present modification, as in the embodiment described above, since an intermediate oil separation mechanism 16 is provided in a section of the intermediate refrigerant tube 8 between the first-stage compression element 2c and the inlet of the intercooler 7, it is possible to prevent oil shortages to the compression mechanism 2 caused by the accumulation of refrigeration oil in the intercooler 7, and also to prevent loss of heat transfer performance and increases in pressure drop in the intercooler 7. Furthermore, in the present modification, since the intermediate oil separation

mechanism 16 is provided in a position farther upstream than the connecting point between the intermediate refrigerant tube 8 and the intercooler bypass tube 9, the accumulation of refrigeration oil in the intercooler bypass tube 9 can also be prevented.

[0088] Moreover, in the configuration of the present modification, since the second-stage injection tube 19 is provided so as to branch off refrigerant fed from the heat source-side heat exchanger 4 to the expansion mechanisms 5a, 5b and return the refrigerant to the second-stage compression element 2d, the temperature of refrigerant drawn into the second-stage compression element 2d can be kept even lower (refer to points C1 and G in FIG. 16) without performing heat radiation to the exterior, such as is done with the intercooler 7. The temperature of refrigerant discharged from the compression mechanism 2 is thereby kept even lower (refer to points D and D' in FIG. 16), and operating efficiency can be further improved because heat radiation loss can be further reduced in proportion to the area enclosed by connecting the points C1, D', D, and G in FIG. 16, in comparison with cases in which no second-stage injection tube 19 is provided.

[0089] In the configuration of the present modification, since an economizer heat exchanger 20 is also provided for conducting heat exchange between the refrigerant fed from the heat source-side heat exchanger 4 to the expansion mechanisms 5a, 5b and the refrigerant flowing through the second-stage injection tube 19, the refrigerant fed from the heat source-side heat exchanger 4 to the expansion mechanisms 5a, 5b can be cooled by the refrigerant flowing through the second-stage injection tube 19 (refer to points E and H in FIGS. 15 and 16), and the cooling capacity per flow rate of refrigerant in the usage-side heat exchanger 6 can be increased in comparison with cases in which the second-stage injection tube 19 and economizer heat exchanger 20 are not provided (in this case, the refrigeration cycle in FIGS. 15 and 16 is performed in the following sequence: point A → point B1 → point C1 → point D' → point E → point F').

<Air-Warming Operation>

[0090] During the air-warming operation, the switching mechanism 3 is brought to the heating operation state shown by the dashed lines in FIG. 14. The opening degrees of the receiver inlet expansion mechanism 5a and receiver outlet expansion mechanism 5b are adjusted. Since the switching mechanism 3 is in the heating operation state, 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 in a state of not functioning as a cooler. Furthermore, the opening degree of the second-stage injection valve 19a is also adjusted by the same superheat degree control as in the air-cooling operation.

[0091] When the compression mechanism 2 is driven while the refrigerant circuit 310 is in this state, low-pres-

sure refrigerant (refer to point A in FIGS. 14, 17, and 18) 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. 14, 17, and 18). As in the embodiment described above, the intermediate-pressure refrigerant discharged from the first-stage compression element 2c flows into the intermediate oil separator 16a constituting the intermediate oil separation mechanism 16, and after the accompanying refrigeration oil is separated, the refrigerant is fed to the intercooler 7. The refrigeration oil separated from the intermediate-pressure refrigerant in the intermediate oil separator 16a flows into the intermediate oil return tube 16b constituting the intermediate oil separation mechanism 16, and after being depressurized by the depressurizing mechanism 16c provided to the intermediate oil return tube 16b, the refrigerant is returned to the compression mechanism 2 (the intake tube 2a in this case) and led back into the compression mechanism 2. After the refrigeration oil has been separated in the intermediate oil separation mechanism 16, the intermediate-pressure refrigerant then passes through the intercooler bypass tube 9 (refer to point C1 in FIGS. 14, 17, and 18) without passing through the intercooler 7 (i.e. without being cooled), unlike the air-cooling operation, and the refrigerant is cooled (refer to point G in FIGS. 14, 17, and 18) by being mixed with refrigerant being returned from the second-stage injection tube 19 to the compression element 2d (refer to point K in FIGS. 14, 17, and 18). Next, having been mixed with the refrigerant returning from the second-stage injection tube 19, the intermediate-pressure refrigerant is led to and further compressed in the compression element 2d connected to the second-stage side of the compression mechanism 2, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 14, 17, and 18). 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. 17), similar to the air-cooling operation. The high-pressure 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 water or air as a cooling source (refer to point F in FIGS. 14, 17, and 18). The high-pressure refrigerant cooled in the usage-side heat exchanger 6 flows through the inlet non-return valve 17b of the bridge circuit 17 into the receiver inlet tube 18a, and some of the refrigerant is branched off to the second-stage injection tube 19. The refrigerant flowing through the second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the second-stage injection valve 19a, and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 14,

17, and 18). The refrigerant flowing through the receiver inlet tube 18a after being branched off to the second-stage injection tube 19 then flows into the economizer heat exchanger 20 and is cooled by heat exchange with the refrigerant flowing through the second-stage injection tube 19 (refer to point H in FIGS. 14, 17, and 18). The refrigerant flowing through the 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. 14, 17, and 18), and the refrigerant is mixed with the intermediate-pressure refrigerant discharged from the first-stage compression element 2c as described above. The high-pressure refrigerant cooled in the economizer heat exchanger 20 is depressurized to a nearly saturated pressure by the receiver inlet expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 14, 17, and 18). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b and is depressurized by the receiver outlet expansion mechanism 5b to become a low-pressure gas-liquid two-phase refrigerant, and is then fed through the outlet non-return valve 17d of the bridge circuit 17 to the heat source-side heat exchanger 4 functioning as a refrigerant heater (refer to point E in FIGS. 14, 17, and 18). 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. 14, 17, and 18). The low-pressure refrigerant heated in the heat source-side heat exchanger 4 is led once again into the compression mechanism 2 via the switching mechanism 3. In this manner the air-warming operation is performed.

[0092] In the configuration of the present modification, since the intercooler 7 is brought to a state of not functioning as a cooler by closing the cooler on/off valve 12 and opening the intercooler bypass on/off valve 11 of the intercooler bypass tube 9 during the air-warming operation in which the switching mechanism 3 is set to the heating operation state, the temperature decrease in the refrigerant discharged from the compression mechanism 2 is minimized (refer to points D and D' in FIG. 18) in comparison with cases in which only the intercooler 7 is provided or cases in which the intercooler 7 is made to function as a cooler as in the air-cooling operation described above. Therefore, in this air-conditioning apparatus 1, heat radiation to the exterior can be minimized, it is possible to minimize the decrease in the temperature of refrigerant supplied to the usage-side heat exchanger 6 functioning as a refrigerant cooler, the decrease of heating capacity can be minimized, and reduction in operating efficiency can be prevented, in comparison with cases in which only the intercooler 7 is provided or cases in which the intercooler 7 is made to function as a cooler as in the air-cooling operation described above.

[0093] In the configuration of the present modification, as in the air-cooling operation described above, since the intermediate oil separation mechanism 16 is provided

in a section of the intermediate refrigerant tube 8 between the first-stage compression element 2c and the inlet of the intercooler 7, it is possible to prevent oil shortages to the compression mechanism 2 caused by the accumulation of refrigeration oil in the intercooler 7, and loss of heat transfer performance and increases in pressure drop in the intercooler 7 can also be prevented.

[0094] Moreover, in the configuration of the present modification, since the second-stage injection tube 19 is provided so as to branch off refrigerant fed from the usage-side heat exchanger 6 to the expansion mechanisms 5a, 5b and return the refrigerant to the second-stage compression element 2d, the temperature of the refrigerant discharged from the compression mechanism 2 is lower (refer to points D and D' in FIG. 18), and the heating capacity per flow rate of refrigerant in the usage-side heat exchanger 6 thereby decreases (refer to points D, D', and F in FIG. 17), but since the flow rate of refrigerant discharged from the second-stage compression element 2d increases, the heating capacity in the usage-side heat exchanger 6 is preserved, and operating efficiency can be improved.

[0095] In the configuration of the present modification, since an economizer heat exchanger 20 is also provided for conducting heat exchange between the refrigerant fed from the usage-side heat exchanger 6 to the expansion mechanisms 5a, 5b and the refrigerant flowing through the second-stage injection tube 19, the refrigerant flowing through the second-stage injection tube 19 can be heated by the refrigerant fed from the usage-side heat exchanger 6 to the expansion mechanisms 5a, 5b (refer to points J and K in FIGS. 17 and 18), and the flow rate of refrigerant discharged from the second-stage compression element 2d can be increased in comparison with cases in which the second-stage injection tube 19 and economizer heat exchanger 20 are not provided (in this case, the refrigeration cycle in FIGS. 17 and 18 is performed in the following sequence: point A → point B1 → point C1 → point D' → point F → point E').

[0096] Advantages of both the air-cooling operation and the air-warming operation in the configuration of the present modification are that the economizer heat exchanger 20 is a heat exchanger which has flow channels through which refrigerant fed from the heat source-side heat exchanger 4 or usage-side heat exchanger 6 to the expansion mechanisms 5a, 5b and refrigerant flowing through the second-stage injection tube 19 both flow so as to oppose each other; therefore, it is possible to reduce the temperature difference between the refrigerant fed to the expansion mechanisms 5a, 5b from the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 in the economizer heat exchanger 20 and the refrigerant flowing through the second-stage injection tube 19, and high heat exchange efficiency can be achieved. In the configuration of the present modification, since the second-stage injection tube 19 is provided so as to branch off the refrigerant fed to the expansion mechanisms 5a, 5b from the heat source-side heat exchanger

4 or the usage-side heat exchanger 6 before the refrigerant fed to the expansion mechanisms 5a, 5b from the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 undergoes heat exchange in the economizer heat exchanger 20, it is possible to reduce the flow rate of the refrigerant fed from the heat source-side heat exchanger 4 or usage-side heat exchanger 6 to the expansion mechanisms 5a, 5b and subjected to heat exchange with the refrigerant flowing through the second-stage injection tube 19 in the economizer heat exchanger 20, the quantity of heat exchanged in the economizer heat exchanger 20 can be reduced, and the size of the economizer heat exchanger 20 can be reduced.

[0097] Though not described in detail herein, a compression mechanism having more stages than a two-stage compression system, such as a three-stage compression system (e.g. the compression mechanism 102 in Modification 3) or the like, may be used instead of the two-stage compression-type compression mechanism 2, or a parallel multi-stage compression-type compression mechanism in which a plurality of compression mechanisms are connected in parallel, such as a refrigerant circuit 410 (see FIG. 19) which uses the compression mechanism 202 having the two-stage compression-type compression mechanisms 203, 204 in Modification 4, may be used instead of the two-stage compression-type compression mechanism 2, and the same effects as those of the present modification can be achieved in this case as well. In the air-conditioning apparatus 1 of the present modification, the use of the bridge circuit 17 is included from the standpoint of keeping the direction of refrigerant flow constant in the receiver inlet expansion mechanism 5a, the receiver outlet expansion mechanism 5b, the receiver 18, the second-stage injection tube 19, or the economizer heat exchanger 20, regardless of whether the air-cooling operation or air-warming operation is in effect. However, the bridge circuit 17 may be omitted in cases in which there is no need to keep the direction of refrigerant flow constant in the receiver inlet expansion mechanism 5a, the receiver outlet expansion mechanism 5b, the receiver 18, the second-stage injection tube 19, or the economizer heat exchanger 20 regardless of whether the air-cooling operation or the air-warming operation is taking place, such as cases in which the second-stage injection tube 19 and economizer heat exchanger 20 are used either during the air-cooling operation alone or during the air-warming operation alone, for example.

(9) Modification 7

[0098] The refrigerant circuit 310 (see FIG. 14) and the refrigerant circuit 410 (see FIG. 19) in Modification 6 described above had configurations in which one usage-side heat exchanger 6 was connected, but they may alternatively have configurations in which a plurality of usage-side heat exchangers 6 are connected and these usage-side heat exchangers 6 can be started and

stopped individually.

[0099] For example, the refrigerant circuit 310 (FIG. 15) of Modification 7, which uses a two-stage compression-type compression mechanism 2, may be fashioned into a refrigerant circuit 510 in which two usage-side heat exchangers 6 are connected, usage-side expansion mechanisms 5c are provided corresponding to the ends of the usage-side heat exchangers 6 on the sides facing the bridge circuit 17, the receiver outlet expansion mechanism 5b previously provided to the receiver outlet tube 18b is omitted, and a bridge outlet expansion mechanism 5d is provided instead of the outlet non-return valve 17d of the bridge circuit 17, as shown in FIG. 20. Alternatively, the refrigerant circuit 410 (see FIG. 19) of Modification 6 which uses the parallel two-stage compression-type compression mechanism 202 may be fashioned into a refrigerant circuit 610 in which two usage-side heat exchangers 6 are connected, usage-side expansion mechanisms 5c are provided corresponding to the ends of the usage-side heat exchangers 6 on the sides facing the bridge circuit 17, the receiver outlet expansion mechanism 5b previously provided to the receiver outlet tube 18b is omitted, and a bridge outlet expansion mechanism 5d is provided instead of the outlet non-return valve 17d of the bridge circuit 17, as shown in FIG. 21.

[0100] The configuration of the present modification has different actions during the air-cooling operation in Modification 6 in that during the air-cooling operation, the bridge outlet expansion mechanism 5d is fully closed, and in place of the receiver outlet expansion mechanism 5b in Modification 7, the usage-side expansion mechanisms 5c perform the action of further depressurizing the refrigerant already depressurized by the receiver inlet expansion mechanism 5a to a lower pressure before the refrigerant is fed to the usage-side heat exchangers 6; but the other actions of the present modification are essentially the same as the actions during the air-cooling operation in Modification 6 (FIGS. 14 through 16 and their relevant descriptions). The present modification also has different actions from those during the air-warming operation in Modification 6 in that during the air-warming operation, the opening degrees of the usage-side expansion mechanisms 5c are adjusted so as to control the flow rate of refrigerant flowing through the usage-side heat exchangers 6, and in place of the receiver outlet expansion mechanism 5b in Modification 6, the bridge outlet expansion mechanism 5d performs the action of further depressurizing the refrigerant already depressurized by the receiver inlet expansion mechanism 5a to a lower pressure before the refrigerant is fed to the heat source-side heat exchanger 4; but the other actions of the present modification are essentially the same as the actions during the air-warming operation in Modification 6 (FIGS. 14, 17, 18, and their relevant descriptions).

[0101] The same operational effects as those of Modification 6 described above can also be achieved with the configuration of the present modification.

[0102] Though not described in detail herein, a com-

pression mechanism having more stages than a two-stage compression system, such as a three-stage compression system (e.g. the compression mechanism 102 in Modification 3) or the like, may be used instead of the two-stage compression-type compression mechanisms 2, 203, and 204.

(10) Other Embodiments

[0103] Embodiments of the present invention and modifications thereof were described above with reference to the drawings, but the specific configuration is not limited to these embodiments or their modifications, and the configuration can be changed within a range that does not deviate from the scope of the invention.

[0104] 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.

[0105] 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.

[0106] The refrigerant that operates in a supercritical range is not limited to carbon dioxide, and ethylene, ethane, nitric oxide, and other gases may also be used.

INDUSTRIAL APPLICABILITY

[0107] If the present invention is used, in a refrigeration apparatus which performs a multistage compression refrigeration cycle by using a refrigerant that operates in a supercritical range, oil shortages to the compression mechanism can be prevented.

Claims

1. A refrigeration apparatus (1) which a refrigerant that operates in a supercritical range is used, the refrigeration apparatus comprising:

a compression mechanism (2, 102, 202) 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);

an expansion mechanism (5, 5a, 5b, 5c, 5d) for depressurizing the refrigerant;
a usage-side heat exchanger (6);
an intercooler (7) 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 functioning as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element; and
an intermediate oil separation mechanism (16) for separating from the refrigerant a refrigeration oil accompanying the refrigerant discharged from the first-stage compression element, the intermediate oil separation mechanism being provided to a section of the intermediate refrigerant tube between the first-stage compression element and an inlet of the intercooler.

2. The refrigeration apparatus (1) according to claim 1, wherein the intermediate oil separation mechanism (16) has an intermediate oil separator (16a) for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first-stage compression element, and an intermediate oil return tube (16b) for returning the refrigeration oil separated from the refrigerant to the compression mechanism (2, 102, 202), the intermediate oil return tube being connected to the intermediate oil separator.
3. The refrigeration apparatus (1) according to claim 1, wherein the intermediate oil separation mechanism (16) has a header (16d) provided to the inlet of the intercooler (7), and an intermediate oil return tube (16b) for connecting a lower end of the header with the compression mechanism (2, 102, 202).
4. The refrigeration apparatus (1) according to any of claims 1 through 3, wherein the refrigerant that operates in the supercritical range is carbon dioxide.

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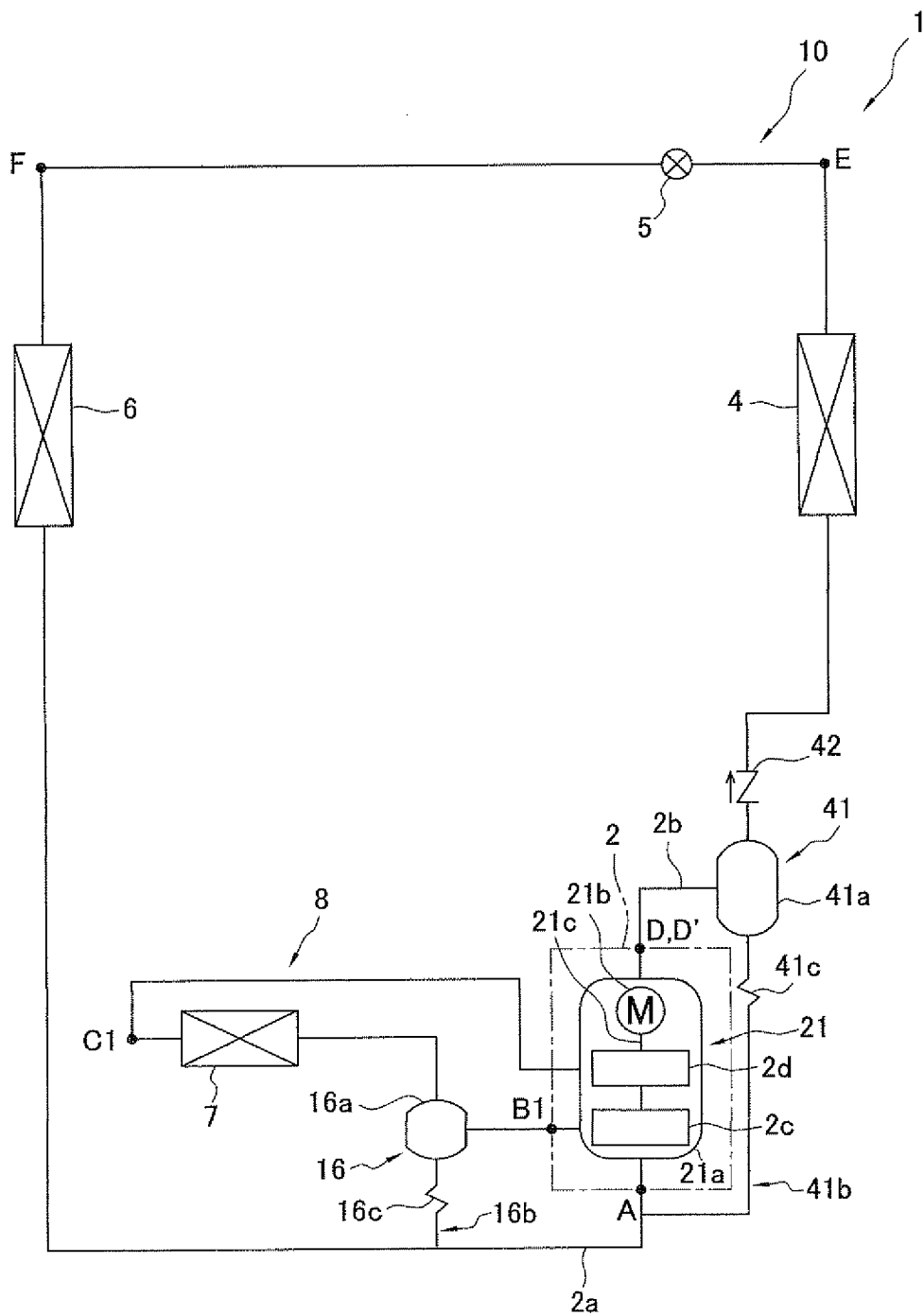


FIG. 1

FIG. 2

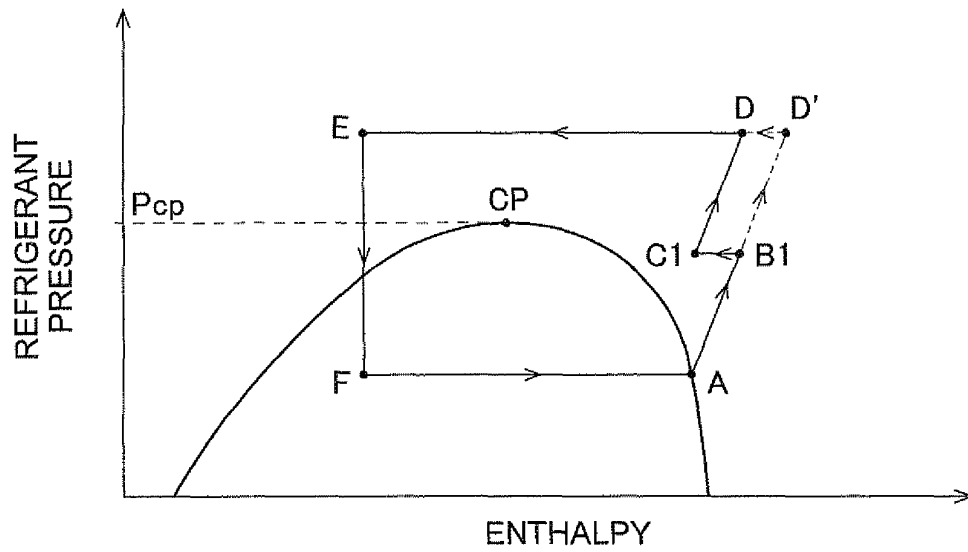
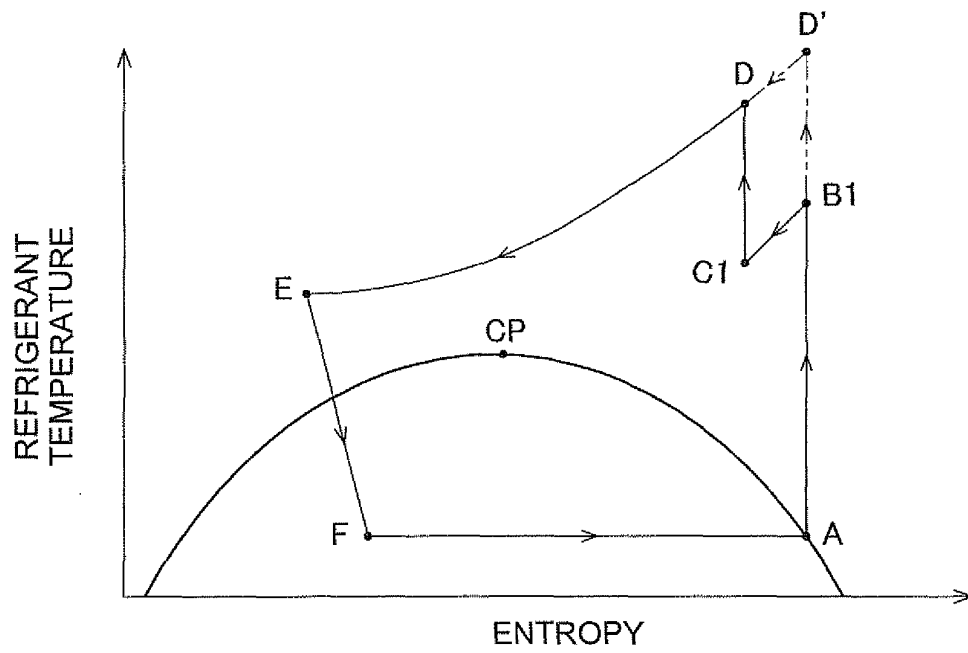


FIG. 3



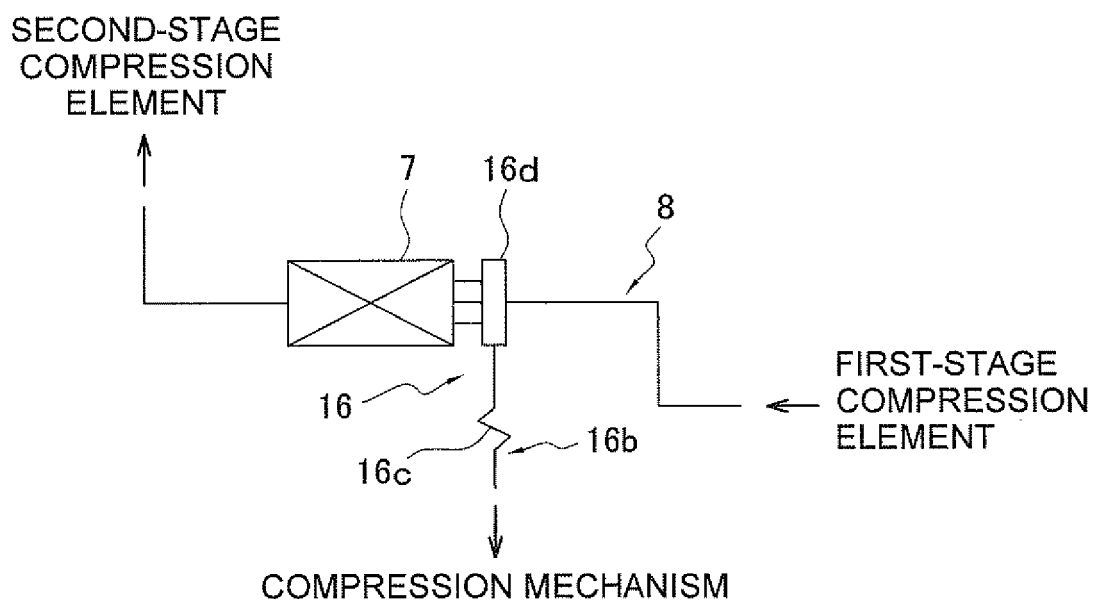


FIG. 4

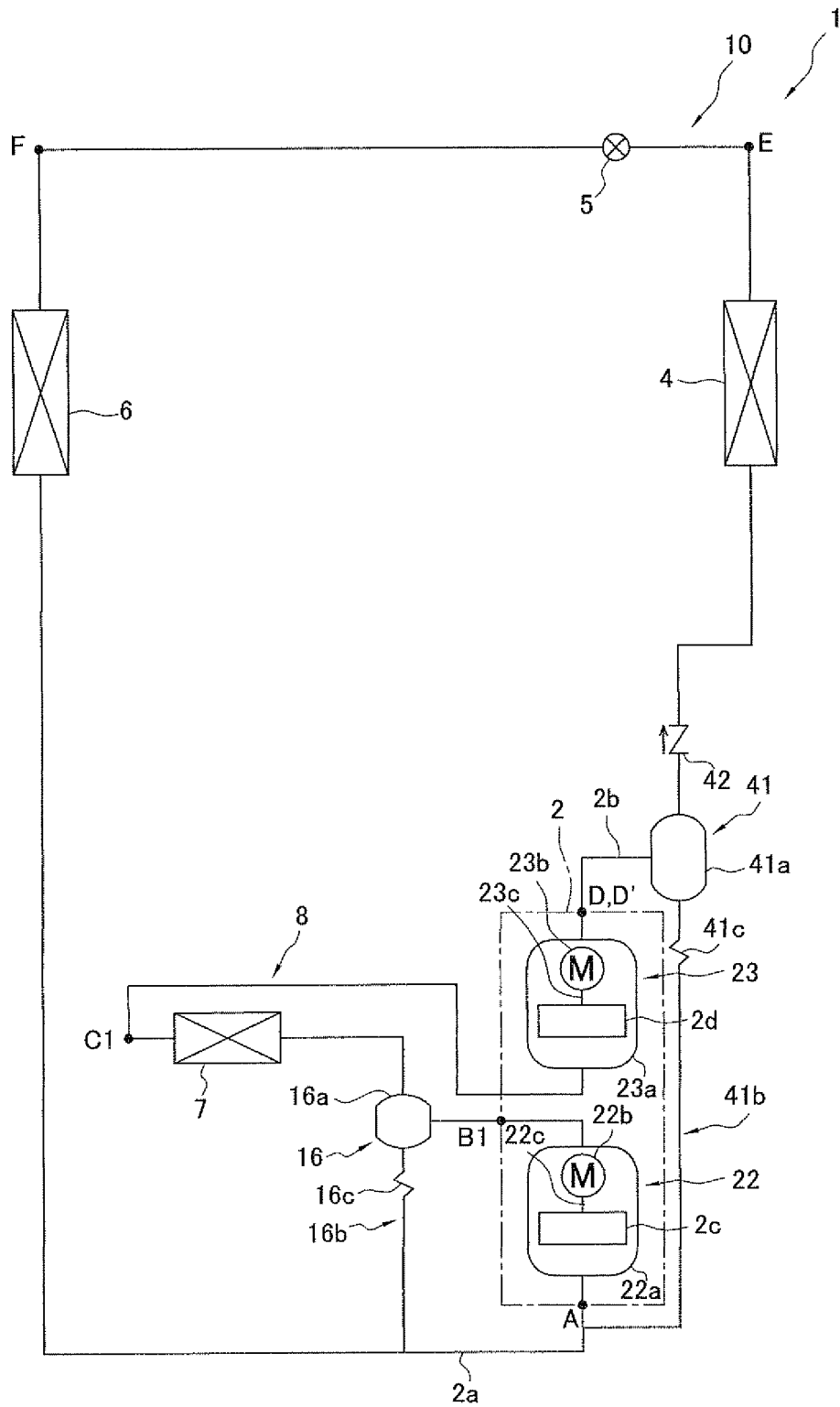


FIG. 5

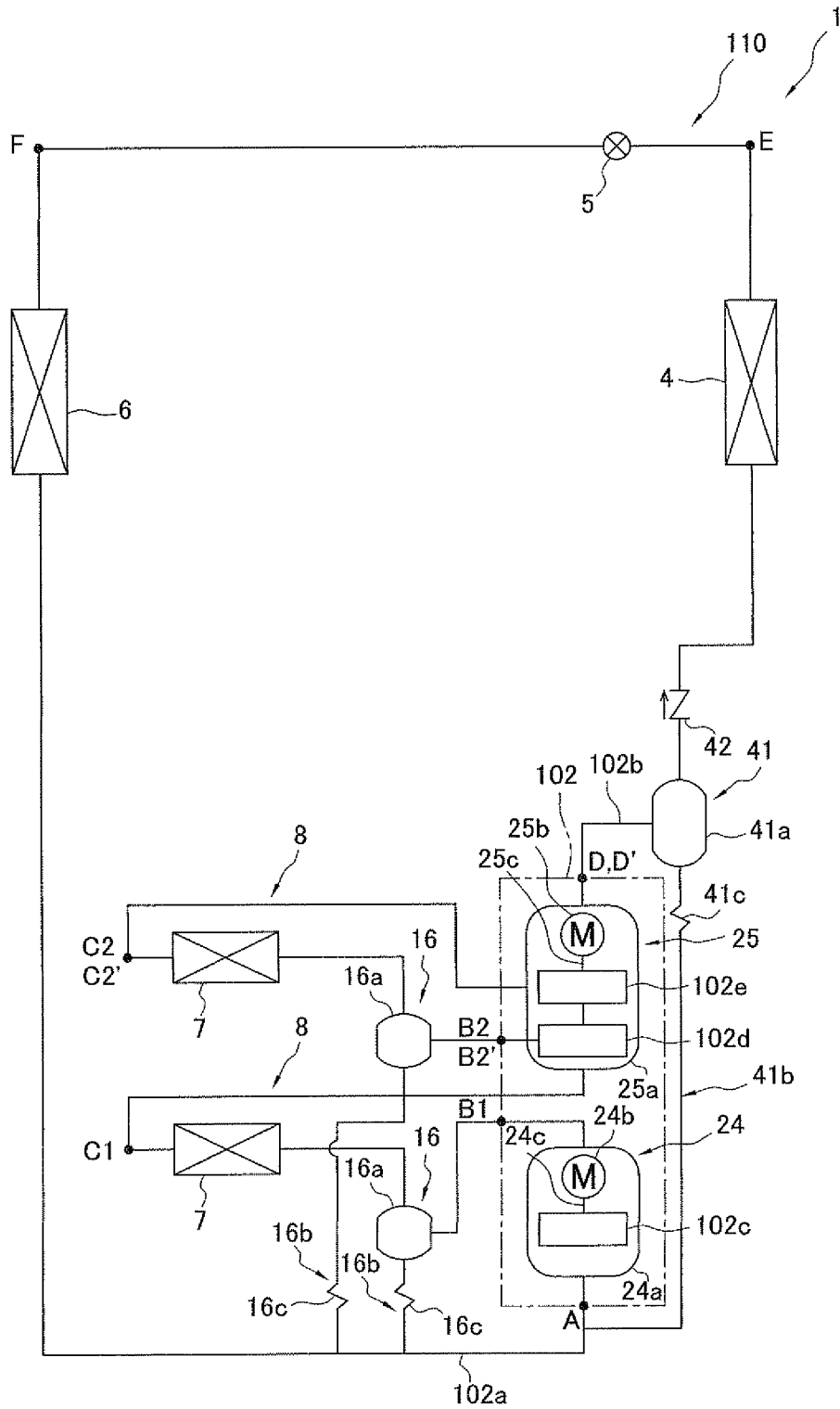


FIG. 6

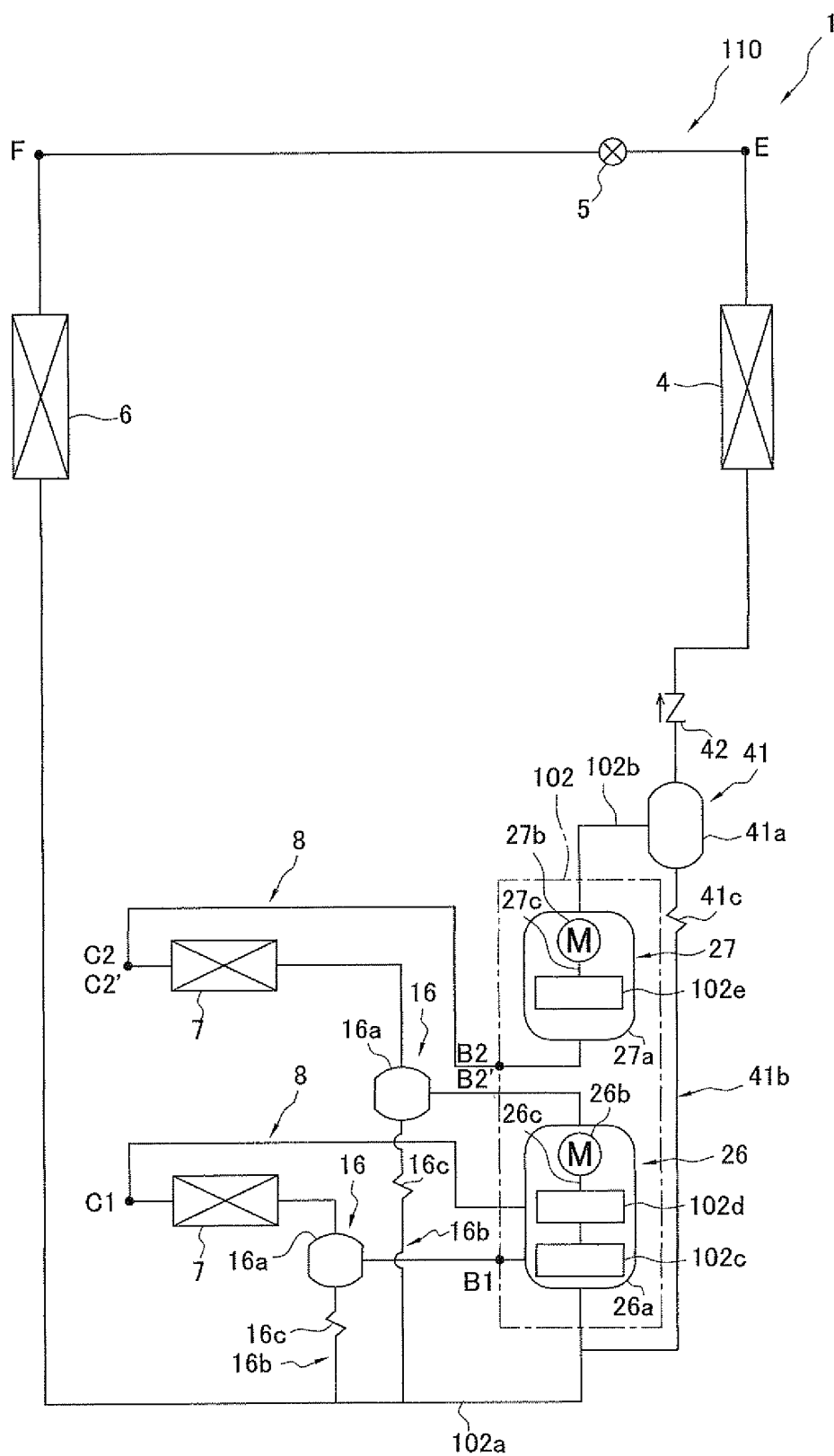


FIG. 7

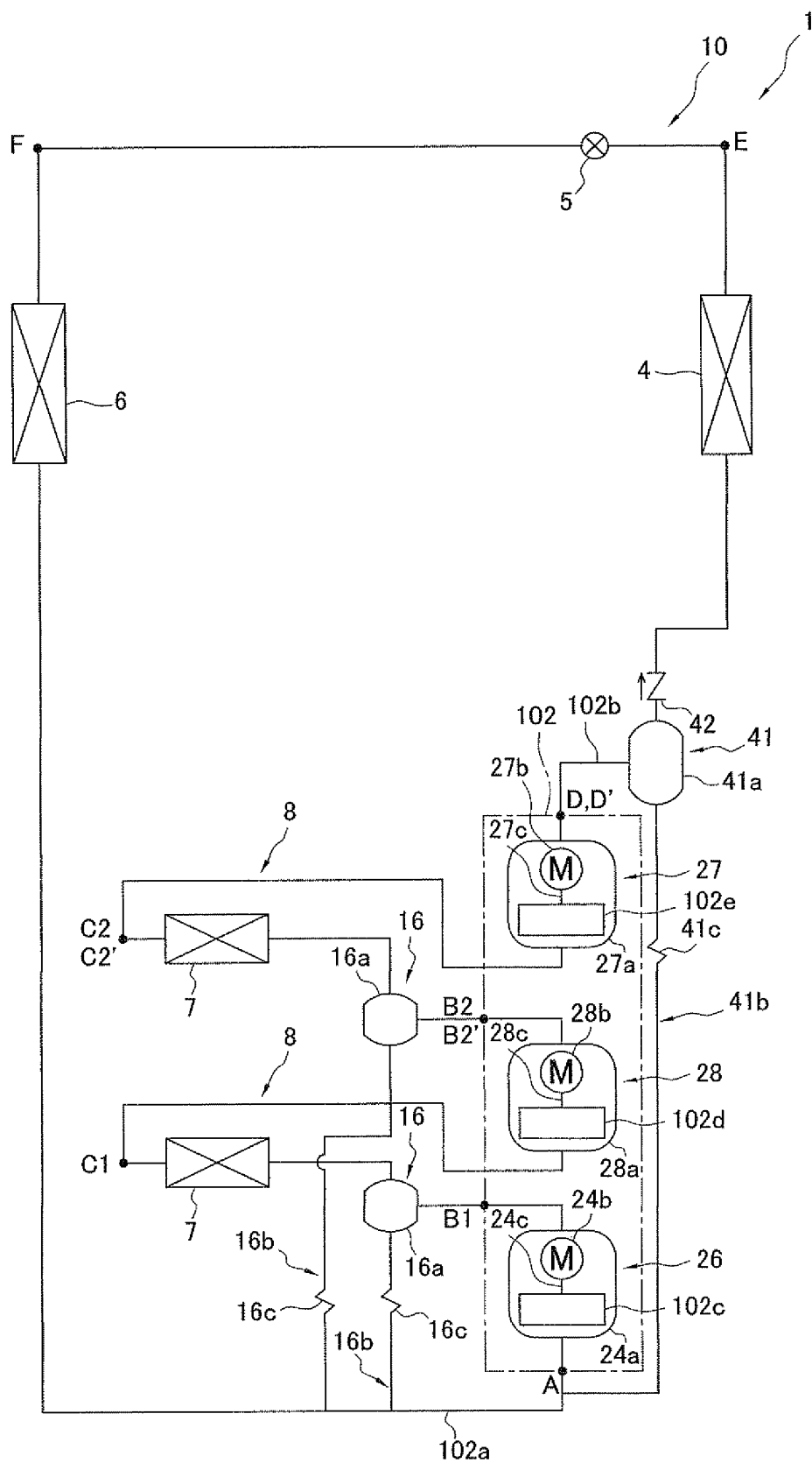


FIG. 8

FIG. 9

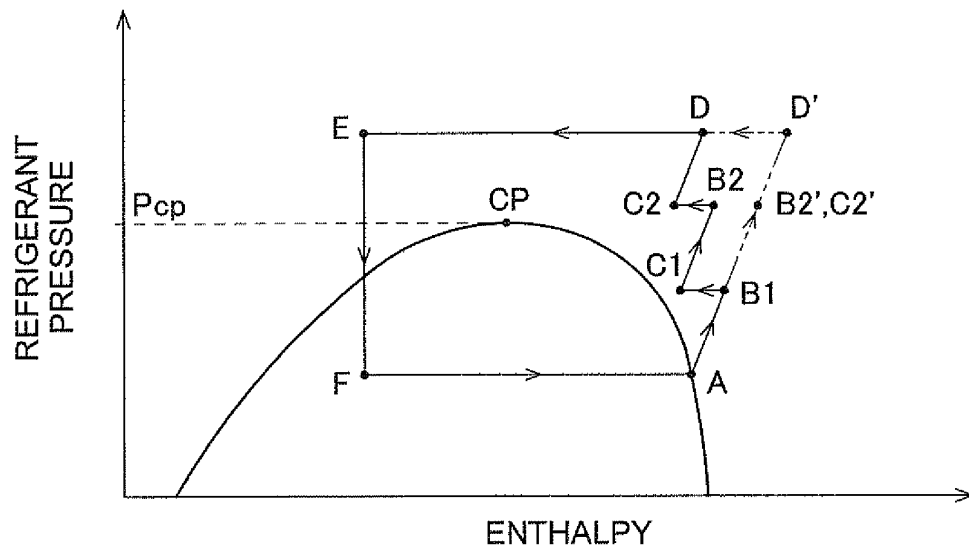
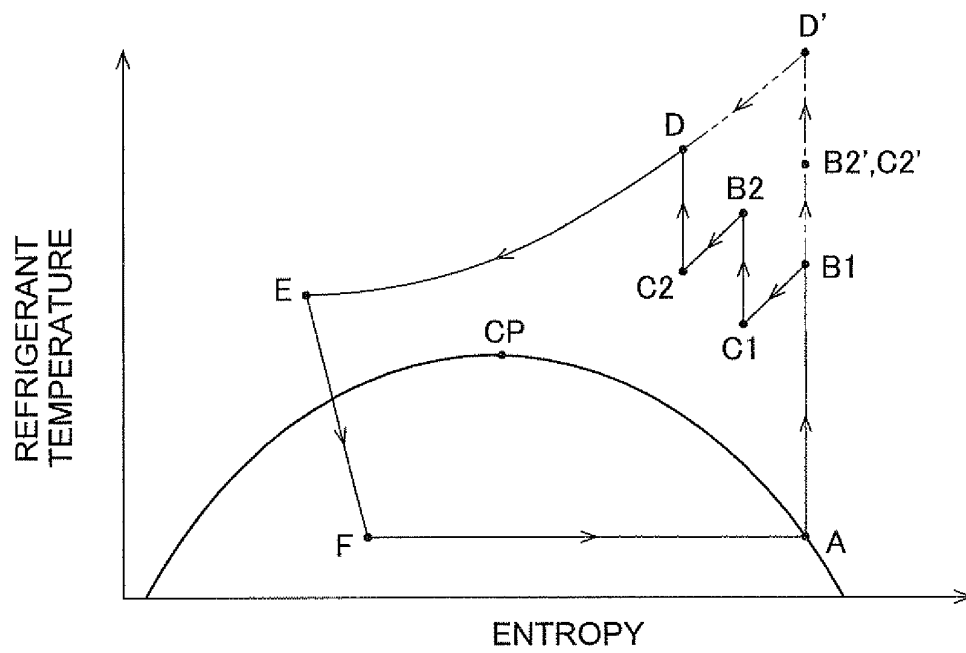


FIG. 10



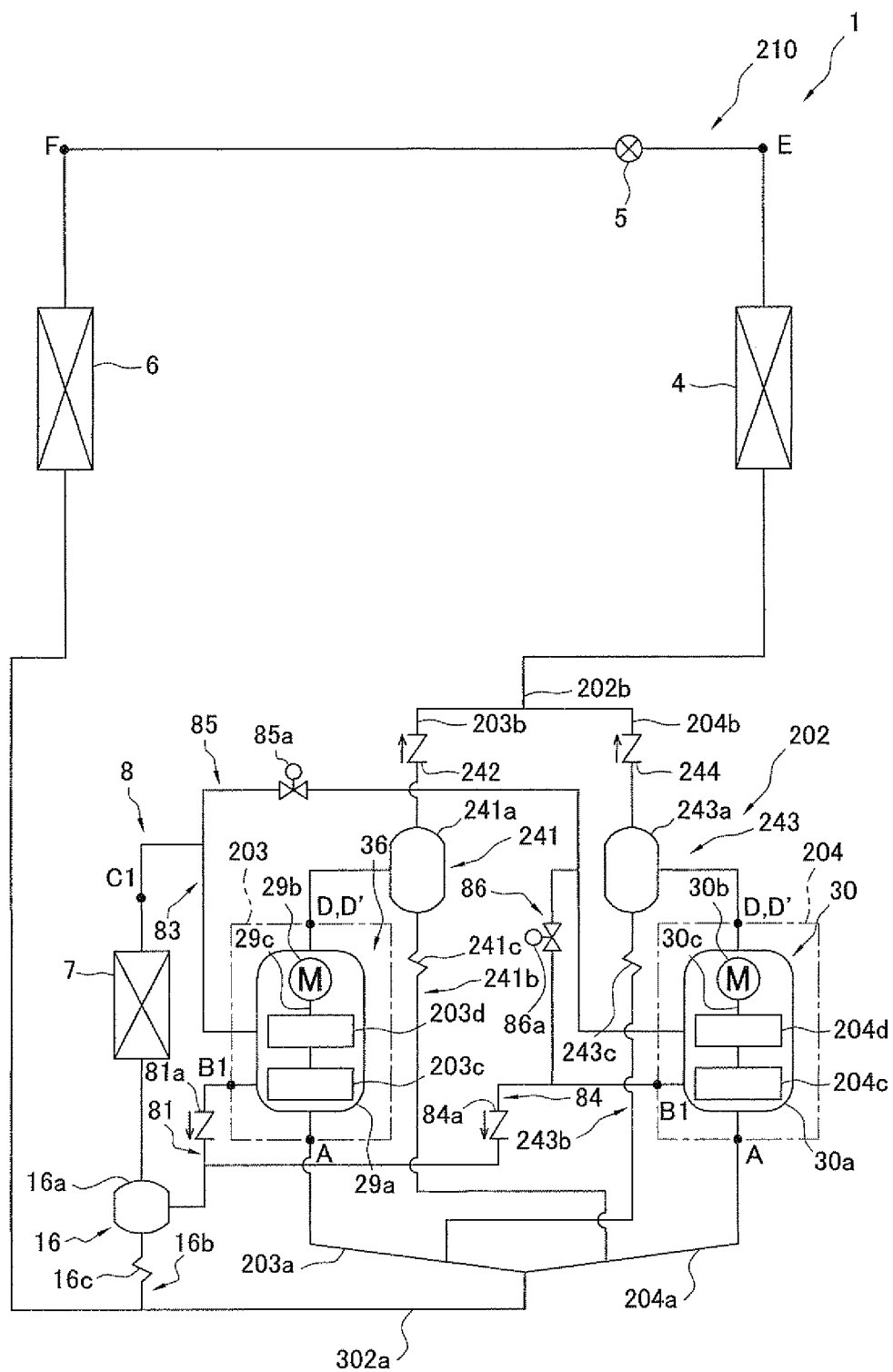


FIG. 11

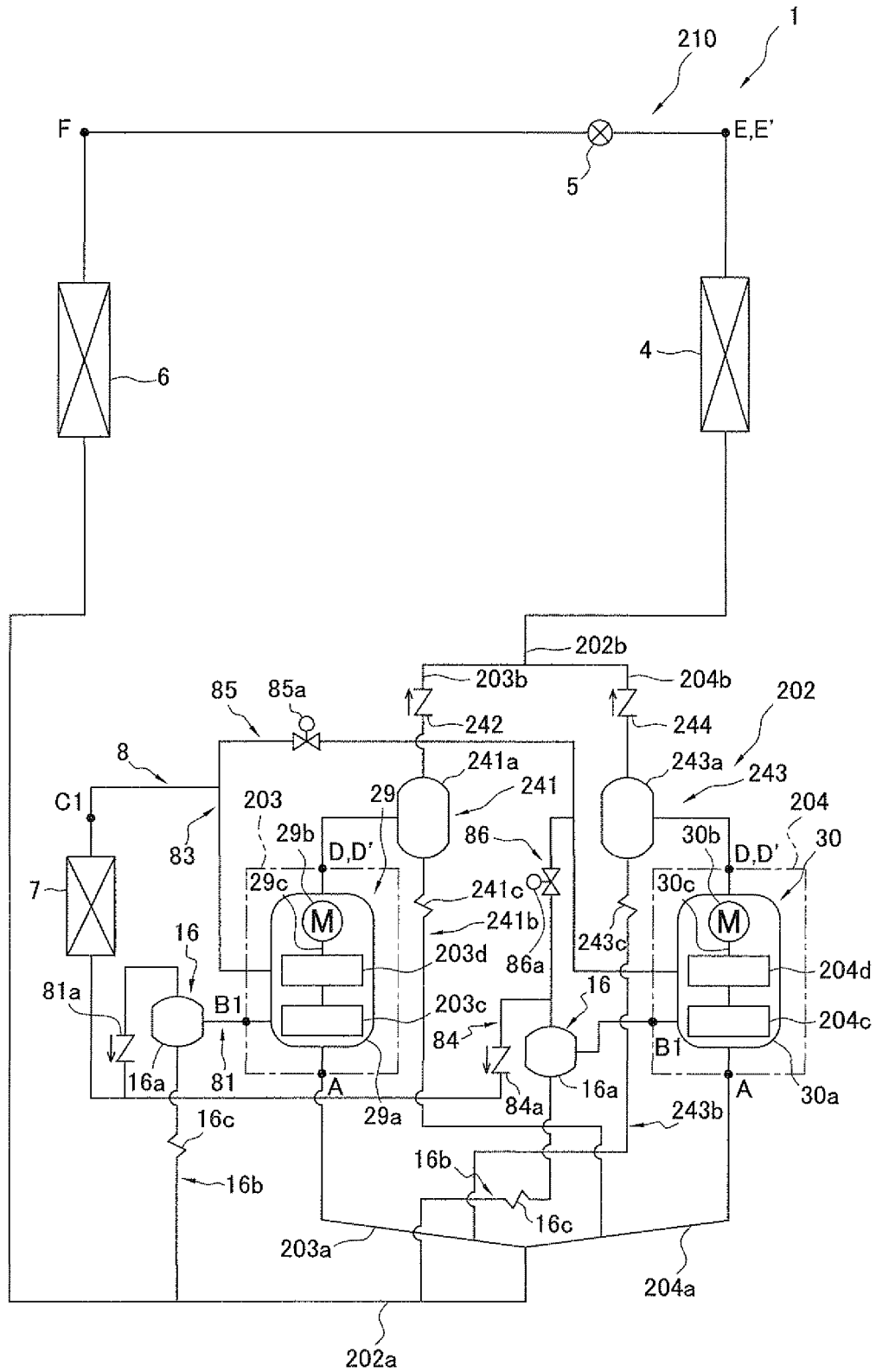


FIG. 12

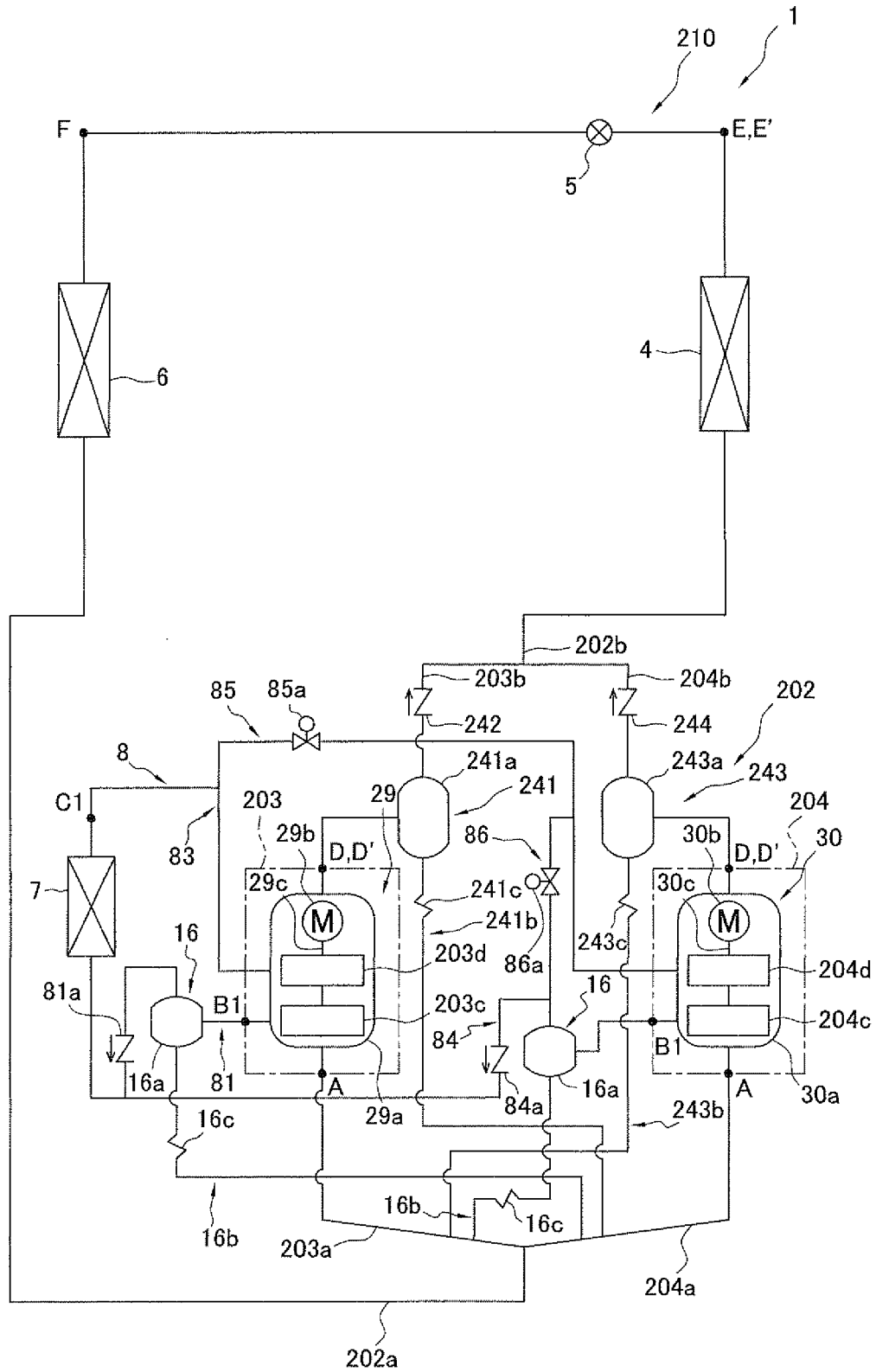


FIG. 13

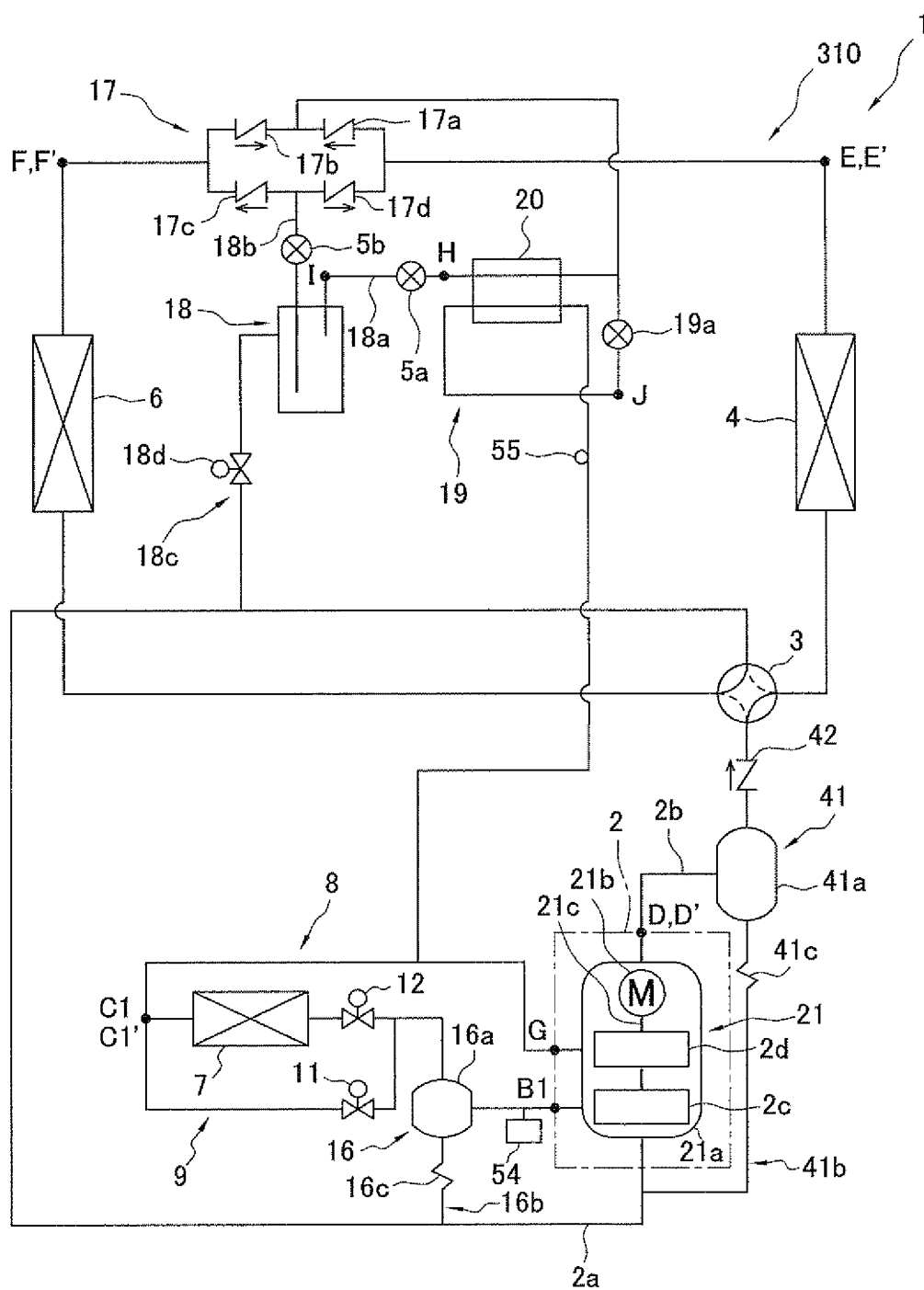


FIG. 14

FIG. 15

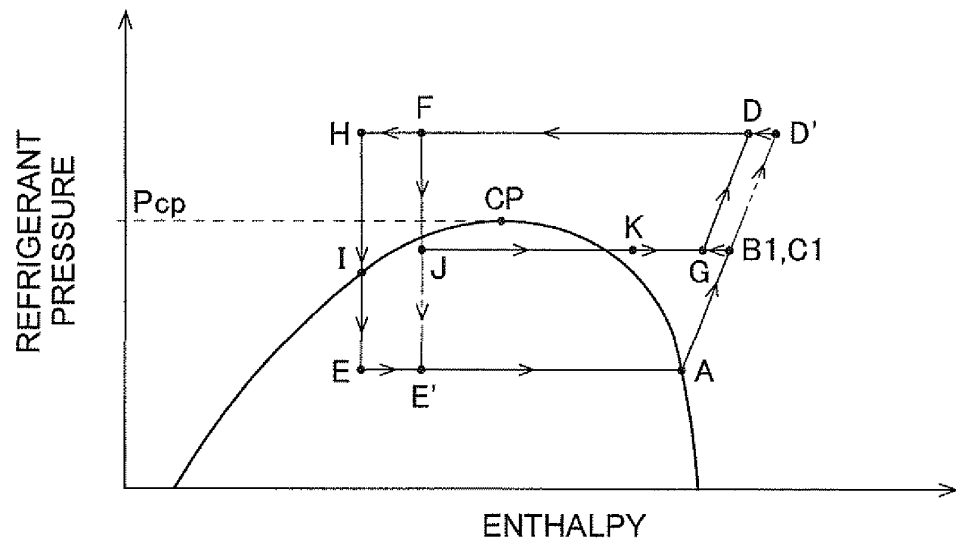


FIG. 16

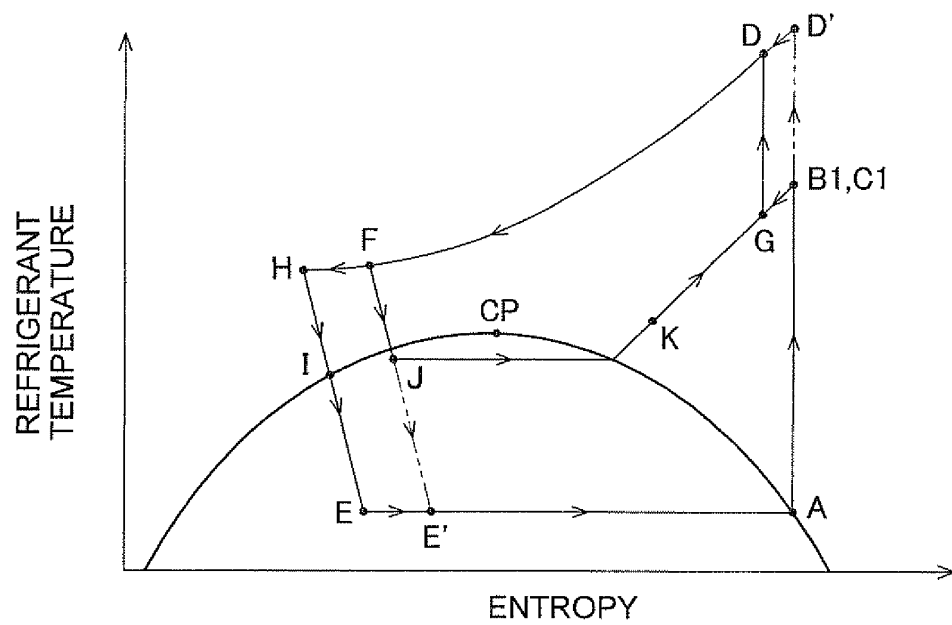


FIG. 17

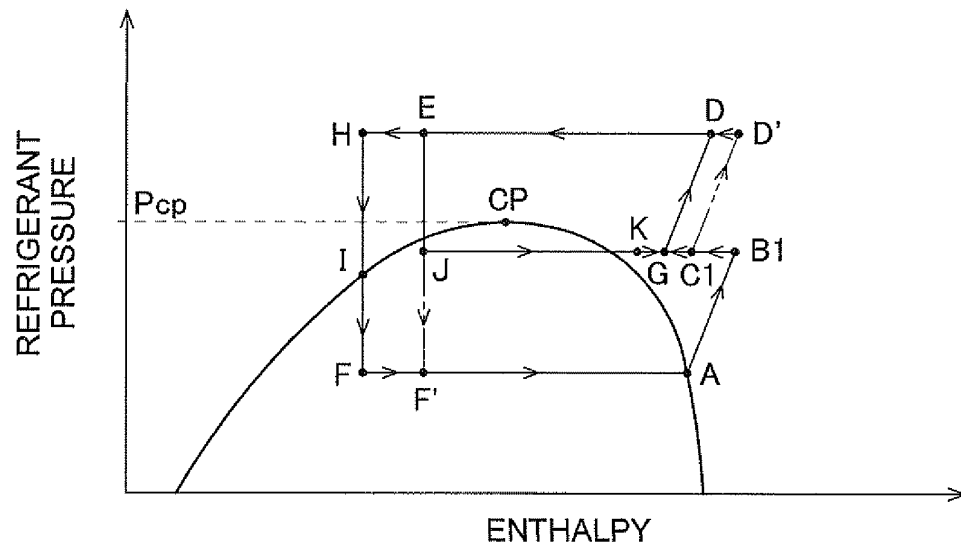
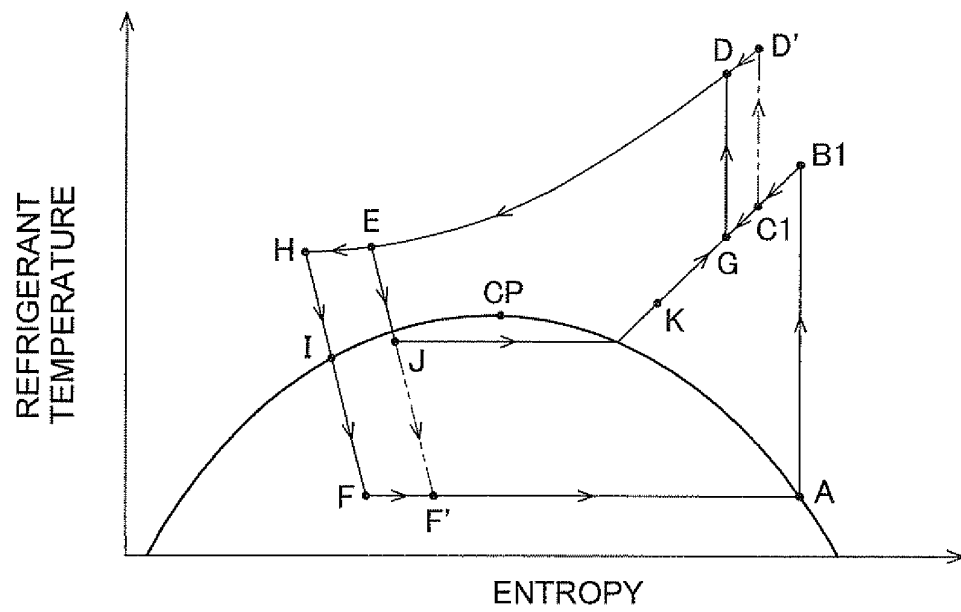


FIG. 18



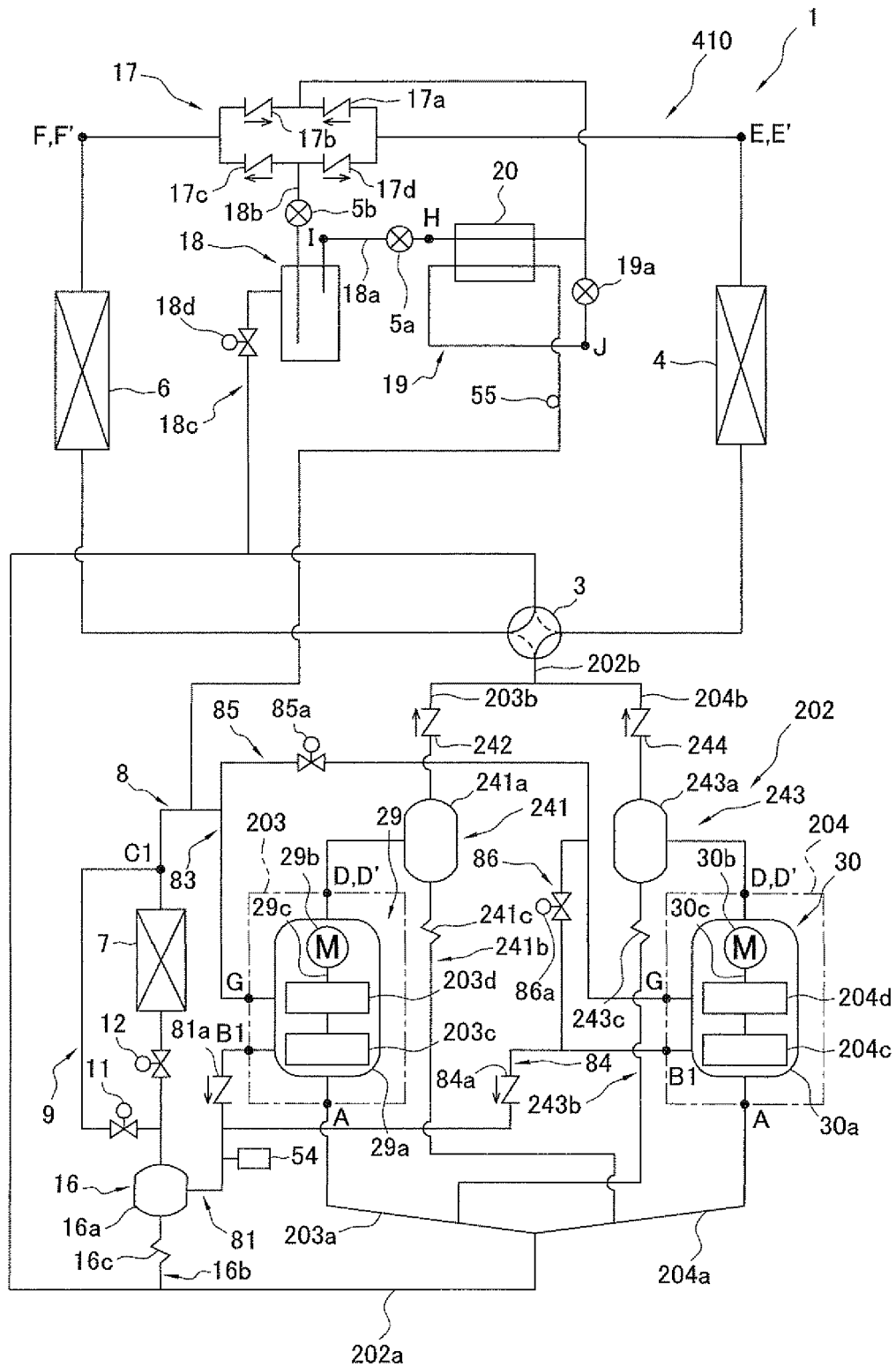


FIG. 19

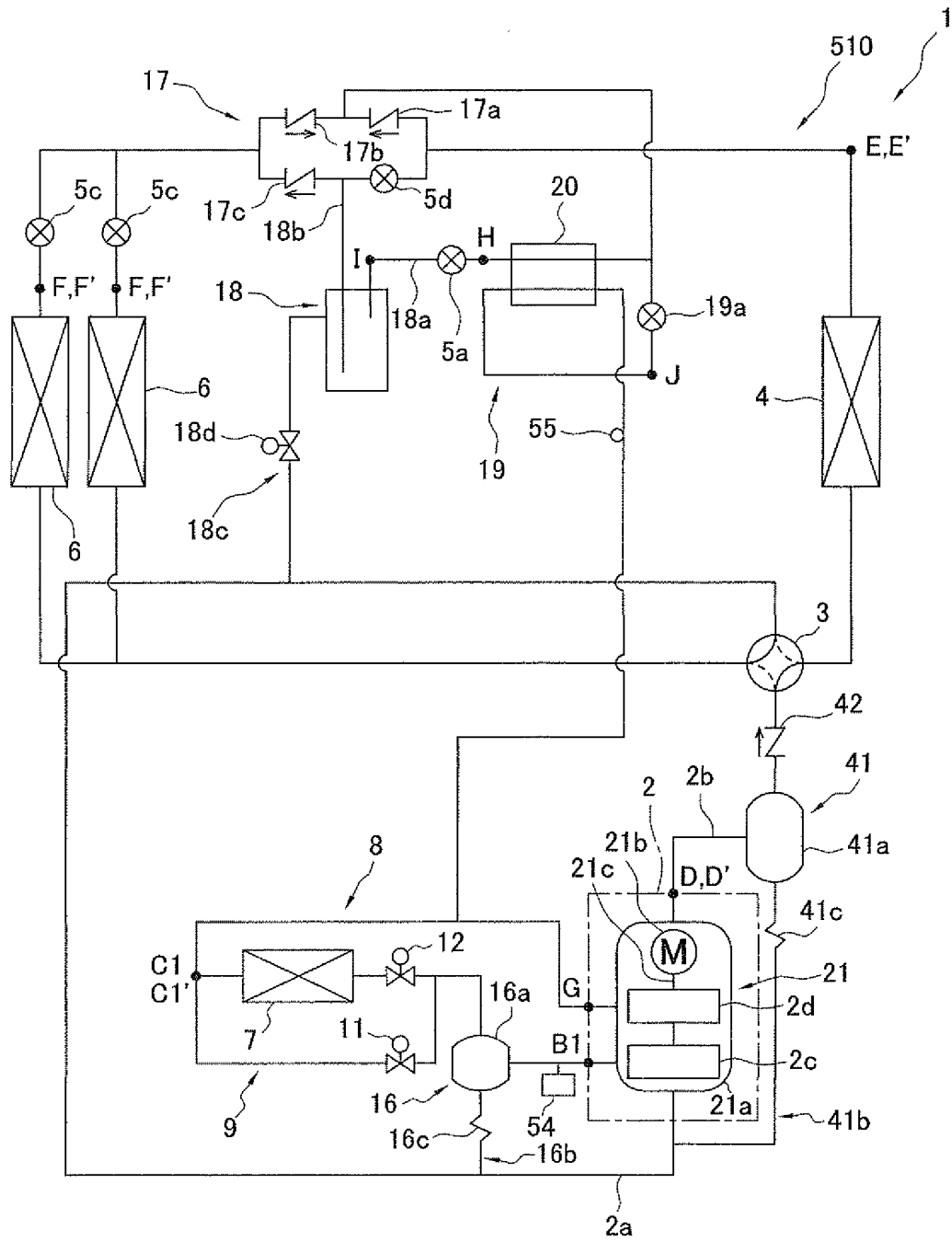


FIG. 20

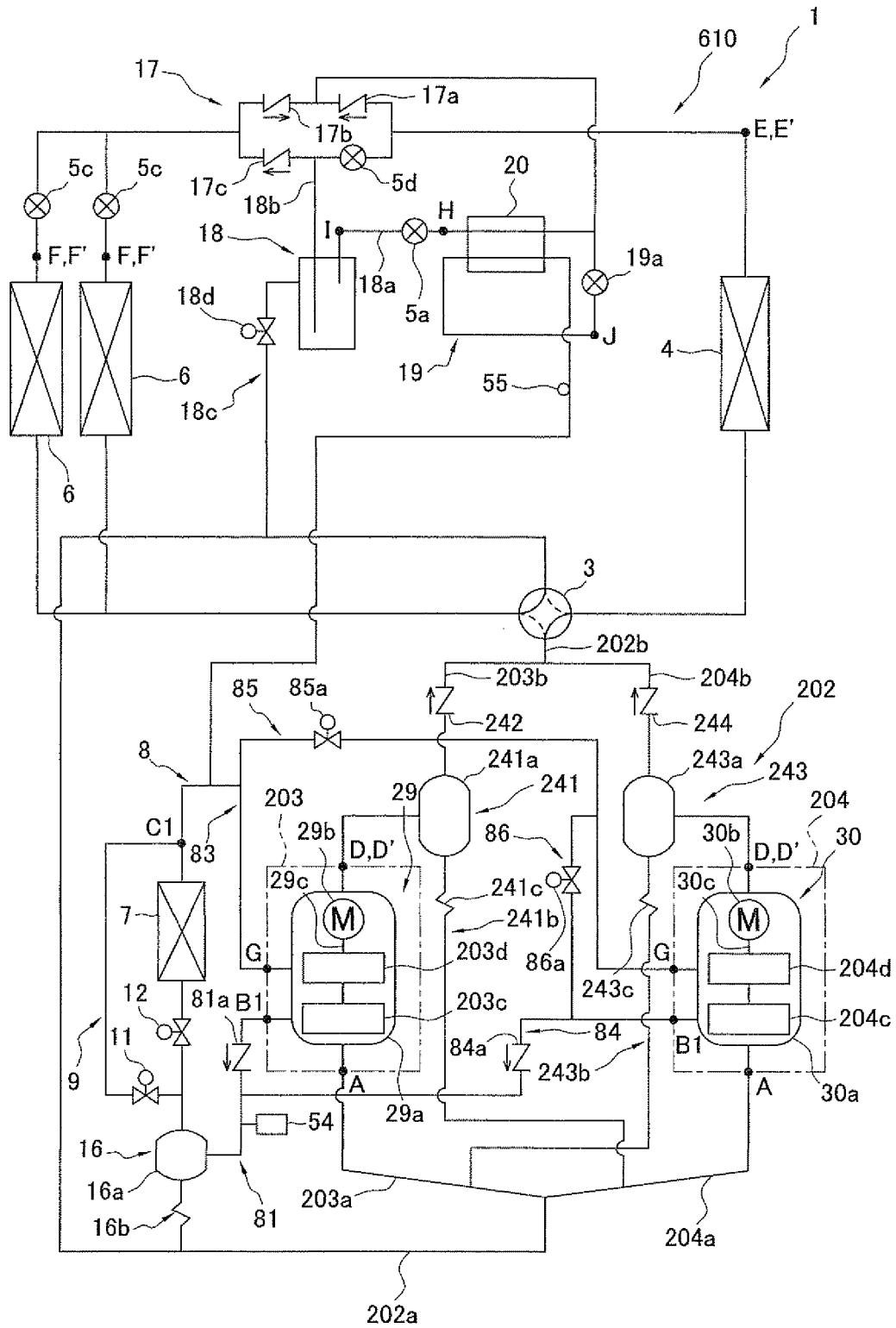


FIG. 21

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/071362

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/10(2006.01)i, F25B1/00(2006.01)i, F25B43/02(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, F25B43/02

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.
X	JP 2006-275495 A (Sanyo Electric Co., Ltd.), 12 October, 2006 (12.10.06), Claims; Par. Nos. [0001] to [0071]; Figs. 1 to 6 & US 2006/0230782 A1 & EP 1707899 A2 & CN 1840986 A	1-4
A	JP 2007-232263 A (Daikin Industries, Ltd.), 13 September, 2007 (13.09.07), Full text; all drawings & WO 2007/105440 A1	1-4

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

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"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
06 January, 2009 (06.01.09)Date of mailing of the international search report
20 January, 2009 (20.01.09)Name and mailing address of the ISA/
Japanese Patent Office

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Patent documents cited in the description

- JP 2007232263 A [0002]