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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), a switching mechanism (3), and a first second-stage injection tube (18c). In the air-conditioning apparatus (1), refrigerant is prevented from returning to a second-stage compression element (2d) through the first second-stage injection tube (18c), at least during the beginning of a reverse cycle defrosting operation for defrosting the heat source-side heat exchanger (4) by switching the switching mechanism (3) to a cooling operation state.

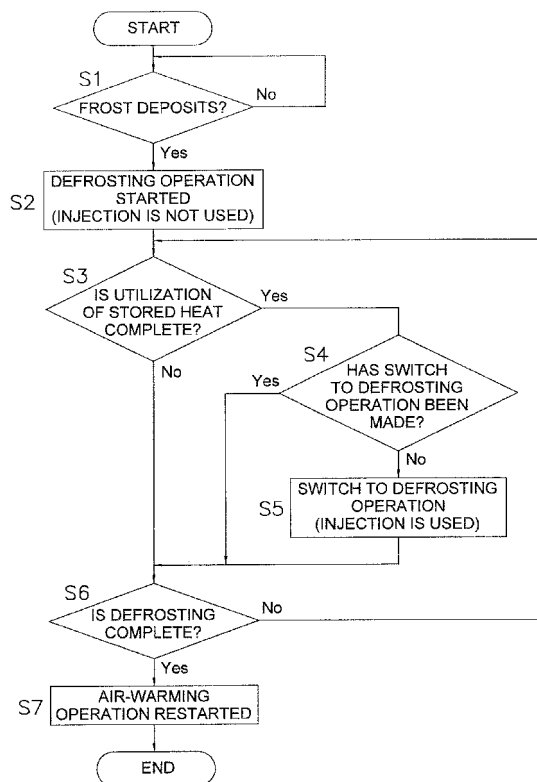


FIG. 6

Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus, and particularly relates to a refrigeration apparatus which has a refrigerant circuit configured to be capable of switching between a cooling operation and a heating operation and 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 has a refrigerant circuit configured to be capable of switching between a cooling operation and a heating operation and 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 which has a refrigerant circuit configured to be capable of switching between an air-cooling operation and an air-warming operation and which 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, a four-way switching valve for switching between an air-cooling operation and an air-warming operation, an outdoor heat exchanger, and an indoor heat exchanger. This air-conditioning apparatus also has a gas-liquid separator for performing gas-liquid separation on refrigerant flowing between the outdoor heat exchanger and the indoor heat exchanger, and a second-stage injection tube for returning the refrigerant from the gas-liquid separator to the second-stage compression element.

<Patent Document 1>

Japanese Laid-open Patent Publication No. 2007-232263

SUMMARY OF INVENTION

[0003] A refrigeration apparatus according to a first aspect of the present invention comprises a compression mechanism, a heat source-side heat exchanger which functions as a radiator or evaporator of refrigerant, a usage-side heat exchanger which functions as an evaporator or radiator of refrigerant, a switching mechanism, and a second-stage injection tube. The compression mechanism has a plurality of compression elements and is configured so that the refrigerant discharged from the first-stage compression element, which is one of a plurality of compression elements, is sequentially compressed by the second-stage compression element. As used herein, the term "compression mechanism" refers to a compressor in which a plurality of compression elements are integrally incorporated, or a configuration that

includes a compression mechanism in which a single compression element is incorporated and/or a plurality of compression mechanisms in which a plurality of compression elements have been incorporated are connected together. The phrase "the refrigerant discharged from a first-stage compression element, which is one of the plurality of compression elements, is sequentially compressed by a second-stage compression element" does not mean merely that two compression elements connected in series are included, namely, the "first-stage compression element" and the "second-stage compression element;" but means that a plurality of compression elements are connected in series and the relationship between the compression elements is the same as the relationship between the aforementioned "first-stage compression element" and "second-stage compression element." The switching mechanism is a mechanism for switching between a cooling operation state, in which the refrigerant is circulated through the compression mechanism, the heat source-side heat exchanger, and the usage-side heat exchanger in a stated order; and a heating operation state, in which the refrigerant is circulated through the compression mechanism, the usage-side heat exchanger, and the heat source-side heat exchanger in a stated order. The heat source-side heat exchanger is a heat exchanger having air as a heat source. The second-stage injection tube is a refrigerant tube for branching off the refrigerant whose heat has been radiated in the heat source-side heat exchanger or the usage-side heat exchanger and returning the refrigerant to the second-stage compression element. In this refrigeration apparatus, refrigerant is prevented from returning to the second-stage compression element through the second-stage injection tube, at least during the beginning of a reverse cycle defrosting operation for defrosting the heat source-side heat exchanger by switching the switching mechanism to the cooling operation state.

[0004] With conventional air-conditioning apparatuses, in cases in which a heat exchanger having air as a heat source is used as the outdoor heat exchanger, when the heating operation is performed while the air as the heat source is low in temperature, frost deposits form on the outdoor heat exchanger functioning as an evaporator of the refrigerant, and a defrosting operation for defrosting the outdoor heat exchanger must therefore be performed by causing the outdoor heat exchanger to function as a radiator of the refrigerant. In cases in which a reverse cycle defrosting operation is used as the defrosting operation, wherein the outdoor heat exchanger is made to function as a radiator of refrigerant by switching the switching mechanism from an air-warming operation state to an air-cooling operation state, the indoor heat exchanger is made to function as an evaporator of refrigerant regardless of the intention being to cause the indoor heat exchanger to function as a radiator of refrigerant, and a problem is encountered in that the temperature decreases on the indoor side. Therefore, to avoid this temperature decrease on the indoor side, a considered

possibility is to reduce the flow rate of the refrigerant flowing through the indoor heat exchanger by using the second-stage injection tube to ensure that the refrigerant fed from the outdoor heat exchanger to the indoor heat exchanger is returned to the second-stage compression element also when the reverse cycle defrosting operation is performed, during both the air-cooling operation and the air-warming operation.

[0005] However, when the second-stage injection tube is used to reduce the flow rate of the refrigerant flowing through the indoor heat exchanger as described above, the refrigerant tube or the like between the indoor heat exchanger and the four-way switching valve is heated and made to store heat by the high-temperature refrigerant discharged from the compressor through the air-warming operation which had been performed until immediately before the reverse cycle defrosting operation, and the defrosting capacity cannot be improved because this stored heat is not sufficiently utilized when the reverse cycle defrosting operation is performed. Particularly with an air-conditioning apparatus using refrigerant that operates in the supercritical range, it is preferable to sufficiently utilize this stored heat because the high pressure in the refrigeration cycle comes to exceed the critical pressure and the temperature of the refrigerant discharged from the refrigerant becomes extremely high.

[0006] In view of this, in the refrigeration apparatus according to a first aspect of the present invention, refrigerant is prevented from returning to the second-stage compression element through the second-stage injection tube, at least at the beginning of the reverse cycle defrosting operation. Thereby, in the refrigerant circuit in this refrigeration apparatus, circulation is performed whereby the refrigerant discharged from the compression mechanism is actively drawn into the compression mechanism through the usage-side heat exchanger. At this time, sufficient use is made of the heat stored in the refrigerant tube or the like between the usage-side heat exchanger and the switching mechanism due to the heating operation performed until immediately before the reverse cycle defrosting operation was performed, the temperature of the low-pressure refrigerant in the refrigeration cycle drawn into the compression mechanism increases, and the refrigerant is prevented from returning to the second-stage compression element through the second-stage injection tube, thereby minimizing the decrease in the temperature of the intermediate-pressure refrigerant in the refrigeration cycle drawn into the second-stage compression element. Therefore, the temperature of the high-pressure refrigerant in the refrigeration cycle discharged from the compression mechanism can be greatly increased, and the defrosting capacity per unit flow rate of the refrigerant when the reverse cycle defrosting operation is performed can be improved. Moreover, it is at least in the beginning of the reverse cycle defrosting operation that a state is created in which refrigerant does not return to the second-stage compression element through the second-stage injection tube,

and circulation for drawing refrigerant into the compression mechanism through the usage-side heat exchanger is not continued excessively in the refrigerant circuit after the amount of heat stored in the refrigerant tube or the like between the usage-side heat exchanger and the switching mechanism has decreased and the effect of improving the defrosting capacity can no longer be sufficiently achieved; therefore, the temperature decrease on the usage side can be minimized.

[0007] Thus, in this refrigeration apparatus, when the reverse cycle defrosting operation is performed, defrosting capacity can be improved while the temperature decrease on the usage side is minimized.

[0008] The refrigeration apparatus according to a second aspect is the refrigeration apparatus according to the first aspect, wherein the phrase "at least the beginning of the reverse cycle defrosting operation" refers to a time starting from the start of the reverse cycle defrosting operation to the elapsing of a predetermined time duration set according to the length of a refrigerant tube between the usage-side heat exchanger and the switching mechanism.

[0009] In this refrigeration apparatus, the fact that at least the beginning of the reverse cycle defrosting operation is a time period from the start of the reverse cycle defrosting operation to when a predetermined time duration set according to the length of a refrigerant tube between the usage-side heat exchanger and the switching mechanism has elapsed makes it possible to determine the point in time at which the amount of heat stored in the refrigerant tube or the like between the usage-side heat exchanger and the switching mechanism has decreased and the effect of improving the defrosting capacity can no longer be sufficiently achieved, according to the length of the refrigerant tube between the usage-side heat exchanger and the switching mechanism.

[0010] The refrigeration apparatus according to a third aspect is the refrigeration apparatus according to the first aspect, wherein the phrase "at least the beginning of the reverse cycle defrosting operation" refers to a time period from the start of the reverse cycle defrosting operation until the temperature of the refrigerant in the usage-side heat exchanger decreases to a predetermined temperature or lower.

[0011] In this refrigeration apparatus, the fact that at least the beginning of the reverse cycle defrosting operation is a time period from the start of the reverse cycle defrosting operation until the temperature of the refrigerant in the usage-side heat exchanger decreases to a predetermined temperature or lower makes it possible to determine, in terms of the temperature decrease on the usage side, whether or not the amount of heat stored in the refrigerant tube or the like between the usage-side heat exchanger and the switching mechanism has decreased and the effect of improving the defrosting capacity can no longer be sufficiently achieved.

[0012] The refrigeration apparatus according to a fourth aspect is the refrigeration apparatus according to

the first aspect, wherein the phrase "at least the beginning of the reverse cycle defrosting operation" refers to a time period from the start of the reverse cycle defrosting operation until the pressure of the refrigerant in the intake side of the compression mechanism decreases to a predetermined pressure or lower.

[0013] In this refrigeration apparatus, the fact that at least the beginning of the reverse cycle defrosting operation is a time period from the start of the reverse cycle defrosting operation until the pressure of the refrigerant in the intake side of the compression mechanism decreases to a predetermined pressure or lower makes it possible to determine, in terms of the decrease in the flow rate of the refrigerant drawn into the compression mechanism that occurs with the temperature decrease on the usage side, whether or not the amount of heat stored in the refrigerant tube or the like between the usage-side heat exchanger and the switching mechanism has decreased and the effect of improving the defrosting capacity can no longer be sufficiently achieved.

[0014] The refrigeration apparatus according to a fifth aspect is the refrigeration apparatus according to the first through fourth aspects, wherein the refrigerant for operating in the supercritical range is carbon dioxide.

BRIEF DESCRIPTION OF DRAWINGS

[0015]

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 diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-cooling operation.

FIG. 3 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation.

FIG. 4 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation.

FIG. 5 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-warming operation.

FIG. 6 is a flowchart of the defrosting operation.

FIG. 7 is a diagram showing the flow of refrigerant within the air-conditioning apparatus at the start of the defrosting operation.

FIG. 8 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation.

FIG. 9 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation.

FIG. 10 is a schematic structural diagram of an air-conditioning apparatus according to Modification 1.

FIG. 11 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-cooling operation.

FIG. 12 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 1.

FIG. 13 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 1.

FIG. 14 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-warming operation.

FIG. 15 is a diagram showing the flow of refrigerant within the air-conditioning apparatus at the start of the defrosting operation.

FIG. 16 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation in the air-conditioning apparatus according to Modification 1.

FIG. 17 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation in the air-conditioning apparatus according to Modification 1.

FIG. 18 is a schematic structural diagram of an air-conditioning apparatus according to Modification 2.

FIG. 19 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-cooling operation.

FIG. 20 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 2.

FIG. 21 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 2.

FIG. 22 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-warming operation.

FIG. 23 is a diagram showing the flow of refrigerant within the air-conditioning apparatus at the start of the defrosting operation.

FIG. 24 is a diagram showing the flow of refrigerant within the air-conditioning apparatus in the defrosting operation after defrosting of the intermediate heat exchanger is complete.

FIG. 25 is a diagram showing the flow of refrigerant within the air-conditioning apparatus in the defrosting operation after defrosting of the intermediate heat exchanger and utilization of the stored heat are complete.

FIG. 26 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation in the air-conditioning apparatus according to Modification 2.

FIG. 27 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation in the air-conditioning apparatus according to Modification 2.

FIG. 28 is a schematic structural diagram of an air-conditioning apparatus according to Modification 3. FIG. 29 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-cooling operation.

FIG. 30 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 3.

FIG. 31 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 3.

FIG. 32 is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-warming operation.

FIG. 33 is a diagram showing the flow of refrigerant within the air-conditioning apparatus at the start of the defrosting operation.

FIG. 34 is a diagram showing the flow of refrigerant within the air-conditioning apparatus in the defrosting operation after defrosting of the intermediate heat exchanger is complete.

FIG. 35 is a diagram showing the flow of refrigerant within the air-conditioning apparatus in the defrosting operation after defrosting of the intermediate heat exchanger and utilization of the stored heat are complete.

FIG. 36 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation in the air-conditioning apparatus according to Modification 3.

FIG. 37 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation in the air-conditioning apparatus according to Modification 3.

FIG. 38 is a schematic structural diagram of an air-conditioning apparatus according to Modification 4.

DESCRIPTION OF EMBODIMENTS

[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 to be capable of switching between an air-cooling operation and an air-warming 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 switching mechanism 3, a heat source-side heat exchanger 4, a bridge circuit 17, a receiver 18, a first expansion mechanism 5a, a second expansion mechanism 5b, a first second-stage injection tube 18c, and a usage-side heat exchanger 6.

[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 draw 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 draw intermediate-pressure refrigerant discharged to the intermediate refrigerant tube 8 in the refrigeration cycle 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 the intermediate-pressure refrigerant in the refrigeration cycle 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. The discharge tube 2b is a refrigerant tube for feeding refrigerant discharged from the compression mechanism 2 to the switching mechanism 3, and the discharge tube 2b is provided with an oil separation mechanism 41 and a non-return mechanism 42. The oil separation mechanism 41 is a mechanism for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism 2 and returning the oil to the intake side of the compression mechanism 2, and the oil separation mechanism 41 has primarily an oil separator 41a for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism 2, and an oil return tube 41b connected to the oil separator 41a for returning the refrigerator oil separated from the refrigerant to the intake tube 2a of the compression mechanism 2. The oil return tube 41b is provided with a depressurization mechanism 41c for depressurizing the refrigerator oil flowing through the oil return tube 41b. A capillary tube is used for the depressurization mechanism 41c in the present embodiment. The non-return mechanism

nism 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.

[0020] 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.

[0021] The switching mechanism 3 is a mechanism for switching the direction of refrigerant flow in the refrigerant circuit 10. In order to allow the heat source-side heat exchanger 4 to function as a radiator of refrigerant compressed by the compression mechanism 2 and to allow the usage-side heat exchanger 6 to function as an evaporator 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. 1, this state of the switching mechanism 3 being referred to below as the "cooling operation state"). In order to allow the usage-side heat exchanger 6 to function as a radiator of refrigerant compressed by the compression mechanism 2 and to allow the heat source-side heat exchanger 4 to function as an evaporator 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. 1, this state of the switching mechanism 3 being referred to below as the "heating operation state"). In the present embodiment, the switching mechanism 3 is a four-way switching valve connected to the intake side of the compression mechanism 2, the discharge side of the compression mechanism 2, the heat source-side heat exchanger 4, and the usage-side heat exchanger 6. The switching mechanism 3 is not limited to a four-way switching valve, and may be configured so as to have a function for switching the direction of the flow of the refrigerant in the same manner as described above by using, e.g., a combination of a plurality of electromagnetic valves.

[0022] Thus, focusing solely on the compression mechanism 2, the heat source-side heat exchanger 4, and the usage-side heat exchanger 6 constituting the refrigerant circuit 10; the switching mechanism 3 is configured to be capable of switching between a cooling operation state in which the refrigerant is circulated sequentially through the compression mechanism 2, the heat

source-side heat exchanger 4 functioning as a radiator of refrigerant, and the usage-side heat exchanger 6 functioning as an evaporator of refrigerant; and a heating operation state in which the refrigerant is circulated sequentially through the compression mechanism 2, the usage-side heat exchanger 6 functioning as a radiator of refrigerant, and the heat source-side heat exchanger 4 functioning as an evaporator of refrigerant.

[0023] The heat source-side heat exchanger 4 is a heat exchanger that functions as a radiator or an evaporator of refrigerant. One end of the heat source-side heat exchanger 4 is connected to the switching mechanism 3, and the other end is connected to the first expansion mechanism 5a via the bridge circuit 17. The heat source-side heat exchanger 4 is a heat exchanger that uses air as a heat source (i.e., a cooling source or a heating source), and a fin-and-tube heat exchanger is used in the present embodiment. The air as the heat source is supplied to the heat source-side heat exchanger 4 by a heat source-side fan 40. The heat source-side fan 40 is driven by a fan drive motor 40a.

[0024] The bridge circuit 17 is disposed 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 the inlet of the receiver 18 and to a receiver outlet tube 18b connected to the outlet of the receiver 18. The bridge circuit 17 has four non-return valves 17a, 17b, 17c, and 17d in the present embodiment. The inlet non-return valve 17a is a non-return valve that allows only the flow of refrigerant 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 that allows only the flow of refrigerant from the usage-side heat exchanger 6 to the receiver inlet tube 18a. In other words, the inlet non-return valves 17a, 17b have a function for allowing refrigerant to flow from one among the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 to the receiver inlet tube 18a. The outlet non-return valve 17c is a non-return valve that allows only the flow of refrigerant from the receiver outlet tube 18b to the usage-side heat exchanger 6. The outlet non-return valve 17d is a non-return valve that allows only the flow of refrigerant 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 a function for allowing refrigerant to flow from the receiver outlet tube 18b to the heat source-side heat exchanger 4 or the usage-side heat exchanger 6.

[0025] The first expansion mechanism 5a is a mechanism for depressurizing the refrigerant, is provided to the receiver inlet tube 18a, and is an electrically driven expansion valve in the present embodiment. In the present embodiment, during the air-cooling operation, the first expansion mechanism 5a depressurizes the high-pressure refrigerant in the refrigeration cycle that has been cooled in the heat source-side heat exchanger 4 nearly to the saturation pressure of the refrigerant before the refrigerant is fed to the usage-side heat exchanger

er 6 via the receiver 18; and during the air-warming operation, the first expansion mechanism 5a depressurizes the high-pressure refrigerant in the refrigeration cycle that has been cooled in the usage-side heat exchanger 6 nearly to the saturation pressure of the refrigerant before the refrigerant is fed to the heat source-side heat exchanger 4 via the receiver 18.

[0026] The receiver 18 is a container provided in order to temporarily retain the refrigerant that has been depressurized by the first expansion mechanism 5a so as to allow storage of excess refrigerant produced according to the operation states, such as the quantity of refrigerant circulating in the refrigerant circuit 10 being different between the air-cooling operation and the air-warming operation, and the inlet of the receiver 18 is connected to the receiver inlet tube 18a, while the outlet is connected to the receiver outlet tube 18b. Also connected to the receiver 18 are the first second-stage injection tube 18c and a first intake return tube 18f. The first second-stage injection tube 18c and the first intake return tube 18f are integrated in the portion near the receiver 18.

[0027] The first second-stage injection tube 18c is a refrigerant tube capable of performing intermediate pressure injection for extracting refrigerant from the receiver 18 and returning the refrigerant to the second-stage compression element 2d of the compression mechanism 2, and in the present modification, the first second-stage injection tube 18c is provided so as to connect the top part of the receiver 18 and the intermediate refrigerant tube 8 (i.e., the intake side of the second-stage compression element 2d of the compression mechanism 2). The first second-stage injection tube 18c is provided with a first second-stage injection on/off valve 18d and a first second-stage injection non-return mechanism 18e. The first second-stage injection on/off valve 18d is a valve capable of opening and closing, and is an electromagnetic valve in the present embodiment. The first second-stage injection non-return mechanism 18e is a mechanism for allowing refrigerant to flow from the receiver 18 to the second-stage compression element 2d and blocking refrigerant from flowing from the second-stage compression element 2d to the receiver 18, and a non-return valve is used in the present embodiment.

[0028] The first intake return tube 18f is connected so as to be 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). A first intake return on/off valve 18g is provided to this first intake return tube 18f. The first intake return on/off valve 18g is an electromagnetic valve in the present embodiment.

[0029] Thus, when the first second-stage injection tube 18c is used by opening the first second-stage injection on/off valve 18d, the receiver 18 functions as a gas-liquid separator for performing gas-liquid separation between the first expansion mechanism 5a and the second expansion mechanism 5b on the refrigerant flowing be-

tween the heat source-side heat exchanger 4 and the usage-side heat exchanger 6, and intermediate pressure injection can be performed by the receiver 18 for returning the gas refrigerant resulting from gas-liquid separation in the receiver 18 from the top part of the receiver 18 to the second-stage compression element 2d of the compression mechanism 2.

[0030] The second expansion mechanism 5b is a mechanism provided to the receiver outlet tube 18b and used for depressurizing the refrigerant, and is an electrically driven expansion valve in the present embodiment. In the present embodiment, during the air-cooling operation, the second expansion mechanism 5b further depressurizes the refrigerant depressurized by the first expansion mechanism 5a to a low pressure in the refrigeration cycle before the refrigerant is fed to the usage-side heat exchanger 6 via the receiver 18; and during the air-warming operation, the second expansion mechanism 5b further depressurizes the refrigerant depressurized by the first expansion mechanism 5a to a low pressure in the refrigeration cycle before the refrigerant is fed to the heat source-side heat exchanger 4 via the receiver 18.

[0031] The usage-side heat exchanger 6 is a heat exchanger that functions as a radiator or an evaporator of refrigerant. One end of the usage-side heat exchanger 6 is connected to the first expansion mechanism 5a via the bridge circuit 17, and the other end is connected to the switching mechanism 3. The usage-side heat exchanger 6 is a heat exchanger that uses water and/or air as a heat source (i.e., a cooling source or a heating source).

[0032] Furthermore, the air-conditioning apparatus 1 is provided with various sensors. Specifically, the heat source-side heat exchanger 4 is provided with a heat source-side heat exchange temperature sensor 51 for detecting the temperature of the refrigerant flowing through the heat source-side heat exchanger 4. The usage-side heat source-side heat exchanger 6 is provided with a usage-side heat exchange temperature sensor 61 for detecting the temperature of the refrigerant flowing through the usage-side heat exchanger 6. An intake pressure sensor 60 for detecting the pressure of the refrigerant flowing through the intake side of the compression mechanism 2 is provided to either the intake tube 2a or the compression mechanism 2. The air-conditioning apparatus 1 is provided with an air temperature sensor 53 for detecting the temperature of the air as a heat source for the heat source-side heat exchanger 4. Though not shown in the drawings, the air-conditioning apparatus 1 also has a controller for controlling the actions of the compression mechanism 2, the switching mechanism 3, the expansion mechanism 5, the heat source-side fan 40, the first second-stage injection on/off valve 18d, the first intake return on/off valve 18g, and the other components constituting the air-conditioning apparatus 1.

(2) Action of the air-conditioning apparatus

[0033] Next, the action of the air-conditioning apparatus 1 of the present embodiment will be described using FIGS. 1 through 9. FIG. 2 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-cooling operation, FIG. 3 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, FIG. 4 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation, FIG. 5 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-warming operation, FIG. 6 is a flowchart of the defrosting operation, FIG. 7 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 at the start of the defrosting operation, FIG. 8 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation, and FIG. 9 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation. Operation control in the air-cooling operation, the air-warming operation, and the defrosting 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', and E in FIGS. 3, 4, 8, and 9), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A, F, W in FIGS. 3, 4, 8, and 9), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B, G, G', I, L, and M in FIGS. 3, 4, 8, and 9).

<Air-cooling operation>

[0034] During the air-cooling operation, the switching mechanism 3 is brought to the cooling operation state shown by the solid lines in FIGS. 1 and 2. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. The first second-stage injection on/off valve 18d is brought to an open state.

[0035] When the refrigerant circuit 10 is in this state, low-pressure refrigerant (refer to point A in FIGS. 1 through 4) 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 A in FIGS. 1 through 4). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled (refer to point G in FIGS. 1 through 4) by mixing with the refrigerant returned from the receiver 18 to the second-stage compression element 2d through the first second-stage injection tube 18c (refer to point M in FIGS. 1 through 4). Next, having been mixed with the refrigerant returning from the first second-stage injection tube 18c (i.e., intermediate pressure injection is carried

out by the receiver 18 which acts as a gas-liquid separator), the intermediate-pressure refrigerant is 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 discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 1 through 4). 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. 3). 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 drawn once more 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 the switching mechanism 3, and is fed to the heat source-side heat exchanger 4 functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger 4 is cooled in the heat source-side heat exchanger 4 by heat exchange with air as a cooling source supplied by the heat source-side fan 40 (refer to point E in FIGS. 1 through 4). The high-pressure refrigerant cooled in the heat source-side heat exchanger 4 then flows through the inlet non-return valve 17a of the bridge circuit 17 into the receiver inlet tube 18a, and the refrigerant is depressurized to a nearly saturated pressure by the first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 1 through 4). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b and is depressurized by the second 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 evaporator (refer to point F in FIGS. 1 through 4). 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 W in FIGS. 1 through 4). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is then drawn once more into the compression mechanism 2 via the switching mechanism 3 (refer to point A in FIGS. 1 through 4). In this manner the air-cooling operation is performed.

[0036] Thus, in the air-conditioning apparatus 1 (refrigeration apparatus) of the present embodiment, since the

first second-stage injection tube 18c is provided to branch off the refrigerant whose heat has been radiated in the heat source-side heat exchanger 4 and return the refrigerant to the second-stage compression element 2d, the temperature of the refrigerant drawn into the second-stage compression element 2d can be kept even lower (refer to points B and G in FIG. 4) without heat being radiated to the exterior. The temperature of the refrigerant discharged from the compression mechanism 2 is thereby minimized (refer to points D and D' in FIG. 4), and it is possible to further reduce the heat radiation loss equivalent to the area enclosed by connecting points B, D', D, and G in FIG. 4 more than in cases in which the first second-stage injection tube 18c is not provided; therefore, the power consumption of the compression mechanism 2 can be further reduced, and operating efficiency can be further improved.

<Air-warming operation>

[0037] During the air-warming operation, the switching mechanism 3 is brought to the heating operation state shown by the dashed lines in FIGS. 1 and 5. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are also adjusted. Furthermore, the first second-stage injection on/off valve 18d is brought to the open state similar to during the air-cooling operation.

[0038] When the refrigerant circuit 10 is in this state, low-pressure refrigerant (refer to point A in FIGS. 1 and 3 through 5) 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 B in FIGS. 1 and 3 through 5). This intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled (refer to point G in FIGS. 1 and 3 through 5) by mixing with the refrigerant returning from the receiver 18 to the second-stage compression element 2d through the first second-stage injection tube 18c (refer to point M in FIGS. 1 and 3 through 5). Next, having been mixed with the refrigerant returning from the first second-stage injection tube 18c (i.e., intermediate pressure injection is carried out by the receiver 18 which acts as a gas-liquid separator), the intermediate-pressure refrigerant is 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 discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 1 and 3 through 5). 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. 3), similar to the air-cooling operation. 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 drawn once more 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 the switching mechanism 3, fed to the usage-side heat exchanger 6 functioning as a radiator of refrigerant, and cooled by heat exchange with the water and/or air as a cooling source (refer to point F in FIGS. 1 and 5, and read point E as point F in FIGS. 3 and 4). The high-pressure refrigerant cooled in the usage-side heat exchanger 6 then flows through the inlet non-return valve 17b of the bridge circuit 17 into the receiver inlet tube 18a, and the refrigerant is depressurized to a nearly saturated pressure by the first expansion mechanism 5a and temporarily retained in the receiver 18 (refer to point I in FIGS. 1 and 3 through 5). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b where it is depressurized by the second expansion mechanism 5b into a low-pressure gas-liquid two-phase refrigerant, which is passed through the outlet non-return valve 17d of the bridge circuit 17 and fed to the heat source-side heat exchanger 4 functioning as an evaporator of refrigerant (refer to point E in FIGS. 1 and 5, and read point F as point E in FIGS. 3 and 4). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger 4 is heated and evaporated in the heat source-side heat exchanger 4 by heat exchange with the air as a heat source supplied by the heat source-side fan 40 (refer to point A in FIGS. 1 and 3 through 5). The low-pressure refrigerant heated and evaporated in the heat source-side heat exchanger 4 is then drawn once more into the compression mechanism 2 via the switching mechanism 3. In this manner the air-warming operation is performed.

[0039] Thus, in the air-conditioning apparatus 1 (refrigeration apparatus) of the present embodiment, since the first second-stage injection tube 18c is provided to branch off the refrigerant whose heat has been radiated in the usage-side heat exchanger 6 and return the refrigerant to the second-stage compression element 2d, similar to during the air-cooling operation, the temperature of the refrigerant drawn into the second-stage compression element 2d can be kept even lower (refer to points B and G in FIG 4) without heat being radiated to the exterior. The temperature of the refrigerant discharged from the compression mechanism 2 is thereby minimized (refer to points D and D' in FIG. 4), and it is possible to further reduce the heat radiation loss equivalent to the area enclosed by connecting points B, D', D, and G in FIG. 4

more than in cases in which the first second-stage injection tube 18c is not provided; therefore, the power consumption of the compression mechanism 2 can be further reduced, and operating efficiency can be further improved.

<Defrosting operation>

[0040] First, in step S1, a decision is made as to whether or not frost deposits have formed in the heat source-side heat exchanger 4 during the air-warming operation. This is determined based on the temperature of the refrigerant flowing through the heat source-side heat exchanger 4 as detected by the heat source-side heat exchange temperature sensor 51, and/or on the cumulative time of the air-warming operation. For example, in cases in which the temperature of refrigerant in the heat source-side heat exchanger 4 as detected by the heat source-side heat exchange temperature sensor 51 is equal to or less than a predetermined temperature equivalent to conditions at which frost deposits occur, or in cases in which the cumulative time of the air-warming operation has elapsed past a predetermined time, it is determined that frost deposits have formed in the heat source-side heat exchanger 4. In cases in which these temperature conditions or time conditions are not met, it is determined that frost deposits have not formed in the heat source-side heat exchanger 4. Since the predetermined temperature and predetermined time depend on the temperature of the air as a heat source, the predetermined temperature and predetermined time are preferably set as a function of the air temperature detected by the air temperature sensor 53. In cases in which a temperature sensor is provided to the inlet or outlet of the heat source-side heat exchanger 4, the refrigerant temperature detected by these temperature sensors may be used in the determination of the temperature conditions instead of the refrigerant temperature detected by the heat source-side heat exchange temperature sensor S1. In cases in which it is determined in step S1 that frost deposits have occurred in the heat source-side heat exchanger 4, the process advances to step S2.

[0041] Next, in step S2, the defrosting operation is started. The defrosting operation is a reverse cycle defrosting operation in which the heat source-side heat exchanger 4 is made to function as a refrigerant radiator by switching the switching mechanism 3 from the heating operation state (i.e., the air-warming operation) to the cooling operation state.

[0042] In the present embodiment, when the reverse cycle defrosting operation is performed, a problem arises with the temperature decrease on the usage side due to the usage-side heat exchanger 6 being made to function as an evaporator of refrigerant. Therefore, to avoid this temperature decrease on the usage side, a considered possibility is to reduce the flow rate of the refrigerant flowing through the usage-side heat exchanger 6 by creating a state in which intermediate pressure injection by the

receiver 18 as a gas-liquid separator is used (i.e., ensuring that refrigerant returns to the second-stage compression element 2d through the first second-stage injection tube 18c), during both the air-cooling operation and the air-warming operation.

[0043] However, when the first second-stage injection tube 18c is used to reduce the flow rate of the refrigerant flowing through the usage-side heat exchanger 6 as described above, the refrigerant tube (hereinbelow, the refrigerant tube connecting the usage-side heat exchanger 6 and the switching mechanism 3 is referred to as the refrigerant tube 1d) or the like between the usage-side heat exchanger 6 and the switching mechanism 3 is heated and made to store heat by the high-temperature refrigerant discharged from the compressor through the air-warming operation which had been performed until immediately before the reverse cycle defrosting operation, and the defrosting capacity cannot be improved because this stored heat is not sufficiently utilized when the reverse cycle defrosting operation is performed. Particularly with an air-conditioning apparatus 1 which uses refrigerant that operates in the supercritical range, such as that of the present embodiment, it is preferable to sufficiently utilize this stored heat because the high pressure in the refrigeration cycle comes to exceed the critical pressure and the temperature of the refrigerant discharged from the refrigerant becomes extremely high, further increasing the amount of stored heat. In cases in which the refrigerant circuit 10 in the present embodiment is configured by connecting the heat source unit (a unit installed outdoors or the like, having primarily the compression mechanism 2, the switching mechanism 3, the heat source-side heat exchanger 4, the expansion mechanisms 5a, 5b, the intermediate refrigerant tube 8, the bridge circuit 17, the receiver 18, the first second-stage injection tube, the first intake return tube 18f, the heat source-side fan 40, and other components) and the usage unit (a unit installed indoors or the like, having primarily the usage-side heat exchanger 6) via a refrigerant communication tube, there are cases in which the length of the refrigerant communication tube is extremely long, the tube length of the refrigerant tube 1d also accordingly becomes extremely long, and the amount of stored heat increases further. It is therefore preferable to sufficiently utilize the stored heat.

[0044] In view of this, in step S2 (the start of the defrosting operation) in the present embodiment, first, a state is created in which intermediate pressure injection by the receiver 18 as a gas-liquid separator is not used (i.e., refrigerant is prevented from returning to the second-stage compression element 2d through the first second-stage injection tube 18c), the switching mechanism 3 is switched from the heating operation state to the cooling operation state, and the reverse cycle defrosting operation is performed (refer to the refrigeration cycle shown by the solid lines in FIGS. 7, 8, and 9).

[0045] Thereby, in the refrigerant circuit 10, circulation is performed whereby the refrigerant discharged from the

compression mechanism 2 is actively drawn into the compression mechanism 2 through the usage-side heat exchanger 6; therefore, the low-pressure refrigerant heated and evaporated in the usage-side heat exchanger 6 (refer to point W in the lines indicating the refrigeration cycle shown by the solid lines in FIGS. 8 and 9) is drawn into the compression mechanism 2 via the switching mechanism 3 (refer to point A in the lines indicating the refrigeration cycle shown by the solid lines in FIGS. 8 and 9) after being heated by the refrigerant tube 1d or the like. That is, sufficient utilization is made of the heat stored in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 by the air-warming operation that had been performed until immediately before the defrosting operation. Thereby, the temperature of the low-pressure refrigerant in the refrigeration cycle drawn into the compression mechanism 2 increases (refer to point B in the lines indicating the refrigeration cycle shown by the solid lines in FIG 9), and the refrigerant is prevented from returning to the second-stage compression element 2d through the first second-stage injection tube 18c, whereby the decrease in the temperature of the intermediate-pressure refrigerant in the refrigeration cycle drawn into the second-stage compression element 2d is minimized (refer to points B and G in the lines indicating the refrigeration cycle shown by the solid lines in FIG. 9), the temperature of the high-pressure refrigerant in the refrigeration cycle discharged from the compression mechanism 2 can therefore be increased (refer to point D in the lines indicating the refrigeration cycle shown by the solid lines in FIG 9), and the defrosting capacity per unit flow rate of the refrigerant when the reverse cycle defrosting operation is performed can be improved.

[0046] However, if the reverse cycle defrosting operation in step S2 described above is continued, there is a high risk that a state will arise in which the amount of heat stored in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 will gradually decrease and the effect of improving the defrosting capacity will not be sufficiently achieved before it is determined in step S6 described hereinafter that defrosting of the heat source-side heat exchanger 4 is complete. When such a state arises, the temperature of the refrigerant in the usage-side heat exchanger 6 decreases (refer to points F and W in the lines indicating the refrigeration cycle shown by the solid lines in FIG. 9, and points F and W in the lines indicating the refrigeration cycle shown by the dashed lines in FIG. 9), the low pressure in the refrigeration cycle decreases, and the flow rate of the refrigerant drawn from the first-stage compression element 2c decreases (refer to points A, F, and W in the lines indicating the refrigeration cycle shown by the solid lines in FIG. 8, and points A, F, and W in the lines indicating the refrigeration cycle shown by the dashed lines in FIG. 8); therefore, a problem emerges that the temperature decreases on the usage side, the flow rate of the refrigerant circulating through the refrigerant

circuit 10 decreases, and the defrosting capacity cannot be guaranteed.

[0047] In view of this, in step S3 in the present embodiment, a decision is made as to whether or not utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has concluded. If it is determined that utilization of the stored heat has concluded, the process advances to step S5, and a state is created in which intermediate pressure injection by the receiver 18 as a gas-liquid separator is used (i.e., the refrigerant is prevented from returning to the second-stage compression element 2d through the first second-stage injection tube 18c), similar to during the air-cooling operation, thereby switching to the reverse cycle defrosting operation in which the flow rate of the refrigerant flowing through the usage-side heat exchanger 6 is reduced (refer to the refrigeration cycle shown by the dashed lines in FIGS. 2, 8, and 9).

[0048] The process of step S4, which is performed ahead of the process of step S5, is a process for avoiding numerous repeated performances of the process of step S5 when the determination in step S3 is repeatedly performed, regardless of whether or not the process of step S5 has already been performed. The determination in step S3 described above of whether or not the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has finished being utilized is made based on the tube length of the refrigerant tube 1d between the usage-side heat exchanger 6 and the switching mechanism 3 (optionally, the tube length of the refrigerant communication tube in cases in which the air-conditioning apparatus 1 is configured by connecting the heat source unit and the usage unit via the refrigerant communication tube), the temperature of the refrigerant in the usage-side heat exchanger 6 as detected by the usage-side heat exchange temperature sensor 61, and/or the temperature of the refrigerant in the intake side of the compression mechanism 2 as detected by the intake pressure sensor 60. For example, as a decision based on the tube length of the refrigerant tube 1d between the usage-side heat exchanger 6 and the switching mechanism 3, a predetermined time duration is designated according to the tube length of the refrigerant tube 1d between the usage-side heat exchanger 6 and the switching mechanism 3, the predetermined time duration being equivalent to the point in time after the start of the reverse cycle defrosting operation when the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and the effect of improving the defrosting capacity is not sufficiently achieved; and it can be determined that utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has concluded when this predetermined time duration has elapsed after the start of the reverse cycle defrosting operation of step S2. For

example, one possibility is to designate the predetermined time duration as a short time duration when the tube length is short (therefore, when the tube length is extremely short, the defrosting operation of step S2 is substantially not performed), and to designate the predetermined time duration as a long time duration when the tube length is long. Thus, in cases in which the decision of whether or not utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has concluded is made based on the tube length of the refrigerant tube 1d between the usage-side heat exchanger 6 and the switching mechanism 3, the decision can be made in view of the extent of the amount of stored heat corresponding to the tube length of the refrigerant tube 1d (or the refrigerant communication tube). As a decision based on the temperature of the refrigerant in the usage-side heat exchanger 6, a predetermined temperature of the refrigerant in the usage-side heat exchanger 6 is designated, the predetermined temperature corresponding to a state in which the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and the effect of improving the defrosting capacity is not sufficiently achieved after the start of the reverse cycle defrosting operation of step S2; and it can be determined that utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has concluded when the temperature of the refrigerant in the usage-side heat exchanger 6 decreases to this predetermined temperature or lower after the start of the reverse cycle defrosting operation of step S2. Thus, when the decision of whether or not utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has concluded is made based on the temperature of the refrigerant in the usage-side heat exchanger 6, the decision can be made in view of the temperature decrease on the usage side. As a decision based on the pressure of the refrigerant in the intake side of the compression mechanism 2, a predetermined pressure of the refrigerant in the intake side of the compression mechanism 2 is designated, the predetermined pressure corresponding to a state in which the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and the effect of improving the defrosting capacity is not sufficiently achieved after the start of the reverse cycle defrosting operation of step S2; and it can be determined that utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 is complete when the pressure of the refrigerant in the intake side of the compression mechanism 2 decreases to this predetermined pressure or lower after the start of the reverse cycle defrosting operation of step S2. Thus, when the decision of whether or not utilization of the stored heat in the refrigerant tube

1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 has concluded is made based on the pressure of the refrigerant in the intake side of the compression mechanism 2, the decision can be made in view of the fact that the flow rate of the refrigerant drawn into the compression mechanism 2 decreases along with the temperature decrease on the usage side. The determination in step S3 may use any one of the three determination methods described above, or it may use a combination of any two or all three of the three determination methods described above. For example, it is considered more preferable when the decision based on the predetermined time duration designated according to the tube length of the refrigerant tube 1d is combined with either the decision based on the temperature of the refrigerant in the usage-side heat exchanger 6 or the decision based on the pressure of the refrigerant in the intake side of the compression mechanism 2 (in this case, the decision is made according to the elapse of the predetermined time duration and either the decrease of the refrigerant temperature to or below the predetermined temperature or the decrease of the refrigerant pressure to or below the predetermined pressure), because the decision can be made in view of both the temperature decrease on the usage side and the amount of heat stored.

[0049] The temperature decrease on the usage side can thereby be minimized in the refrigerant circuit 10 because circulation through the usage-side heat exchanger 6 into the compression mechanism 2 no longer continues excessively. Moreover, the temperature of the intermediate-pressure refrigerant in the refrigeration cycle drawn into the second-stage compression element 2d decreases (refer to points B and G in the lines indicating the refrigeration cycle shown by the dashed lines of FIG 9) and the temperature of the refrigerant discharged from the compression mechanism 2 decreases (refer to point D in the lines indicating the refrigeration cycle shown by the dashed lines of FIG. 9) due to the refrigerant returning to the second-stage compression element 2d through the first second-stage injection tube 18c, whereby the defrosting capacity per unit flow rate of the refrigerant when the reverse cycle defrosting operation is performed decreases, but the flow rate of the refrigerant discharged from the second-stage compression element 2d increases, and as much defrosting capacity as is possible can be guaranteed.

[0050] Next, in cases in which it is determined by the process in steps S3 to S5 that utilization of the stored heat has not concluded, or in cases in which it is determined that utilization of the stored heat has concluded and a switch is made to the defrosting operation, a decision is made in step S6 as to whether or not defrosting of the heat source-side heat exchanger 4 is complete. This decision is made based on the temperature of refrigerant flowing through the heat source-side heat exchanger 4 as detected by the heat source-side heat exchange temperature sensor 51, and/or on the operation

time of the defrosting operation. For example, in the case that the temperature of refrigerant in the heat source-side heat exchanger 4 as detected by the heat source-side heat exchange temperature sensor 51 is equal to or greater than a temperature equivalent to conditions at which frost deposits do not occur, or in the case that the defrosting operation has continued for a predetermined time or longer, it is determined that defrosting of the heat source-side heat exchanger 4 has concluded. In the case that the temperature conditions or time conditions are not met, it is determined that defrosting of the heat source-side heat exchanger 4 is not complete. In the case that a temperature sensor is provided to the inlet or outlet of the heat source-side heat exchanger 4, the temperature of the refrigerant as detected by either of these temperature sensors may be used in the determination of the temperature conditions instead of the refrigerant temperature detected by the heat source-side heat exchange temperature sensor 51. In cases in which it is determined in step S6 that defrosting of the heat source-side heat exchanger 4 has not concluded, the process returns once again to steps S3 to S5, and in cases in which it is determined that defrosting of the heat source-side heat exchanger 4 has concluded, the process advances to step S7, the defrosting operation is ended, and a process is again performed for restarting the air-warming operation. More specifically, a process is performed for switching the switching mechanism 3 from the cooling operation state to the heating operation state (i.e. the air-warming operation).

[0051] Thus, in the air-conditioning apparatus 1 (refrigeration apparatus) of the present embodiment, during at least the beginning of the reverse cycle defrosting operation, which takes place from the start of the defrosting operation until the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and a state arises in which the effect of improving the defrosting capacity is not sufficiently achieved, a state is created in which refrigerant does not return to the second-stage compression element 2d through the first second-stage injection tube 18c (refer to steps S2, S3, and S6), and sufficient utilization is made of the heat stored in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 by the air-warming operation which was being performed until immediately before the reverse cycle defrosting operation was performed to improve the defrosting capacity per unit flow rate of the refrigerant during the reverse cycle defrosting operation. After the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and a state has arisen in which the effect of improving the defrosting capacity is not sufficiently achieved, a state is created in which refrigerant does not return to the second-stage compression element 2d through the first second-stage injection tube 18c (refer to steps S3 to S6), similar to the air-cooling operation,

and in the refrigerant circuit 10, the temperature decrease on the usage side is minimized by preventing the circulation through the usage-side heat exchanger 6 into the compression mechanism 2 from continuing excessively, while as much defrosting capacity as possible is guaranteed by increasing the flow rate of the refrigerant discharged from the second-stage compression element 2d. Specifically, in this air-conditioning apparatus 1, when the reverse cycle defrosting operation is performed, it is possible to improve the defrosting capacity while minimizing the temperature decrease on the usage side.

(3) Modification 1

[0052] In the embodiment described above, in the air-conditioning apparatus 1 configured to be capable of switching between the air-cooling operation and the air-warming operation via the switching mechanism 3, the first second-stage injection tube 18c is provided for performing intermediate pressure injection through the receiver 18 as a gas-liquid separator, and intermediate pressure injection is performed by the receiver 18 as a gas-liquid separator, but instead of intermediate pressure injection by the receiver 18, another possible option is to provide a second second-stage injection tube 19 and an economizer heat exchanger 20 and to perform intermediate pressure injection through the economizer heat exchanger 20.

[0053] For example, as shown in FIG. 10, a refrigerant circuit 110 can be used which is provided with a second second-stage injection tube 19 and an economizer heat exchanger 20 instead of the first second-stage injection tube 18c in the embodiment described above.

[0054] The second second-stage injection tube 19 has a function for branching off and returning the refrigerant cooled in the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 to the second-stage compression element 2d of the compression mechanism 2. In the present modification, the second second-stage injection tube 19 is provided so as to branch off refrigerant flowing through the receiver inlet tube 18a and return the refrigerant to the second-stage compression element 2d. More specifically, the second second-stage injection tube 19 is provided so as to branch off and return the refrigerant from a position (i.e., between the heat source-side heat exchanger 4 and the first expansion mechanism 5a when the switching mechanism 3 is in the cooling operation state, or between the usage-side heat exchanger 6 and the first expansion mechanism 5a when the switching mechanism 3 is in the heating operation state) on the upstream side of the first expansion mechanism 5a of the receiver inlet tube 18a to a position on the downstream side of the intercooler 7 of the intermediate refrigerant tube 8. The second second-stage injection tube 19 is provided with a second second-stage injection valve 19a whose opening degree can be controlled. The second second-stage injection valve 19a is an electrically driven expansion valve in the present modification.

fication.

[0055] The economizer heat exchanger 20 is a heat exchanger for carrying out heat exchange between the refrigerant from which heat has been released in the heat source-side heat exchanger 4 or the usage-side heat exchanger 6 and the refrigerant that flows through the second second-stage injection tube 19 (more specifically, the refrigerant that has been depressurized to near intermediate pressure in the second second-stage injection valve 19a). In the present modification, the economizer heat exchanger 20 is provided so as to perform heat exchange between the refrigerant flowing through a position in the receiver inlet tube 18a upstream of the first expansion mechanism 5a (i.e., between the heat source-side heat exchanger 4 and the first expansion mechanism 5a when the switching mechanism 3 is in the cooling operation state, or between the usage-side heat exchanger 6 and the first expansion mechanism 5a when the switching mechanism 3 is in the heating operation state) and the refrigerant flowing through the second second-stage injection tube 19, and the economizer heat exchanger 20 has a passage through which both refrigerants flow against each other. In the present modification, the economizer heat exchanger 20 is provided upstream of the second second-stage injection tube 19 of the receiver inlet tube 18a. Therefore, the refrigerant from which heat has been released in the heat source-side heat exchanger 4 or usage-side heat exchanger 6 is branched off in the receiver inlet tube 18a into the second second-stage injection tube 19 before undergoing heat exchange in the economizer heat exchanger 20, and heat exchange is then conducted in the economizer heat exchanger 20 with the refrigerant flowing through the second second-stage injection tube 19.

[0056] Furthermore, the air-conditioning apparatus 1 of the present modification is provided with various sensors. Specifically, the intermediate refrigerant tube 8 or the compression mechanism 2 is provided with an intermediate pressure sensor 54 for detecting the pressure of the refrigerant that flows through the intermediate refrigerant tube 8. The outlet of the second second-stage injection tube 19 side of the economizer heat exchanger 20 is provided with an economizer outlet temperature sensor 55 for detecting the temperature of the refrigerant at the outlet of the second second-stage injection tube 19 side of the economizer heat exchanger 20.

[0057] Next, the action of the air-conditioning apparatus 1 will be described using FIGS. 6 and 10 through 17. FIG. 11 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-cooling operation, FIG. 12 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, FIG. 13 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation, FIG. 14 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-warming operation, FIG. 15 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1

at the start of the defrosting operation, FIG. 16 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation, and FIG. 17 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation. Operation control in the air-cooling operation, the air-warming operation, and the defrosting operation described hereinbelow is performed by the aforementioned controller (not shown) in the present embodiment. 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. 12, 13, 16, and 17), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A, F, W in FIGS. 12, 13, 16, and 17), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B, G, G', J, and K in FIGS. 12, 13, 16, and 17).

<Air-cooling operation>

[0058] During the air-cooling operation, the switching mechanism 3 is brought to the cooling operation state shown by the solid lines in FIGS. 10 and 11. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. Furthermore, the opening degree of the second 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 second-stage injection valve 19a is adjusted so that a target value is achieved in the degree of superheat of the refrigerant at the outlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20. In the present modification, the degree of superheat of the refrigerant at the outlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20 is obtained by converting the intermediate pressure detected by the intermediate pressure sensor 54 to a saturation temperature and subtracting this refrigerant saturation temperature value from the refrigerant temperature detected by the economizer outlet temperature sensor 55. Though not used in the present embodiment, another possible option is to provide a temperature sensor to the inlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20, and to obtain the degree of superheat of the refrigerant at the outlet in the second second-stage injection tube 19 side of the economizer heat exchanger 20 by subtracting the refrigerant temperature detected by this temperature sensor from the refrigerant temperature detected by the economizer outlet temperature sensor 55. The opening degree adjustment of the second second-stage injection valve 19a is not limited to superheat degree control; the opening degree may be opened to a predetermined opening degree in accordance with the flow rate of refrigerant circulating in the refrigerant circuit 110 or other factors, for example.

[0059] When the refrigerant circuit 110 is in this state, low-pressure refrigerant (refer to point A in FIGS. 10 through 13) 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 A in FIGS. 10 through 13). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled (refer to point G in FIGS. 10 through 13) by being mixed with refrigerant being returned from the second second-stage injection tube 19 to the second-stage compression element 2d (refer to point K in FIGS. 10 through 13). Next, having been mixed with the refrigerant returning from the second second-stage injection tube 19 (i.e., intermediate pressure injection is carried out by the economizer heat exchanger 20), the intermediate-pressure refrigerant is drawn into and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 10 through 13). 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. 12). 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 drawn once more 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 the switching mechanism 3, and is fed to the heat source-side heat exchanger 4 functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger 4 is cooled in the heat source-side heat exchanger 4 by heat exchange with air as a cooling source supplied by the heat source-side fan 40 (refer to point E in FIGS. 10 through 13). The high-pressure refrigerant cooled in the heat source-side heat exchanger 4 flows through the inlet non-return valve 17a of the bridge circuit 17 into the receiver inlet tube 18a, and some of the refrigerant is branched off into the second second-stage injection tube 19. The refrigerant flowing through the second second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the second second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 10

through 13). After being branched off into the second second-stage injection tube 19, the refrigerant flows into the economizer heat exchanger 20, where it is cooled by heat exchange with the refrigerant flowing through the second second-stage injection tube 19 (refer to point H in FIGS. 10 through 13). The refrigerant flowing through the second second-stage injection tube 19 is heated by heat exchange with the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 as a radiator (refer to point K in FIGS. 10 through 13), and 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 first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 10 and 11). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b and is depressurized by the second 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 evaporator (refer to point F in FIGS. 10 through 13). 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 W in FIGS. 10 through 13). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is then drawn once more into the compression mechanism 2 via the switching mechanism 3 (refer to point A in FIGS. 10 through 13). In this manner the air-cooling operation is performed.

[0060] Thus, in the air-conditioning apparatus 1 of the present modification, the second second-stage injection tube 19 and the economizer heat exchanger 20 are provided to branch off the refrigerant whose heat has been radiated in the heat source-side heat exchanger 4 and return the refrigerant to the second-stage compression element 2d, and the temperature of the refrigerant drawn into the second-stage compression element 2d can therefore be kept even lower without heat being radiated to the exterior (refer to points C and G in FIG. 13), similar to the embodiment described above. The temperature of the refrigerant discharged from the compression mechanism 2 is thereby minimized (refer to points D and D' in FIG. 13), and it is possible to further reduce the heat radiation loss equivalent to the area enclosed by connecting points C, D', D, and G in FIG. 13 more than in cases in which the second second-stage injection tube 19 and the economizer heat exchanger 20 are not provided; therefore, the power consumption of the compression mechanism 2 can be further reduced, and operating efficiency can be further improved.

[0061] Moreover, the intermediate pressure injection by the economizer heat exchanger 20 used in the present modification is more beneficial than the intermediate pressure injection by the receiver 18 as a gas-liquid sep-

arator used in the embodiment described above, because in a refrigerant circuit configuration in which no significant depressurizing operations are performed except for the first expansion mechanism 5a as a heat source-side expansion mechanism after the refrigerant is cooled in the heat source-side heat exchanger 4 as a radiator and the pressure difference from the high pressure in the refrigeration cycle to the nearly intermediate pressure of the refrigeration cycle can be used, the quantity of heat exchanged in the economizer heat exchanger 20 can be increased, and the flow rate of the refrigerant passing through the second second-stage injection tube 19 and returning to the second-stage compression element 2d can thereby be increased. Particularly in cases in which refrigerant that operates in the supercritical range is used as in the present modification, the intermediate pressure injection by the economizer heat exchanger 20 is extremely beneficial because there is an extremely large pressure difference from the high pressure in the refrigeration cycle to the nearly intermediate pressure of the refrigeration cycle.

<Air-warming operation>

[0062] During the air-warming operation, the switching mechanism 3 is brought to the heating operation state shown by the dashed lines in FIGS. 1 and 5. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. Furthermore, the opening degree of the second second-stage injection valve 19a is adjusted in the same manner as in the air-cooling operation.

[0063] When the refrigerant circuit 110 is in this state, low-pressure refrigerant (refer to point A in FIGS. 10 and 12 through 14) 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 B in FIGS. 10 and 12 through 14). This intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled (refer to point G in FIGS. 10 and 12 through 14) by mixing with the refrigerant returned from the second second-stage injection tube 19 to the second-stage compression element 2d (refer to point K in FIGS. 10 and 12 through 14). Next, having been mixed with the refrigerant returning from the second second-stage injection tube 19 (i.e., intermediate pressure injection is carried out by the economizer heat exchanger 20), the intermediate-pressure refrigerant is drawn into and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 10 and 12 through 14). 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. 12), similar to the air-cooling operation. The high-pressure refrigerant discharged from the compression mechanism 2 flows into the oil separator 41 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 drawn once more 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 the switching mechanism 3, fed to the usage-side heat exchanger 6 functioning as a radiator of refrigerant, and cooled by heat exchange with the water and/or air as a cooling source (refer to point F in FIGS. 10 and 14, and read point E as point F in FIGS. 12 and 13). 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 into the second second-stage injection tube 19. The refrigerant flowing through the second second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the second second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 10 and 12 through 14). The refrigerant after being branched off to the second second-stage injection tube 19 then flows into the economizer heat exchanger 20, where it is cooled by heat exchange with the refrigerant flowing through the second second-stage injection tube 19 (refer to point H in FIGS. 10 and 12 through 14). The refrigerant flowing through the second second-stage injection tube 19 is heated by heat exchange with the high-pressure refrigerant cooled in the usage-side heat exchanger 6 functioning as a radiator (refer to point K in FIGS. 10 and 12 through 14), and 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 first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 10 and 14). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b where it is depressurized by the second expansion mechanism 5b to a low-pressure gas-liquid two-phase refrigerant, which is fed through the outlet non-return valve 17d of the bridge circuit 17 to the heat source-side heat exchanger 4 functioning as an evaporator of refrigerant (refer to point E in FIGS. 10 and 14, and read point F as point E in FIGS. 12 and 13). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger 4 is then heated and

evaporated in the heat source-side heat exchanger 4 by heat exchange with the air as a heating source supplied by the heat source-side fan 40 (refer to point A in FIGS. 10 and 12 through 14). The low-pressure refrigerant heated and evaporated in the heat source-side heat exchanger 4 is then drawn once more into the compression mechanism 2 via the switching mechanism 3. In this manner the air-warming operation is performed.

[0064] Thus, in the air-conditioning apparatus 1 of the present modification, similar to the embodiment described above, the second second-stage injection tube 19 and economizer heat exchanger 20 are provided to branch off the refrigerant whose heat has been radiated in the usage-side heat exchanger 6 and return the refrigerant to the second-stage compression element 2d similar to the air-cooling operation; therefore, the temperature of the refrigerant drawn into the second-stage compression element 2d can be further minimized without heat being radiated to the exterior (refer to points C and G FIG. 13). Thereby, the temperature of the refrigerant discharged from the compression mechanism 2 is kept lower (refer to points D and D' in FIG. 13), and the heat radiation loss equivalent to the area enclosed by connecting points C, D', D, and G in FIG. 13 can be further reduced in comparison with cases in which the second second-stage injection tube 19 and the economizer heat exchanger 20 are not provided; therefore, the power consumption of the compression mechanism 2 can be further reduced and operating efficiency can be further improved.

[0065] Moreover, the intermediate pressure injection by the economizer heat exchanger 20 used in the present modification is more beneficial than the intermediate pressure injection by the receiver 18 as a gas-liquid separator used in the embodiment described above, similar to the air-cooling operation, because in a refrigerant circuit configuration in which no significant depressurizing operations are performed except for the first expansion mechanism 5a as a heat source-side expansion mechanism after the refrigerant is cooled in the usage-side heat exchanger 6 as a radiator and the pressure difference from the high pressure in the refrigeration cycle to the nearly intermediate pressure of the refrigeration cycle can be used, the quantity of heat exchanged in the economizer heat exchanger 20 can be increased, and the flow rate of the refrigerant passing through the second second-stage injection tube 19 and returning to the second-stage compression element 2d can thereby be increased. Particularly in cases in which refrigerant that operates in the supercritical range is used as in the present modification, the intermediate pressure injection by the economizer heat exchanger 20 is extremely beneficial because there is an extremely large pressure difference from the high pressure in the refrigeration cycle to the nearly intermediate pressure of the refrigeration cycle.

<Defrosting operation>

[0066] In the present modification, the second second-stage injection tube 19 and the economizer heat exchanger 20 are provided and intermediate pressure injection by the economizer heat exchanger 20 is used, which is different from the embodiment described above in which intermediate pressure injection by the receiver 18 as a gas-liquid separator is used, but the modification and embodiment are similar in having the objectives of reducing the temperature on the usage side when the reverse cycle defrosting operation is performed and/or utilizing the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3.

[0067] In view of this, in the present modification, in step S2 shown in FIG. 6, a state is created in which intermediate pressure injection by the economizer heat exchanger 20 is not used (i.e., refrigerant is prevented from returning to the second-stage compression element 2d through the second second-stage injection tube 19), while the switching mechanism 3 is switched from the heating operation state to the cooling operation state and the reverse cycle defrosting operation is performed (refer to the refrigeration cycle shown by the solid lines in FIGS. 15, 16, and 17).

[0068] Thereby, as in the embodiment described above, during at least the beginning of the reverse cycle defrosting operation, which takes place from the start of the defrosting operation until the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and a state arises in which the effect of improving the defrosting capacity is not sufficiently achieved, circulation is performed in the refrigerant circuit 110 in which the refrigerant discharged from the compression mechanism 2 is actively drawn into the compression mechanism 2 through the usage-side heat exchanger 6, and the low-pressure refrigerant heated and evaporated in the usage-side heat exchanger 6 (refer to point W in the lines indicating the refrigeration cycle shown by the solid lines in FIGS. 16 and 17) is therefore drawn into the compression mechanism 2 via the switching mechanism 3 (refer to point A in the lines indicating the refrigeration cycle shown by the solid lines in FIGS. 16 and 17) after being heated by the refrigerant tube 1d or the like. Specifically, sufficient utilization is made of the heat stored in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 by the air-warming operation that had been performed until immediately before the defrosting operation was performed. The low-pressure refrigerant in the refrigeration cycle drawn into the compression mechanism 2 thereby increases in temperature (refer to point B in the lines indicating the refrigeration cycle shown by the solid lines in FIGS. 17) and the refrigerant is prevented from returning to the second-stage compression element 2d through the second second-stage injection tube

19, thereby minimizing the decrease in the temperature of the intermediate-pressure refrigerant in the refrigeration cycle drawn into the second-stage compression element 2d (refer to points B and G in the lines indicating the refrigeration cycle shown by the solid lines in FIG. 17). Therefore, the temperature of the high-pressure refrigerant in the refrigeration cycle discharged from the compression mechanism 2 can be greatly increased (refer to point D in the lines indicating the refrigeration cycle shown by the solid lines in FIG. 17), and the defrosting capacity per unit flow rate of the refrigerant during the reverse cycle defrosting operation can be improved.

[0069] In the present modification, in step S5 shown in FIG. 6, a state is created in which intermediate pressure injection by the economizer heat exchanger 20 is used (i.e., the refrigerant returns to the second-stage compression element 2d through the second second-stage injection tube 19), similar to the air-cooling operation, thereby switching to the reverse cycle defrosting operation in which the flow rate of the refrigerant flowing through the usage-side heat exchanger 6 is reduced (refer to the refrigeration cycle shown by the dashed lines in FIGS. 11, 16, and 17). Opening degree control is herein performed so that the opening degree of the second second-stage injection valve 19a is greater than the opening degree of the second second-stage injection valve 19a during the air-cooling operation and/or the air-warming operation. In a case in which the opening degree of the second second-stage injection valve 19a when fully close is 0%, the opening degree when fully open is 100%, and the second second-stage injection valve 19a is controlled during the air-cooling operation and air-warming operation within the opening-degree range of 50% or less, for example; the second second-stage injection valve 19a in step S2 is controlled so that the opening degree increases up to about 70%, and this opening degree is kept constant until it is determined in step S3 that defrosting of the heat source-side heat exchanger 4 is complete.

[0070] Thereby, as in the embodiment described above, after the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and a state has arisen in which the effect of improving the defrosting capacity is not sufficiently achieved, the temperature decrease on the usage side is minimized in the refrigerant circuit 110 because the circulation through the usage-side heat exchanger 6 into the compression mechanism 2 no longer continues excessively. Moreover, the refrigerant is made to return to the second-stage compression element 2d through the second second-stage injection tube 19, whereby the temperature of the intermediate-pressure refrigerant in the refrigeration cycle drawn into the second-stage compression element 2d decreases (refer to points B and G in the lines indicating the refrigeration cycle shown by the dashed lines in FIG. 17) and the temperature of the refrigerant discharged from the compression mechanism 2 decreases (refer to point D in the lines indicating the refrigeration

cycle shown by the dashed lines in FIG. 17). The defrosting capacity per unit flow rate of the refrigerant during the reverse cycle defrosting operation thereby decreases, but since the flow rate of the refrigerant discharged from the second-stage compression element 2d increases, the defrosting capacity can be guaranteed as much as is possible. Furthermore, in the present modification, since it is possible to control the flow rate of the refrigerant returned to the second-stage compression element 2d through the second second-stage injection tube 19 by controlling the opening degree of the second second-stage injection valve 19a, the flow rate of the refrigerant returning to the second-stage compression element 2d can be greatly increased by performing opening degree control so that the opening degree of the second second-stage injection valve 19a is greater than during the air-cooling operation and/or the air-warming operation as described above, for example, whereby the flow rate of the refrigerant flowing through the heat source-side heat exchanger 4 can be further increased while further reducing the flow rate of the refrigerant flowing through the usage-side heat exchanger 6.

[0071] Thus, in the present modification, the same effects as those of the defrosting operation of the embodiment described above are achieved, and since intermediate pressure injection by the economizer heat exchanger 20 is used, the effect of minimizing the temperature decrease on the usage side can be improved more so than in the case of using intermediate pressure injection by the receiver 18 in the embodiment described above.

[0072] The other steps S1, S3, S4, S6, and S7 of the defrosting operation in the present modification are identical to those of the defrosting operation in the embodiment described above, and are therefore not described herein.

(4) Modification 2

[0073] In the refrigerant circuits 10 and 110 (FIGS. 1 and 10) in the embodiment and Modification 1 described above, intermediate pressure injection by the receiver 18 as a gas-liquid separator or intermediate pressure injection by the economizer heat exchanger 20 is performed, whereby the temperature of the refrigerant discharged from the second-stage compression element 2d is reduced, the power consumption of the compression mechanism 2 is reduced, and operating efficiency is improved, but in addition to this configuration, the intermediate refrigerant tube 8 for drawing the refrigerant discharged from the first-stage compression element 2c into the second-stage compression element 2d may also be provided with an intermediate heat exchanger 7 that functions as a cooler of refrigerant discharged from the first-stage compression element 2c and drawn into the second-stage compression element 2d.

[0074] For example, the refrigerant circuit 110 of Modification 1 described above can be replaced by a refrigerant circuit 210 provided with the intermediate heat ex-

changer 7 and an intermediate heat exchanger bypass tube 9, as shown in FIG. 18.

[0075] The intermediate heat exchanger 7 herein is a heat exchanger which is provided to the intermediate refrigerant tube 8 and which functions as a cooler of refrigerant discharged from the first-stage compression element 2c and drawn into the compression element 2d, and a fin-and-tube heat exchanger is used in the present modification. The intermediate heat exchanger 7 is integrated with the heat source-side heat exchanger 4. More specifically, the intermediate heat exchanger 7 is integrated by sharing heat transfer fins with the heat source-side heat exchanger 4. In the present modification, the air as the heat source is supplied by the heat source-side fan 40 for supplying air to the heat source-side heat exchanger 4. Specifically, the heat source-side fan 40 is designed so as to supply air as a heat source to both the heat source-side heat exchanger 4 and the intermediate heat exchanger 7.

[0076] An intermediate heat exchanger bypass tube 9 is connected to the intermediate refrigerant tube 8 so as to bypass the intermediate heat exchanger 7. This intermediate heat exchanger bypass tube 9 is a refrigerant tube for limiting the flow rate of refrigerant flowing through the intermediate heat exchanger 7. The intermediate heat exchanger bypass tube 9 is provided with an intermediate heat exchanger bypass on/off valve 11. The intermediate heat exchanger bypass on/off valve 11 is an electromagnetic valve in the present modification. In the present modification, the intermediate heat exchanger bypass on/off valve 11 essentially is controlled so as to close when the switching mechanism 3 is set for the cooling operation state, and to open when the switching mechanism 3 is set for the heating operation state. In other words, excluding cases in which temporary operations such as the hereinafter-described defrosting operation are performed, the intermediate heat exchanger bypass on/off valve 11 essentially is controlled so as to close when the air-cooling operation is performed and to open when the air-warming operation is performed.

[0077] In the intermediate refrigerant tube 8, an intermediate heat exchanger on/off valve 12 is provided to the portion extending from the connection with the end of the intermediate heat exchanger bypass tube 9 near the first-stage compression element 2c to the end of the intermediate heat exchanger 7 near the first-stage compression element 2c. This intermediate heat exchanger on/off valve 12 is a mechanism for limiting the flow rate of refrigerant flowing through the intermediate heat exchanger 7. The intermediate heat exchanger on/off valve 12 is an electromagnetic valve in the present modification. Excluding cases in which temporary operations such as the hereinafter-described defrosting operation are performed, in the present modification the intermediate heat exchanger on/off valve 12 is essentially controlled so as to open when the switching mechanism 3 is set for the cooling operation state, and to close when the switching mechanism 3 is set for the heating operation

state. In other words, the intermediate heat exchanger on/off valve 12 is controlled so as to open when the air-cooling operation is performed and close when the air-warming operation is performed.

[0078] The intermediate refrigerant tube 8 is also provided with a non-return mechanism 15 for allowing refrigerant to flow from the discharge side of the first-stage compression element 2c to the intake side of the second-stage compression element 2d and for blocking the refrigerant from flowing from the intake side of the second-stage compression element 2d to the discharge side of the first-stage compression element 2c. The non-return mechanism 15 is a non-return valve in the present modification. In the present modification, the non-return mechanism 15 is provided to the portion of the intermediate refrigerant tube 8 extending from the end of the intermediate heat exchanger 7 near the second-stage compression element 2d to the connection with the end of the intermediate heat exchanger bypass tube 9 near the second-stage compression element 2d.

[0079] Furthermore, an intermediate heat exchange outlet temperature sensor 52 for detecting the temperature of the refrigerant in the outlet of the intermediate heat exchanger 7 is provided to the outlet of the intermediate heat exchanger 7.

[0080] Next, the action of the air-conditioning apparatus 1 will be described using FIGS. 6, 12, 13 and 16 through 27. FIG. 19 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-cooling operation, FIG. 20 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, FIG. 21 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation, FIG. 22 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-warming operation, FIG. 23 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 at the start of the defrosting operation, FIG. 24 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 in the defrosting operation after defrosting of the intermediate heat exchanger 7 has concluded, FIG. 25 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 in the defrosting operation after defrosting of the intermediate heat exchanger 7 and utilization of the stored heat have concluded, FIG. 26 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation, and FIG. 27 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation. Operation control in the air-cooling operation, the air-warming operation, and the defrosting operation described hereinbelow is performed by the aforementioned controller (not shown) in the present embodiment. 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. 20, 21, 12, 13, 16, 17, 26, and 27), the term "low pressure" means a low pressure in the refrigeration cycle (specifi-

cally, the pressure at points A, F, W in FIGS. 20, 21, 12, 13, 16, 17, 26, and 27), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B, C, C', G, G', J, and K in FIGS. 20, 21, 12, 13, 16, 17, 26, and 27).

<Air-cooling operation>

[0081] During the air-cooling operation, the switching mechanism 3 is brought to the cooling operation state shown by the solid lines in FIGS. 18 and 19. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. Since the switching mechanism 3 is in the cooling operation state, the intermediate heat exchanger on/off valve 12 of the intermediate refrigerant tube 8 is opened and the intermediate heat exchanger bypass on/off valve 11 of the intermediate heat exchanger bypass tube 9 is closed, thereby creating a state in which the intermediate heat exchanger 7 functions as a cooler. Furthermore, the opening degree of the second second-stage injection valve 19a is adjusted in the same manner as in Modification 1 described above.

[0082] When the refrigerant circuit 210 is in this state, low-pressure refrigerant (refer to point A in FIGS. 18 through 21) 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 A in FIGS. 18 through 21). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled in the intermediate heat exchanger 7 by undergoing heat exchange with the air as a cooling source supplied by the heat source-side fan 40 (refer to point C in FIGS. 18 through 21). The refrigerant cooled in the intermediate heat exchanger 7 is further cooled (refer to point G in FIGS. 18 through 21) by being mixed with refrigerant being returned from the second second-stage injection tube 19 to the second-stage compression element 2d (refer to point K in FIGS. 18 through 21). Next, having been mixed with the refrigerant returning from the second second-stage injection tube 19 (i.e., intermediate pressure injection is carried out by the economizer heat exchanger 20), the intermediate-pressure refrigerant is drawn into and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 18 through 21). 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. 20). 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 drawn once more 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 the switching mechanism 3, and is fed to the heat source-side heat exchanger 4 functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger 4 is cooled in the heat source-side heat exchanger 4 by heat exchange with air as a cooling source supplied by the heat source-side fan 40 (refer to point E in FIGS. 18 through 21). The high-pressure refrigerant cooled in the heat source-side heat exchanger 4 flows through the inlet non-return valve 17a of the bridge circuit 17 into the receiver inlet tube 18a, and some of the refrigerant is branched off into the second second-stage injection tube 19. The refrigerant flowing through the second second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the second second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 18 through 21). The refrigerant after being branched off into the second second-stage injection tube 19 then flows into the economizer heat exchanger 20, where it is cooled by heat exchange with the refrigerant flowing through the second second-stage injection tube 19 (refer to point H in FIGS. 18 through 21). The refrigerant flowing through the second second-stage injection tube 19 is heated by heat exchange with the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 as a radiator (refer to point K in FIGS. 18 through 21), and 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 first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 18 and 19). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b and is depressurized by the second 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 evaporator (refer to point F in FIGS. 18 through 21). 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 W in FIGS. 18 through 21). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is then drawn once more into the compression mechanism 2 via the

switching mechanism 3 (refer to point A in FIGS. 18 through 21). In this manner the air-cooling operation is performed.

[0083] Thus, in the air-conditioning apparatus 1 of the present modification, in addition to the configuration of the intermediate pressure injection (as performed by the second second-stage injection tube 19 and the economizer heat exchanger 20 herein), the intermediate heat exchanger 7 is provided to the intermediate refrigerant tube 8 for drawing the refrigerant discharged from the compression element 2c into the compression element 2d, and in the air-cooling operation, the intermediate heat exchanger on/off valve 12 is opened and the intermediate heat exchanger bypass on/off valve 11 of the intermediate heat exchanger bypass tube 9 is closed, thereby bringing the intermediate heat exchanger 7 to a state of functioning as a cooler. Therefore, the temperature of the refrigerant drawn into the compression element 2d on the second-stage side of the compression element 2c decreases (refer to points G and G' in FIG. 21) and the temperature of the refrigerant discharged from the compression element 2d also decreases (refer to points D and D' in FIG. 21), more so than in cases in which the intermediate heat exchanger 7 is not provided (in this case, the refrigeration cycle is performed in the following sequence shown in FIGS. 20 and 21: point A → point B, C' → point G' → point D' → point E → point H → point F). Therefore, in the heat source-side heat exchanger 4 functioning as a radiator of the refrigerant in this air-conditioning apparatus 1, operating efficiency can be improved over cases in which no intermediate heat exchanger 7 is provided, because the temperature difference between the refrigerant and water or air as the cooling source can be further reduced, and heat radiation loss can be reduced by an amount equivalent to the area enclosed by connecting points G', D', D, and G in FIG. 21.

<Air-warming operation>

[0084] During the air-warming operation, the switching mechanism 3 is brought to the heating operation state shown by the dashed lines in FIGS. 18 and 22. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. Since the switching mechanism 3 is in the heating operation state, the intermediate heat exchanger on/off valve 12 of the intermediate refrigerant tube 8 is closed and the intermediate heat exchanger bypass on/off valve 11 of the intermediate heat exchanger bypass tube 9 is opened, thereby creating a state in which the intermediate heat exchanger 7 does not function as a cooler. Furthermore, the opening degree of the second second-stage injection valve 19a is adjusted in the same manner as in the air-cooling operation.

[0085] When the refrigerant circuit 210 is in this state, low-pressure refrigerant (refer to point A in FIGS. 18, 22, 12, and 13) 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 B in FIGS. 18, 22, 12, and 13). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c passes through the intermediate heat exchanger bypass tube 9 (refer to point C" in FIGS. 18 and 22) without passing through the intermediate heat exchanger 7 (i.e., without being cooled), unlike during the air-cooling operation. This intermediate-pressure refrigerant that has passed through the intermediate heat exchanger bypass tube 9 without being cooled by the intermediate heat exchanger 7 is further cooled (refer to point G in FIGS. 18, 22, 12, and 13) by being mixed with refrigerant being returned from the second second-stage injection tube 19 to the second-stage compression element 2d (refer to point K in FIGS. 18, 22, 12, and 13). Next, having been mixed with the refrigerant returning from the second second-stage injection tube 19 (i.e., intermediate pressure injection is carried out by the economizer heat exchanger 20), the intermediate-pressure refrigerant is drawn into and further compressed in the compression element 2d connected to the second-stage side of the compression element 2c, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 18, 22, 12, and 13). 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. 12), similar to the air-cooling operation. 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 drawn once more 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 the switching mechanism 3, fed to the usage-side heat exchanger 6 functioning as a radiator of refrigerant, and cooled by heat exchange with the water and/or air as a cooling source (refer to point F in FIGS. 18 and 22, and read point E as point F in FIGS. 12 and 13). 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 into the second second-stage injection tube 19. The refrigerant flowing through the second second-stage injection tube 19 is depressurized to a nearly intermediate pressure in the

second second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 18, 22, 12, and 13). The refrigerant after being branched off to the second second-stage injection tube 19 then flows into the economizer heat exchanger 20, where it is cooled by heat exchange with the refrigerant flowing through the second second-stage injection tube 19 (refer to point H in FIGS. 18, 22, 12, and 13). The refrigerant flowing through the second second-stage injection tube 19 is heated by heat exchange with the high-pressure refrigerant cooled in the usage-side heat exchanger 6 functioning as a radiator (refer to point K in FIGS. 18, 22, 12, and 13), and 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 first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 18 and 22). The refrigerant retained in the receiver 18 is fed to the receiver outlet tube 18b and is depressurized by the second 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 evaporator (refer to point E in FIGS. 18 and 22, and read point F as point E in FIGS. 12 and 13). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger 4 is heated in the heat source-side heat exchanger 4 by heat exchange with air as a heating source supplied by the heat source-side fan 40, and the refrigerant is evaporated (refer to point A in FIGS. 18, 22, 12, and 13). The low-pressure refrigerant heated and evaporated in the heat source-side heat exchanger 4 is then drawn once more into the compression mechanism 2 via the switching mechanism 3. In this manner the air-warming operation is performed.

[0086] Thus, in the air-conditioning apparatus 1 of the present modification, in addition to the configuration of the intermediate pressure injection (as performed by the second second-stage injection tube 19 and the economizer heat exchanger 20 herein), the intermediate heat exchanger 7 is provided to the intermediate refrigerant tube 8 for drawing the refrigerant discharged from the compression element 2c into the compression element 2d, and in the air-warming operation, the intermediate heat exchanger on/off valve 12 is closed and the intermediate heat exchanger bypass on/off valve 11 of the intermediate heat exchanger bypass tube 9 is opened, thereby bringing the intermediate heat exchanger 7 to a state of not functioning as a cooler. Therefore, the decrease in the temperature of the refrigerant discharged from the compression mechanism 2 is minimized, more so than in cases in which the intermediate heat exchanger 7 is made to function as a cooler, similar to the air-cooling operation described above. Therefore, in the air-conditioning apparatus 1, heat radiation to the exterior

can be minimized, temperature decreases can be minimized in the refrigerant supplied to the usage-side heat exchanger 6 functioning as a refrigerant cooler, loss of heating performance in the usage-side heat exchanger 6 can be reduced, and loss of operating efficiency can be prevented, in comparison with cases in which the intermediate heat exchanger 7 is made to function as a radiator similar to the air-cooling operation described above.

<Defrosting operation>

[0087] In the present modification, since the intermediate heat exchanger 7 is provided to the intermediate refrigerant tube 8 for drawing the refrigerant discharged from the compression element 2c into the compression element 2d, a heat exchanger having air as a heat source is used as the intermediate heat exchanger 7, and the intermediate heat exchanger 7 is integrated with the heat source-side heat exchanger 4; there is a risk of frost deposition occurring on the intermediate heat exchanger 7, although the frost deposition is not much in comparison with the heat source-side heat exchanger 4, and it is therefore preferable for refrigerant to flow not only to the heat source-side heat exchanger 4 but to the intermediate heat exchanger 7 as well and for defrosting of the intermediate heat exchanger 7 to be performed.

[0088] In view of this, in the present modification, in step S2 shown in FIG. 6, a state is created in which intermediate pressure injection is not used (herein, refrigerant is prevented from returning to the second-stage compression element 2d through the second second-stage injection tube 19), a state in which the intermediate heat exchanger 7 is not made to function as a cooler is created by opening the intermediate heat exchanger on/off valve 12 and closing the intermediate heat exchanger bypass on/off valve 11, similar to the air-cooling operation described above; the switching mechanism 3 is switched from the heating operation state to the cooling operation state, and the reverse cycle defrosting operation is performed (refer to the refrigeration cycle shown by the solid lines in FIGS. 23, 26, and 27).

[0089] Defrosting of the intermediate heat exchanger 7 is thereby performed along with defrosting of the heat source-side heat exchanger 4. Since the amount of frost deposition in the intermediate heat exchanger 7 is small, defrosting of the intermediate heat exchanger 7 will be complete before defrosting of the heat source-side heat exchanger 4 is complete and before utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 is determined to be complete in step S3 shown in FIG 6. However, if refrigerant continues to flow to the intermediate heat exchanger 7 even after defrosting of the intermediate heat exchanger 7 is complete, heat is radiated from the intermediate heat exchanger 7 to the exterior and the temperature of the refrigerant drawn into the second-stage compression element 2d

decreases, and as a result, the temperature of the refrigerant discharged from the compression mechanism 2 decreases, creating a problem of the loss of defrosting capacity of the heat source-side heat exchanger 4.

[0090] In view of this, in the present modification, in step S6 shown in FIG. 6, a decision is made as to whether or not defrosting of the intermediate heat exchanger 7 is complete, and when defrosting of the intermediate heat exchanger 7 is determined to be complete, the intermediate heat exchanger 7 is brought to a state of not functioning as a cooler by closing the intermediate heat exchanger on/off valve 12 and opening the intermediate heat exchanger bypass on/off valve 11, and the process therefore returns to step S3 shown in FIG. 6. The decision of whether or not defrosting of the intermediate heat exchanger 7 has concluded is made based on the temperature of the refrigerant in the outlet of the intermediate heat exchanger 7. For example, when the temperature of the refrigerant in the outlet of the intermediate heat exchanger 7 as detected by the intermediate heat exchange outlet temperature sensor 52 is detected as being equal to or greater than a predetermined temperature, defrosting of the intermediate heat exchanger 7 is determined to have concluded, and when such temperature conditions are not met, defrosting of the intermediate heat exchanger 7 is determined not to have concluded.

[0091] Heat radiation from the intermediate heat exchanger 7 to the exterior thereby does not take place, the decrease in the temperature of the refrigerant drawn into the second-stage compression element 2d is therefore minimized, and as a result, the decrease in the temperature of the refrigerant discharged from the compression mechanism 2 can be minimized, and the decrease in the defrosting capacity of the heat source-side heat exchanger 4 can be minimized (Refer to the refrigeration cycle shown by the solid lines in FIGS. 24, 16, and 17).

[0092] In the present modification, in step S5 shown in FIG. 6, a state of using intermediate pressure injection is created (refrigerant returns to the second-stage compression element 2d through the second second-stage injection tube 19) in the same manner as in Modification 1 described above, thereby switching to the reverse cycle defrosting operation in which the flow rate of refrigerant flowing through the usage-side heat exchanger 6 is reduced (refer to the refrigeration cycle shown by the dashed lines in FIGS. 25, 26, and 27).

[0093] Thereby, as in Modification 1 described above, after a state has arisen in which the amount of stored heat in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 decreases and the effect of improving the defrosting capacity is not sufficiently achieved, circulation through the usage-side heat exchanger 6 into the compression mechanism 2 is no longer continued excessively in the refrigerant circuit 210, the temperature decrease on the usage side can therefore be minimized, and as much defrosting capacity as possible can be guaranteed because the flow rate of the refrigerant discharged from

the second-stage compression element 2d increases.

[0094] Thus, in the present modification, the same effects as those of the defrosting operation of Modification 1 described above are achieved, the heat stored in the refrigerant tube 1d or the like between the usage-side heat exchanger 6 and the switching mechanism 3 can be utilized to efficiently defrost the intermediate heat exchanger 7, and after defrosting of the intermediate heat exchanger 7 is complete, the refrigerant bypasses so as not to flow to the intermediate heat exchanger 7, whereby needless heat radiation to the exterior is suppressed, and the loss of defrosting capacity of the heat source-side heat exchanger 4 can be minimized.

[0095] The other steps S1, S3, S4, and S7 of the defrosting operation in the present modification are the same as in the defrosting operation of Modification 1 described above, and are therefore not described herein.

(5) Modification 3

[0096] In the refrigerant circuits 110 and 210 (see FIGS. 10 and 18) in Modifications 1 and 2 described above, in both the air-cooling operation in which the switching mechanism 3 is brought to the cooling operation state and the air-warming operation in which the switching mechanism 3 is brought to the heating operation state, the temperature of the refrigerant, discharged from the second-stage compression element 2d is reduced, the power consumption of the compression mechanism 2 is reduced, and operating efficiency can be improved by performing intermediate pressure injection by the economizer heat exchanger 20 as described above. The intermediate pressure injection by the economizer heat exchanger 20 is believed to be beneficial in a refrigerant circuit configuration having a single usage-side heat exchanger 6, wherein the pressure difference from the high pressure in the refrigeration cycle to the nearly intermediate pressure of the refrigeration cycle can be used.

[0097] However, there are cases in which the configuration has a plurality of usage-side heat exchangers 6 connected to each other in parallel with the objective of performing air cooling and/or air warming corresponding to air-conditioning loads for a plurality of air-conditioned spaces, and usage-side expansion mechanisms 5c are provided between the receiver 18 as a gas-liquid separator and the usage-side heat exchangers 6 so as to correspond to each of the usage-side heat exchangers 6, in order to make it possible to control the flow rates of refrigerant flowing through each of the usage-side heat exchangers 6 and obtain the refrigeration loads required in each of the usage-side heat exchangers 6.

[0098] For example, although the details are not shown, in the refrigerant circuit 210 (see FIG. 18) having a bridge circuit 17 in Modifications 1 and 2 described above, another possibility is to provide a plurality (two in this case) of usage-side heat exchangers 6 connected to each other in parallel, to provide usage-side expansion

mechanisms 5c (see FIG. 28) between the receiver 18 as a gas-liquid separator (more specifically, the bridge circuit 17) and the usage-side heat exchangers 6 so as to correspond to each of the usage-side heat exchangers 6, to omit the second expansion mechanism 5b that had been provided to the receiver outlet tube 18b, and to provide a third expansion mechanism (not shown) for depressurizing the refrigerant to a low pressure in the refrigeration cycle during the air-warming operation instead of the outlet non-return valve 17d of the bridge circuit 17.

[0099] In such a configuration, intermediate pressure injection by the economizer heat exchanger 20 is beneficial, similar to Modification 2 described above, in conditions in which the pressure difference from the high pressure in the refrigeration cycle to the nearly intermediate pressure of the refrigeration cycle can be used without any significant depressurizing operations being performed except for the first expansion mechanism 5a as a heat source-side expansion mechanism after the refrigerant is cooled in the heat source-side heat exchanger 4 as a radiator, as in the case in the air-cooling operation in which the switching mechanism 3 is brought to the cooling operation state.

[0100] However, in conditions in which each of the usage-side expansion mechanisms 5c control the flow rate of the refrigerant flowing through each of the usage-side heat exchangers 6 as radiators so as to obtain the refrigeration loads required in each of the usage-side heat exchangers 6 as radiators, and the flow rate of the refrigerant passing through each of the usage-side heat exchangers 6 as radiators is mostly determined by depressurizing the refrigerant by controlling the opening degrees of the usage-side expansion mechanisms 5c provided downstream of each of the usage-side heat exchangers 6 as radiators and upstream of the economizer heat exchanger 20, as in the case in the air-warming operation in which the switching mechanism 3 is brought to the heating operation state; the extent to which the refrigerant is depressurized by controlling the opening degrees of the usage-side expansion mechanisms 5c fluctuates not only according to the flow rate of the refrigerant flowing through each of the usage-side heat exchangers 6 as radiators but also according to the state of the flow rate distribution among the plurality of usage-side heat exchangers 6 as radiators, and there are cases in which a state arises in which the extent of depressurization differs greatly among the plurality of usage-side expansion mechanisms 5c, or the extent of depressurization in the usage-side expansion mechanisms 5c is comparatively large. Therefore, there is a risk that the pressure of the refrigerant in the inlet of the economizer heat exchanger 20 will decrease, in which case there is a risk that the rate of heat exchange in the economizer heat exchanger 20 (i.e., the flow rate of the refrigerant, flowing through the second second-stage injection tube 19) will decrease and use will be difficult. Particularly in cases in which this type of air-conditioning apparatus 1 is configured as a separate-type air-conditioning appa-

ratus in which a heat source unit including primarily the compression mechanism 2, the heat source-side heat exchanger 4, and the receiver 18 is connected by a communication tube with a usage unit including primarily the usage-side heat exchanger 6, the communication tube could be extremely long depending on the arrangement of the usage unit and the heat source unit; therefore, the pressure drop has an effect, and the pressure of the refrigerant in the inlet of the economizer heat exchanger 20 decreases further. In cases in which there is a risk that the pressure of the refrigerant in the inlet of the economizer heat exchanger 20 will decrease, it is beneficial to use intermediate pressure injection by the receiver 18 as a gas-liquid separator in the embodiment described above, which can be used even in conditions in which there is a small pressure difference between the pressure in the receiver 18 and the intermediate pressure in the refrigeration cycle (the pressure of the refrigerant flowing through the intermediate refrigerant tube 8 in this case).

[0101] In cases in which the configuration has a plurality of usage-side heat exchangers 6 connected to each other in parallel with the objective of performing air cooling and/or air warming corresponding to air-conditioning loads for a plurality of air-conditioned spaces, and a configuration is used which is provided with usage-side expansion mechanisms 5c between the receiver 18 and the usage-side heat exchangers 6 so as to correspond to each of the usage-side heat exchangers 6 in order to make it possible to control the flow rates of refrigerant flowing through each of the usage-side heat exchangers 6 and obtain the refrigeration loads required in each of the usage-side heat exchangers 6 as described above; during the air-cooling operation, the refrigerant depressurized by the first expansion mechanism 5a to a nearly saturated pressure and temporarily retained in the receiver 18 (refer to point L in FIG. 28) is distributed to each of the usage-side expansion mechanisms 5c, but if the refrigerant fed from the receiver 18 to each of the usage-side expansion mechanisms 5c is in a gas-liquid two-phase state, there is a risk of the flow being uneven when the refrigerant is distributed among the usage-side expansion mechanisms 5c, and it is therefore preferable that the refrigerant fed from the receiver 18 to each of the usage-side expansion mechanisms 5c is brought as much as possible to a subcooled state.

[0102] In view of this, in the present modification, the configuration of Modification 2 described above (see FIG. 18) is replaced by a refrigerant circuit 310 in which the first second-stage injection tube 18c is connected to the receiver 18 in order to allow the receiver 18 to function as a gas-liquid separator and enable intermediate pressure injection to be performed, intermediate pressure injection by the economizer heat exchanger 20 can be performed during the air-cooling operation, intermediate pressure injection by the receiver 18 as a gas-liquid separator can be performed during the air-warming operation, and a subcooling heat exchanger 96 as a cooler and a second intake return tube 95 are between the receiver

18 and the usage-side expansion mechanisms 5c, as shown in FIG. 28.

[0103] The second intake return tube 95 herein is a refrigerant tube for branching off the refrigerant fed from the heat source-side heat exchanger 4 as a radiator to the usage-side heat exchangers 6 and returning the refrigerant to the intake side of the compression mechanism 2 (i.e., the intake tube 2a). In the present modification, the second intake return tube 95 is provided so as to branch off the refrigerant fed from the receiver 18 to the usage-side expansion mechanisms 5c. More specifically, the second intake return tube 95 is provided so as to branch off the refrigerant from a position upstream of the subcooling heat exchanger 96 (i.e., between the receiver 18 and the subcooling heat exchanger 96) and return the refrigerant to the intake tube 2a. This second intake return tube 95 is provided with a second intake return valve 95a whose opening degree can be controlled. The second intake return valve 95a is an electrically driven expansion valve in the present modification.

[0104] The subcooling heat exchanger 96 is a heat exchanger for performing heat exchange between the refrigerant fed from the heat source-side heat exchanger 4 as a radiator to the usage-side heat exchangers 6 as evaporators and the refrigerant flowing through the second intake return tube 95 (more specifically, the refrigerant that has been depressurized in the second intake return valve 95a to a nearly low pressure). In the present modification, the subcooling heat exchanger 96 is provided so as to perform heat exchange between the refrigerant flowing through a position upstream of the usage-side expansion mechanisms 5c (i.e., between the position where the second intake return tube 95 branches off and the usage-side expansion mechanisms 5c) and the refrigerant flowing through the second intake return tube 95. In the present modification, the subcooling heat exchanger 96 is provided farther downstream than the position where the second intake return tube 95 branches off. Therefore, the refrigerant cooled in the heat source-side heat exchanger 4 as a radiator is branched off to the second intake return tube 95 after passing through the economizer heat exchanger 20 as a cooler, and in the subcooling heat exchanger 96, heat exchange is performed with the refrigerant flowing through the second intake return tube 95.

[0105] The first second-stage injection tube 18c and the first intake return tube 18f are integrated in the portion near the receiver 18, similar to the embodiment described above. The first second-stage injection tube 18c and the second second-stage injection tube 19 are integrated in the portion near the intermediate refrigerant tube 8. The first intake return tube 18f and the second intake return tube 95 are integrated in the portion on the intake side of the compression mechanism 2. In the present modification, the usage-side expansion mechanisms 5c are electrically driven expansion valves. In the present modification, since the second second-stage injection tube 19 and the economizer heat exchanger 20 are used dur-

ing the air-cooling operation, and on the other hand the first second-stage injection tube 18c is used during the air-warming operation as described above, there is no need for the direction of refrigerant flow to the economizer heat exchanger 20 to be constant during both the air-cooling operation and the air-warming operation, and the bridge circuit 17 can therefore be omitted to simplify the configuration of the refrigerant circuit 310.

[0106] The outlet of the subcooling heat exchanger 96 on the side near the second intake return tube 95 is provided with a subcooling heat exchange outlet temperature sensor 59 for detecting the temperature of the refrigerant in the outlet of the subcooling heat exchanger 96 on the side near the second intake return tube 95.

[0107] Next, the action of the air-conditioning apparatus 1 will be described using FIGS. 3, 4, 16, 17 and 28 through 37. FIG. 29 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-cooling operation, FIG. 30 is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, FIG. 31 is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation, FIG. 32 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 during the air-warming operation, FIG. 33 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 at the start of the defrosting operation, FIG. 34 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 in the defrosting operation after defrosting of the intermediate heat exchanger 7 is complete, FIG. 35 is a diagram showing the flow of refrigerant within the air-conditioning apparatus 1 in the defrosting operation after defrosting of the intermediate heat exchanger 7 and utilization of the stored heat have concluded, FIG. 36 is a pressure-enthalpy graph representing the refrigeration cycle during the defrosting operation, and FIG. 37 is a temperature-entropy graph representing the refrigeration cycle during the defrosting operation. Operation control in the air-cooling operation, the air-warming operation, and the defrosting operation described hereinbelow is performed by the aforementioned controller (not shown) in the present embodiment. In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', E, H, I, R in FIGS. 30, 31, 16, 17, 36, and 37, and the pressure at points D, D', and E in FIGS. 3 and 4), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A, F, S, U, and W in FIGS. 30, 31, 16, 17, 36, and 37, and the pressure at points A and F in FIGS. 3 and 4), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B, C, C', G, G', J, and K in FIGS. 30, 31, 16, 17, 36, and 37, and the pressure at points B, C, C', G, G', I, L, and M in FIGS. 3 and 4).

<Air-cooling operation>

[0108] During the air-cooling operation, the switching mechanism 3 is brought to the cooling operation state shown by the solid lines in FIGS. 28 and 29. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. Since the switching mechanism 3 is in the cooling operation state, the intermediate heat exchanger on/off valve 12 of the intermediate refrigerant tube 8 is opened and the intermediate heat exchanger bypass on/off valve 11 of the intermediate heat exchanger bypass tube 9 is closed, thereby creating a state in which the intermediate heat exchanger 7 functions as a cooler. When the switching mechanism 3 is brought to the cooling operation state, intermediate pressure injection by the receiver 18 as a gas-liquid separator is not performed, but intermediate pressure injection is performed by the economizer heat exchanger 20 which returns to the second-stage compression element 2d the refrigerant that has been passed through the second second-stage injection tube 19 and heated in the economizer heat exchanger 20. More specifically, the first second-stage injection on/off valve 18d is closed, and the opening degree of the second second-stage injection valve 19a is adjusted in the same manner as in Modification 2 described above. Furthermore, when the switching mechanism 3 is in the cooling operation state, the opening degree of the second intake return valve 95a is adjusted as well because the subcooling heat exchanger 96 is used. More specifically, in the present modification, so-called superheat degree control is performed wherein the opening degree of the second intake return valve 95a is adjusted so that a target value is achieved in the degree of superheat of the refrigerant at the outlet in the second intake return tube 95 side of the subcooling heat exchanger 96. In the present modification, the degree of superheat of the refrigerant at the outlet in the second intake return tube 95 side of the subcooling heat exchanger 96 is obtained by converting the low pressure detected by the intake pressure sensor 60 to a saturation temperature and subtracting this refrigerant saturation temperature value from the refrigerant temperature detected by the subcooling heat exchanger outlet temperature sensor 59. Though not used in the present modification, another possible option is to provide a temperature sensor to the inlet in the second intake return tube 95 side of the subcooling heat exchanger 96, and to obtain the degree of superheat of the refrigerant at the outlet in the second intake return tube 95 side of the subcooling heat exchanger 96 by subtracting the refrigerant temperature detected by this temperature sensor from the refrigerant temperature detected by the subcooling heat exchanger outlet temperature sensor 59. Adjusting the opening degree of the second intake return valve 95a is not limited to the superheat degree control, and the second intake return valve 95a may be opened to a predetermined opening degree in accordance with the flow rate of refrigerant circulating within the refrigerant

circuit 310, for example.

[0109] When the refrigerant circuit 310 is in this state, low-pressure refrigerant (refer to point A in FIGS. 28 through 31) 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 A in FIGS. 28 through 31). The intermediate-pressure refrigerant discharged from the first-stage compression element 2c is cooled in the intermediate heat exchanger 7 by undergoing heat exchange with the air as a cooling source supplied by the heat source-side fan 40 (refer to point C in FIGS. 28 through 31). The refrigerant cooled in the intermediate heat exchanger 7 is further cooled (refer to point G in FIGS. 28 through 31) by being mixed with refrigerant being returned from the second second-stage injection tube 19 to the second-stage compression element 2d (refer to point K in FIGS. 28 through 31). Next, having been mixed with the refrigerant returning from the second second-stage injection tube 19 (i.e., intermediate pressure injection is carried out by the economizer heat exchanger 20), the intermediate-pressure refrigerant is drawn into and further compressed in the compression element 2d connected to the second-stage side of the compression mechanism 2, and the refrigerant is discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 28 through 31). 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. 30). 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 drawn once more 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 the switching mechanism 3, and is fed to the heat source-side heat exchanger 4 functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger 4 is cooled in the heat source-side heat exchanger 4 by heat exchange with air as a cooling source supplied by the heat source-side fan 40 (refer to point E in FIGS. 28 through 31). Some of the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 is then branched off to the second second-stage injection tube 19. The refrigerant flowing through the second second-stage injection

tube 19 is depressurized to a nearly intermediate pressure in the second second-stage injection valve 19a and is then fed to the economizer heat exchanger 20 (refer to point J in FIGS. 28 through 31). The refrigerant after being branched off to the second second-stage injection tube 19 then flows into the economizer heat exchanger 20, where it is cooled by heat exchange with the refrigerant flowing through the second second-stage injection tube 19 (refer to point H in FIGS. 28 through 31). The refrigerant flowing through the second second-stage injection tube 19 is heated by heat exchange with the high-pressure refrigerant cooled in the heat source-side heat exchanger 4 as a radiator (refer to point K in FIGS. 28 through 31), and 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 first expansion mechanism 5a and is temporarily retained in the receiver 18 (refer to point I in FIGS. 28 through 31). Some of the refrigerant retained in the receiver 18 is then branched off to the second intake return tube 95. The refrigerant flowing through the second intake return tube 95 is depressurized to a nearly low pressure in the second intake return valve 95a and is then fed to the subcooling heat exchanger 96 (refer to point S in FIGS. 28 through 31). The refrigerant branched off into the second intake return tube 95 then flows into the subcooling heat exchanger 96, where it is further cooled by heat exchange with the refrigerant flowing through the second intake return tube 95 (refer to point R in FIGS. 28 through 31). The refrigerant flowing through the second intake return tube 95 is heated by heat exchange with the high-pressure refrigerant cooled in the economizer heat exchanger 20 (refer to point U in FIGS. 28 through 31), and is mixed with the refrigerant flowing through the intake side of the compression mechanism 2 (here, the intake tube 2a). The refrigerant cooled in the subcooling heat exchanger 96 is then fed to the usage-side expansion mechanisms 5c and depressurized by the usage-side expansion mechanisms 5c to become a low-pressure gas-liquid two-phase refrigerant, and is then fed to the usage-side heat exchangers 6 functioning as evaporators of refrigerant (refer to point F in FIGS. 28 through 31). 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 W in FIGS. 28 through 31). The low-pressure refrigerant heated in the usage-side heat exchanger 6 is then drawn once more into the compression mechanism 2 via the switching mechanism 3 (refer to point A in FIGS. 28 through 31). In this manner the air-cooling operation is performed.

[0110] Thus, in the air-conditioning apparatus 1 of the present modification, in addition to the intermediate heat exchanger 7 being made to function as a cooler similar to the air-cooling operation in Modification 2 described above, the second second-stage injection tube 19 and

the economizer heat exchanger 20 are provided to ensure that the refrigerant whose heat has been radiated in the heat source-side heat exchanger 4 is branched off and returned to the second-stage compression element 2d, and the temperature of the refrigerant drawn into the second-stage compression element 2d can therefore be kept even lower without radiating heat to the exterior, similar to Modification 2 described above. Thereby, the temperature of the refrigerant discharged from the compression mechanism 2 is kept low, and the power consumption of the compression mechanism 2 can be further reduced and operating efficiency further improved in comparison with cases in which the second second-stage injection tube 19 and the economizer heat exchanger 20 are not provided, because heat radiation loss can be further reduced.

[0111] Moreover, in the present modification, since the refrigerant fed from the receiver 18 to the usage-side expansion mechanisms 5c (refer to point I in FIGS. 28 through 31) can be cooled by the subcooling heat exchanger 96 to a subcooled state (refer to point R in FIGS. 30 and 31), it is possible to reduce the risk of the flows being uneven when the refrigerant is distributed to each of the usage-side expansion mechanisms 5c.

<Air-warming operation>

[0112] During the air-warming operation, the switching mechanism 3 is brought to the heating operation state shown by the dashed lines in FIGS. 28 and 32. The opening degrees of the first expansion mechanism 5a and the second expansion mechanism 5b are adjusted. Since the switching mechanism 3 is in the heating operation state, the intermediate heat exchanger on/off valve 12 of the intermediate refrigerant tube 8 is closed and the intermediate heat exchanger bypass on/off valve 11 of the intermediate heat exchanger bypass tube 9 is opened, thereby creating a state in which the intermediate heat exchanger 7 does not function as a cooler. When the switching mechanism 3 is brought to the heating operation state, intermediate pressure injection by the economizer heat exchanger 20 is not performed, but intermediate pressure injection is performed by the receiver 18 whereby the refrigerant is passed through the first second-stage injection tube 18c and returned from the receiver 18 as a gas-liquid separator to the second-stage compression element 2d. More specifically, the first second-stage injection on/off valve 18d is brought to an opened state and the second second-stage injection valve 19a is brought to a fully closed state. Furthermore, when the switching mechanism 3 is brought to the heating operation state, the second intake return valve 95a is also brought to the fully closed state because the subcooling heat exchanger 96 is not used.

[0113] When the refrigerant circuit 310 is in this state, low-pressure refrigerant (refer to point A in FIGS. 28, 32, 3, and 4) 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 B in FIGS. 28, 32, 3, and 4). This intermediate-pressure refrigerant discharged from the first-stage compression element 2c passes through the intermediate heat exchanger bypass tube 9 (refer to point C' in FIGS. 28 and 32) without passing through the intermediate heat exchanger 7 (i.e., without being cooled), similar to the air-warming operation in Modification 2 described above. This intermediate-pressure refrigerant that has passed through the intermediate heat exchanger bypass tube 9 without being cooled by the intermediate heat exchanger 7 is cooled (refer to point G in FIGS. 28, 32, 3, and 4) by mixing with the refrigerant returned from the receiver 18 through the first second-stage injection tube 18c to the second-stage compression element 2d (refer to point M in FIGS. 28, 32, 3, and 4). Next, having been mixed with the refrigerant returning from the first second-stage injection tube 18c (i.e., intermediate pressure injection is carried out by the receiver 18 which acts as a gas-liquid separator), the intermediate-pressure refrigerant is 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 discharged from the compression mechanism 2 to the discharge tube 2b (refer to point D in FIGS. 28, 32, 3, and 4). 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. 3), similar to the air-cooling operation. 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 41 a flows into the oil return tube 41 b constituting the oil separation mechanism 41 wherein it is depressurized by the depressurization mechanism 41 provided to the oil return tube 41b, and the oil is then returned to the intake tube 2a of the compression mechanism 2 and drawn once more into the compression mechanism 2. Next, after the refrigeration oil has been separated in the oil separation mechanism 41, the high-pressure refrigerant is fed through the non-return mechanism 42 and the switching mechanism 3 to the usage-side heat exchangers 6 functioning as radiators of refrigerant, and the refrigerant is cooled by heat exchange with the water and/or air as a cooling source (refer to point F in FIGS. 28 and 32, and read point E as point F in FIGS. 3 and 4). After the high-pressure refrigerant cooled in the usage-side heat exchangers 6 is then depressurized to a nearly intermediate pressure by the usage-side expansion mechanisms 5c, the refrigerant is temporarily retained in the receiver 18 and subjected to gas-liquid separation (refer to points I, L, and M in FIGS. 28, 32, 3, and 4). The gas

refrigerant that has undergone gas-liquid separation in the receiver 18 is then extracted out from the top part of the receiver 18 by the first second-stage injection tube 18c and mixed with the intermediate-pressure refrigerant discharged from the first-stage compression element 2c as described above. The liquid refrigerant retained in the receiver 18 is then depressurized by the first expansion mechanism 5a into a low-pressure gas-liquid two-phase refrigerant, which is fed to the heat source-side heat exchanger 4 functioning as an evaporator of refrigerant (refer to point E in FIGS. 28 and 32, and read point F as point E in FIGS. 3 and 4). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger 4 is then heated and evaporated in the heat source-side heat exchanger 4 by heat exchange with the air as a heat source supplied by the heat source-side fan 40 (refer to point A in FIGS. 28, 32, 3, and 4). The low-pressure refrigerant heated and evaporated in the heat source-side heat exchanger 4 is then drawn once more into the compression mechanism 2 via the switching mechanism 3. In this manner the air-warming operation is performed.

[0114] Thus, in the air-conditioning apparatus 1 of the present modification, the intermediate heat exchanger 7 is brought to a state of not functioning as a cooler similar to the air-warming operation in Modification 2 described above, and the first second-stage injection tube 18c is provided to branch off the refrigerant whose heat has been radiated in the heat source-side heat exchanger 4 and return the refrigerant to the second-stage compression element 2d, similar to the air-warming operation in the embodiment described above; therefore, the temperature of the refrigerant drawn into the second-stage compression element 2d can be kept lower without heat being radiated to the exterior, similar to the embodiment described above. Thereby, although the temperature of the refrigerant discharged from the compression mechanism 2 decreases and the heating capacity per unit flow rate of the refrigerant in the usage-side heat exchangers 6 decreases, the flow rate of the refrigerant discharged from the second-stage compression element 2d increases, the decrease in the heating capacity of the usage-side heat exchangers 6 is therefore minimized, and as a result, the power consumption of the compression mechanism 2 can be reduced and operating efficiency can be improved.

<Defrosting operation>

[0115] In the present modification, the second intake return tube 95 and the subcooling heat exchanger 96 are provided so that refrigerant fed from the receiver 18 to the usage-side expansion mechanisms 5c during the air-cooling operation can be cooled to a subcooled state. Therefore, in step S2 shown in FIG. 6, when a state of using the subcooling heat exchanger 96 is created, some of the refrigerant fed from the receiver 18 to the usage-side heat exchangers 6 returns to the compression mech-

anism 2 through the second intake return tube 95 without passing through the refrigerant tube 1d or the like between the usage-side heat exchangers 6 and the switching mechanism 3, which is not preferable in terms of utilizing the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchangers 6 and the switching mechanism 3.

[0116] In view of this, in the present modification, in step S2 shown in FIG. 6, intermediate pressure injection is not used (herein, refrigerant is prevented from returning to the second-stage compression element 2d through the first second-stage injection tube 18c and the second second-stage injection tube 19), a state is created in which the intermediate heat exchanger 7 is made to function as a cooler by opening the intermediate heat exchanger on/off valve 12 and closing the intermediate heat exchanger bypass on/off valve 11, similar to the air-cooling operation described above, the switching mechanism 3 is switched from the heating operation state to the cooling operation state, the subcooling heat exchanger 96 is also not used (that is, the second intake return valve 95a is shut off and refrigerant is prevented from returning to the second-stage compression element 2d through the second intake return tube 95), and the reverse cycle defrosting operation is performed (refer to the refrigeration cycle shown by the solid lines in FIGS. 33, 34, 36, and 37).

[0117] Thereby, in the refrigerant circuit 310, the second intake return tube 95 and the subcooling heat exchanger 96 no longer pose a hindrance to utilizing the heat stored in the refrigerant tube 1d or the like between the usage-side heat exchangers 6 and the switching mechanism 3.

[0118] In the present modification, intermediate pressure injection by the economizer heat exchanger 20 and intermediate pressure injection by the receiver 18 as a gas-liquid separator are used according to the characteristics in the air-cooling operation and the air-warming operation. Therefore, in step S5 shown in FIG. 6, either intermediate pressure injection by the economizer heat exchanger 20 or intermediate pressure injection by the receiver 18 as a gas-liquid separator can be used.

[0119] In view of this, in the present modification, taking into account the possibility of controlling the opening degree of the second second-stage injection valve 19a, a state of using intermediate pressure injection by the economizer heat exchanger 20 is created (that is, refrigerant is returned to the second-stage compression element 2d through the second second-stage injection tube 19), similar to Modifications 1 and 2 described above, the flow rate of the refrigerant flowing through the usage-side heat exchangers 6 is further reduced, and the flow rate of the refrigerant flowing through the heat source-side heat exchanger 4 is further increased (refer to the refrigeration cycle shown by the dashed lines in FIGS. 35, 36, and 37). Moreover, in the present modification, since some of the refrigerant fed from the receiver 18 to the usage-side heat exchangers 6 can be returned to the compression mechanism 2 through the second intake

return tube 95 without passing through the refrigerant tube 1d or the like between the usage-side heat exchangers 6 and the switching mechanism 3 by creating a state in which the subcooling heat exchanger 96 is used as described above, this fact can be used to create a state in which intermediate pressure injection by the economizer heat exchanger 20 is used, to create a state in which the subcooling heat exchanger 96 is used, and also to reduce the flow rate of the refrigerant flowing through the usage-side heat exchangers 6 and further minimize the temperature decrease on the usage side in step S5 shown in FIG. 6 (refer to the refrigeration cycle shown by the dashed lines in FIGS. 35, 36, and 37).

[0120] Thus, in the present modification, the same effects as those of the defrosting operation of Modification 2 described above are achieved, it is possible to promote utilization of the stored heat in the refrigerant tube 1d or the like between the usage-side heat exchangers 6 and the switching mechanism 3 and to minimize the temperature decrease on the usage side by appropriately switching the second intake return tube 95 and the subcooling heat exchanger 96 between use and non-use, and taking into account the fact that the opening degree of the second second-stage injection valve 19a can be controlled, a state of using intermediate pressure injection by the economizer heat exchanger 20 can be created to effectively minimize the temperature decrease on the usage side when the reverse cycle defrosting operation is performed during a state of using intermediate pressure injection.

[0121] The other steps S1, S3, S4, S6, and S7 of the defrosting operation in the present modification are similar to those of the defrosting operation in Modification 2 described above, and are therefore not described herein.

(6) Modification 4

[0122] In the above-described embodiment and the modifications thereof, a two-stage compression-type compression mechanism 2 is configured such that the refrigerant discharged from the first-stage compression element of two compression elements 2c, 2d is sequentially compressed in the second-stage compression element by one compressor 21 having a single-axis two-stage compression structure, but other options include using a compression mechanism having more stages than a two-stage compression system, such as a three-stage compression system or the like; or configuring a multistage compression mechanism by connecting in series a plurality of compressors incorporated with a single compression element and/or compressors incorporated with a plurality of compression elements. In cases in which the capacity of the compression mechanism must be increased, such as cases in which numerous usage-side heat exchangers 6 are connected, for example, a parallel multistage compression-type compression mechanism may be used in which two or more multistage compression-type compression mechanisms are con-

nected in parallel.

[0123] For example, the refrigerant circuit 310 in Modification 3 described above (see FIG. 28) may be replaced by a refrigerant circuit 410 that uses a compression mechanism 102 in which two-stage compression-type compression mechanisms 103, 104 are connected in parallel instead of the two-stage compression-type compression mechanism 2, as shown in FIG. 38.

[0124] In the present modification, the first compression mechanism 103 is configured using a compressor 29 for subjecting the refrigerant to two-stage compression through two compression elements 103c, 103d, and is connected to a first intake branch tube 103a which branches off from an intake header tube 102a of the compression mechanism 102, and also to a first discharge branch tube 103b whose flow merges with a discharge header tube 102b of the compression mechanism 102. In the present modification, the second compression mechanism 104 is configured using a compressor 30 for subjecting the refrigerant to two-stage compression through two compression elements 104c, 104d, and is connected to a second intake branch tube 104a which branches off from the intake header tube 102a of the compression mechanism 102, and also to a second discharge branch tube 104b whose flow merges with the discharge header tube 102b of the compression mechanism 102. Since the compressors 29, 30 have the same configuration as the compressor 21 in the embodiment and modifications thereof described above, symbols indicating components other than the compression elements 103c, 103d, 104c, 104d are replaced with symbols beginning with 29 or 30, and these components are not described. The compressor 29 is configured so that refrigerant is drawn from the first intake branch tube 103a, the drawn refrigerant is compressed by the compression element 103c and then discharged to a first inlet-side intermediate branch tube 81 that constitutes the intermediate refrigerant tube 8, the refrigerant discharged to the first inlet-side intermediate branch tube 81 is caused to be drawn into the compression element 103d by way of an intermediate header tube 82 and a first outlet-side intermediate branch tube 83 constituting the intermediate refrigerant tube 8, and the refrigerant is further compressed and then discharged to the first discharge branch tube 103b. The compressor 30 is configured so that refrigerant is drawn through the second intake branch tube 104a, the drawn refrigerant, is compressed by the compression element 104c 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 into the compression element 104d via the intermediate header tube 82 and a second outlet-side intermediate branch tube 85 constituting the intermediate refrigerant tube 8, and the refrigerant is further compressed and then discharged to the second discharge branch tube 104b. In the present modification, the intermediate refrigerant tube 8 is a refrigerant tube for drawing

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

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

[0125] Thus, in the present modification, the compression mechanism 102 is configured by connecting two compression mechanisms in parallel; namely, the first compression mechanism 103 having two compression elements 103c, 103d and configured so that refrigerant discharged from the first-stage compression element of these compression elements 103c, 103d is sequentially compressed by the second-stage compression element, and the second compression mechanism 104 having two compression elements 104c, 104d and configured so that refrigerant discharged from the first-stage compression element of these compression elements 104c, 104d is

sequentially compressed by the second-stage compression element.

[0126] In the present modification, the intermediate heat exchanger 7 is provided to the intermediate header tube 82 constituting the intermediate refrigerant tube 8, and the intermediate heat exchanger 7 is a heat exchanger for cooling the conjoined flow of the refrigerant discharged from the first-stage compression element 103c of the first compression mechanism 103 and the refrigerant discharged from the first-stage compression element 104c of the second compression mechanism 104 during the air-cooling operation. Specifically, the intermediate heat exchanger 7 functions as a shared cooler for two compression mechanisms 103, 104 during air-cooling operation. Accordingly, the circuit configuration is simplified around the compression mechanism 102 when the intermediate heat exchanger 7 is provided to the parallel-multistage-compression-type compression mechanism 102 in which a plurality of multistage-compression-type compression mechanisms 103, 104 are connected in parallel.

[0127] The first inlet-side intermediate branch tube 81 constituting the intermediate refrigerant tube 8 is provided with a non-return mechanism 81a for allowing the flow of refrigerant from the discharge side of the first-stage compression element 103c of the first compression mechanism 103 toward the intermediate header tube 82 and for blocking the flow of refrigerant from the intermediate header tube 82 toward the discharge side of the first-stage compression element 103c, while the second inlet-side intermediate branch tube 84 constituting the intermediate refrigerant tube 8 is provided with a non-return mechanism 84a for allowing the flow of refrigerant from the discharge side of the first-stage compression element 104c of the second compression mechanism 103 toward the intermediate header tube 82 and for blocking the flow of refrigerant from the intermediate header tube 82 toward the discharge side of the first-stage compression element 104c. 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 103, 104 is stopped, there are no instances in which refrigerant discharged from the first-stage compression element of the operating compression mechanism passes through the intermediate refrigerant tube 8 and travels to the discharge side of the first-stage compression element of the stopped compression mechanism. Therefore, there are no instances in which refrigerant discharged from the first-stage compression element of the operating compression mechanism passes through the interior of the first-stage compression element of the stopped compression mechanism and exits out through the intake side of the compression mechanism 102, which would cause the refrigeration oil of the stopped compression mechanism to flow out, and it is thus unlikely that there will be insufficient refrigeration oil for starting up the stopped compression mechanism. In the case that the compression mecha-

nisms 103, 104 are operated in order of priority (for example, in the case of a compression mechanism in which priority is given to operating the first compression mechanism 103), the stopped compression mechanism described above will always be the second compression mechanism 104, and therefore in this case only the non-return mechanism 84a corresponding to the second compression mechanism 104 need be provided.

[0128] In cases of a compression mechanism which prioritizes operating the first compression mechanism 103 as described above, since a shared intermediate refrigerant tube 8 is provided for both compression mechanisms 103, 104, the refrigerant discharged from the first-stage compression element 103c corresponding to the operating first compression mechanism 103 passes through the second outlet-side intermediate branch tube 85 of the intermediate refrigerant tube 8 and travels to the intake side of the second-stage compression element 104d of the stopped second compression mechanism 104, whereby there is a danger that refrigerant discharged from the first-stage compression element 103c of the operating first compression mechanism 103 will pass through the interior of the second-stage compression element 104d of the stopped second compression mechanism 104 and exit out through the discharge side of the compression mechanism 102, causing the refrigeration oil of the stopped second compression mechanism 104 to flow out, resulting in insufficient refrigeration oil for starting up the stopped second compression mechanism 104. In view of this, an on/off valve 85a is provided to the second outlet-side intermediate branch tube 85 in the present modification, and when the second compression mechanism 104 is stopped, the flow of refrigerant through the second outlet-side intermediate branch tube 85 is blocked by the on/off valve 85a. The refrigerant discharged from the first-stage compression element 103c of the operating first compression mechanism 103 thereby no longer passes through the second outlet-side intermediate branch tube 85 of the intermediate refrigerant tube 8 and travels to the intake side of the second-stage compression element 104d of the stopped second compression mechanism 104; therefore, there are no longer any instances in which the refrigerant discharged from the first-stage compression element 103c of the operating first compression mechanism 103 passes through the interior of the second-stage compression element 104d of the stopped second compression mechanism 104 and exits out through the discharge side of the compression mechanism 102 which causes the refrigeration oil of the stopped second compression mechanism 104 to flow out, and it is thereby made even more unlikely that there will be insufficient refrigeration oil for starting up the stopped second compression mechanism 104. An electromagnetic valve is used as the on/off valve 85a in the present modification.

[0129] In the case of a compression mechanism which prioritizes operating the first compression mechanism 103, the second compression mechanism 104 is started

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

electromagnetic valve is used as the on/off valve 86a in the present modification.

[0130] The actions of the air-cooling operation, air-warming operation, and/or defrosting operation of the air-conditioning apparatus 1 of the present modification are not described herein because they are essentially the same as the actions in Modification 3 described above (FIGS. 3, 4, 16, 17, 28 through 37, and their relevant descriptions), except for the points of modification owing to the somewhat higher level of complexity of the circuit configuration surrounding the compression mechanism 102 due to the compression mechanism 102 being provided instead of the compression mechanism 2.

[0131] The same operational effects as those of Modification 3 described above can also be achieved with the configuration of the present modification.

(7) Other embodiments

[0132] Embodiments of the present invention and modifications thereof are described above with reference to the drawings; however, the specific configuration is not limited to these embodiments or their modifications, and can be changed within a range that does not deviate from the scope of the invention.

[0133] 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.

[0134] 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.

[0135] The refrigerant that operates in a supercritical range is not limited to carbon dioxide; ethylene, ethane, nitric oxide, and other gases may also be used.

INDUSTRIAL APPLICABILITY

[0136] If the present invention is used, when the reverse cycle defrosting operation is performed in a refrigeration apparatus which has a refrigerant circuit configured to be capable of switching between a cooling operation and a heating operation and which uses a refrigerant that operates in the supercritical range to perform a multistage compression-type refrigeration cycle, the temperature decrease on the usage side can be minimized, and the defrosting capacity can be improved.

REFERENCE SIGNS LIST

[0137]

5	1	Air-conditioning apparatus (refrigeration apparatus)
	2, 102	Compression mechanisms
10	3	Switching mechanism
	4	Heat source-side heat exchanger
	6	Usage-side heat exchanger
15	18c	First second-stage injection tube
	19	Second second-stage injection tube

Claims

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

a compression mechanism (2, 102) having a plurality of compression elements and configured so that refrigerant discharged from a first-stage compression element of the plurality of compression elements is sequentially compressed by a second-stage compression element;
 a heat source-side heat exchanger (4) which is a heat exchanger in which air is used as a heat source and which functions as a radiator or evaporator of refrigerant;
 a usage-side heat exchanger (6) which functions as a evaporator or radiator of refrigerant;
 a switching mechanism (3) for switching between a cooling operation state wherein the refrigerant is circulated through the compression mechanism, the heat source-side heat exchanger, and the usage-side heat exchanger, in a stated order; and a heating operation state wherein the refrigerant is circulated through the compression mechanism, the usage-side heat exchanger, and the heat source-side heat exchanger, in a stated order; and
 a second-stage injection tube (18c, 19) for branching off the refrigerant whose heat has been radiated in the heat source-side heat exchanger or the usage-side heat exchanger and returning the refrigerant to the second-stage compression element; wherein
 refrigerant is prevented from returning to the second-stage compression element through the second-stage injection tube, at least during the beginning of a reverse cycle defrosting opera-

tion for defrosting the heat source-side heat exchanger by switching the switching mechanism to the cooling operation state.

2. The refrigeration apparatus (1) according to claim 1, wherein the phrase "at least the beginning of the reverse cycle defrosting operation" refers to a time period from the start of the reverse cycle defrosting operation to the elapsing of a predetermined time duration set according to the length of a refrigerant tube between the usage-side heat exchanger (6) and the switching mechanism (3). 5 10
3. The refrigeration apparatus (1) according to claim 1, wherein the phrase "at least the beginning of the reverse cycle defrosting operation" refers to a time period from the start of the reverse cycle defrosting operation until the temperature of the refrigerant in the usage-side heat exchanger (6) decreases to a predetermined temperature or lower. 15 20
4. The refrigeration apparatus (1) according to claim 1, wherein the phrase "at least the beginning of the reverse cycle defrosting operation" refers to a time period from the start of the reverse cycle defrosting operation until the pressure of the refrigerant in the intake side of the compression mechanism (2, 102) decreases to a predetermined pressure or lower. 25
5. The refrigeration apparatus (1) according to any of claims 1 through 4, wherein the refrigerant that operates in the supercritical range is carbon dioxide. 30

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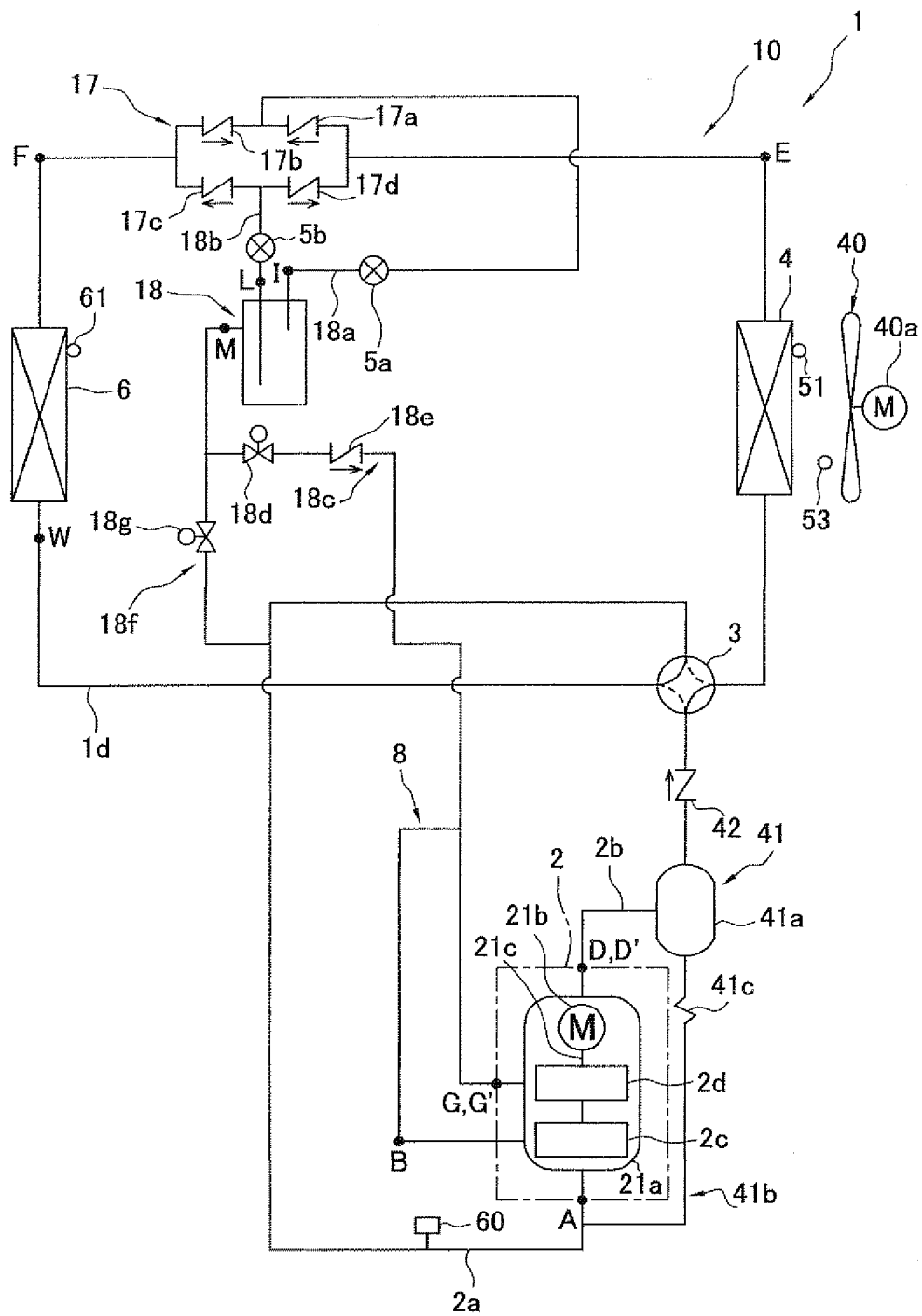


FIG. 1

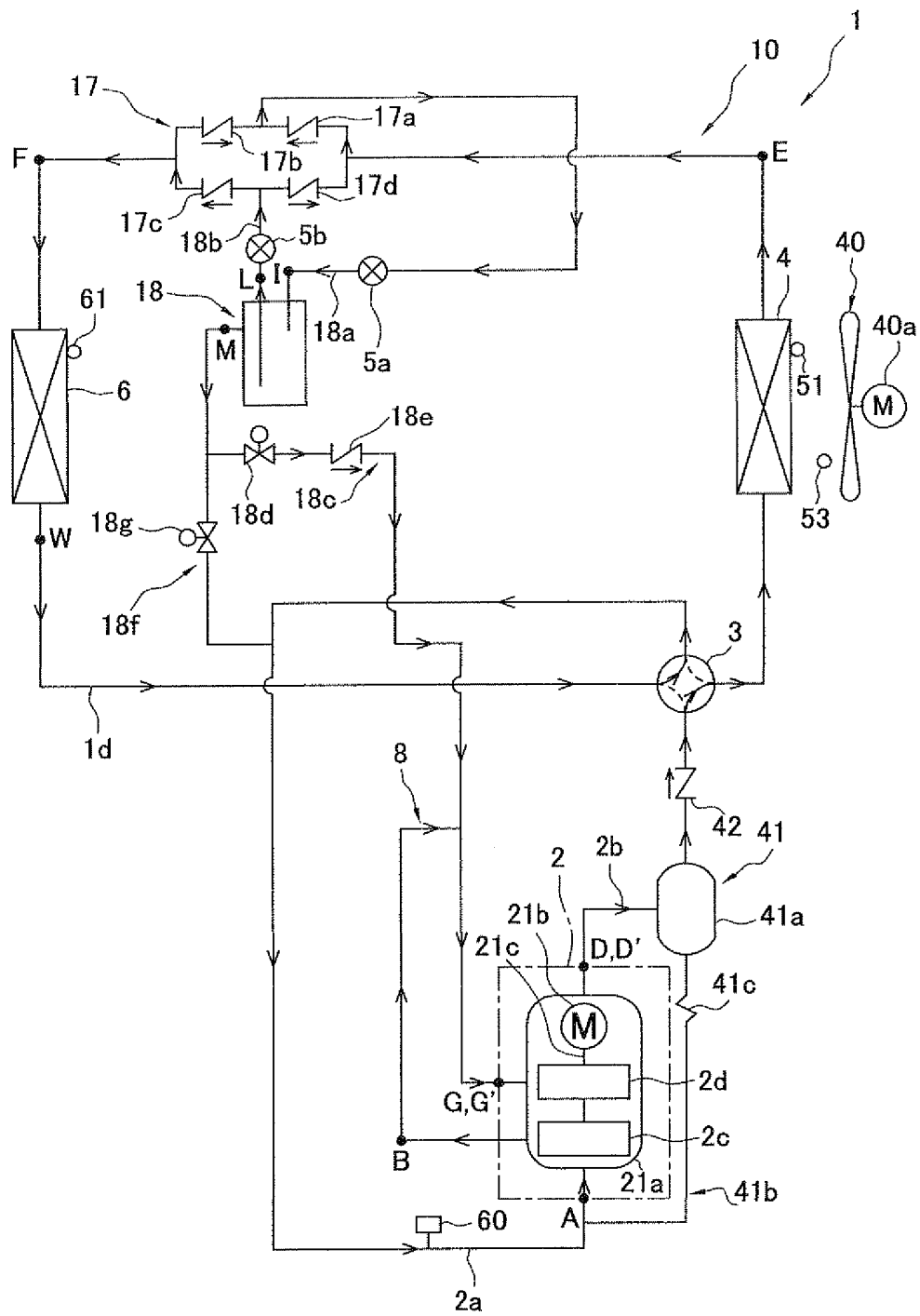


FIG. 2

FIG. 3

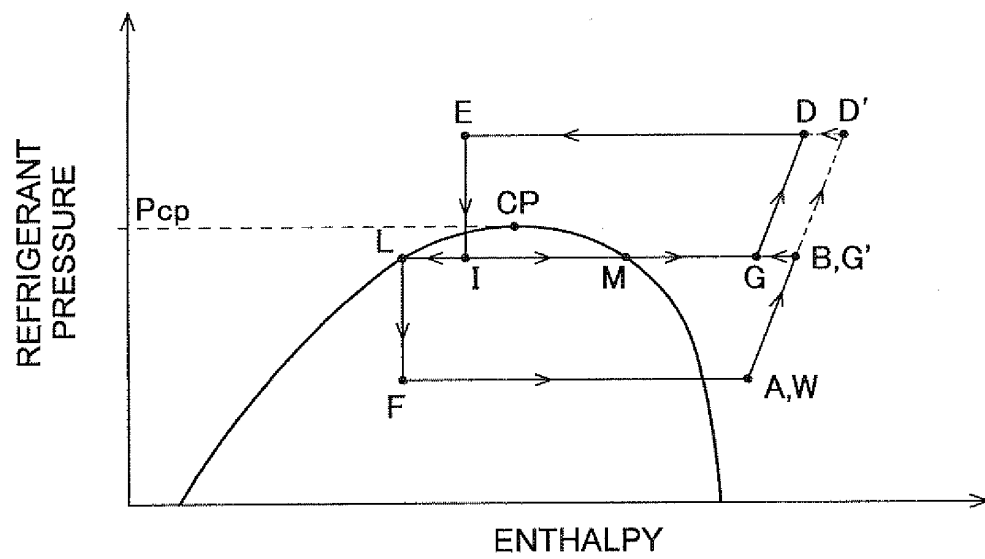
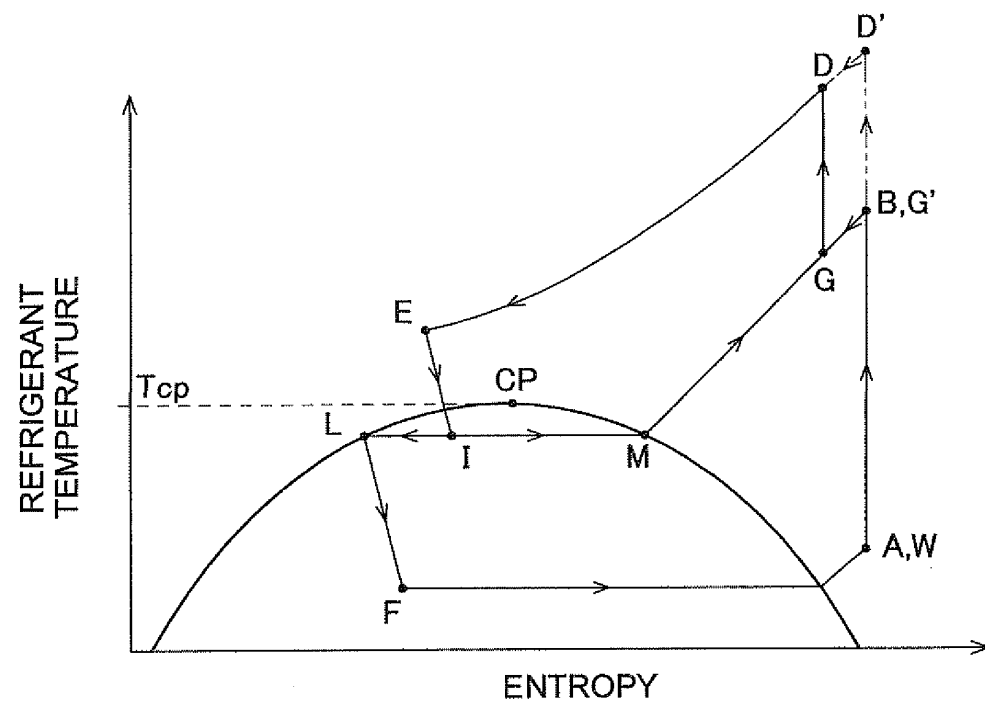


FIG. 4



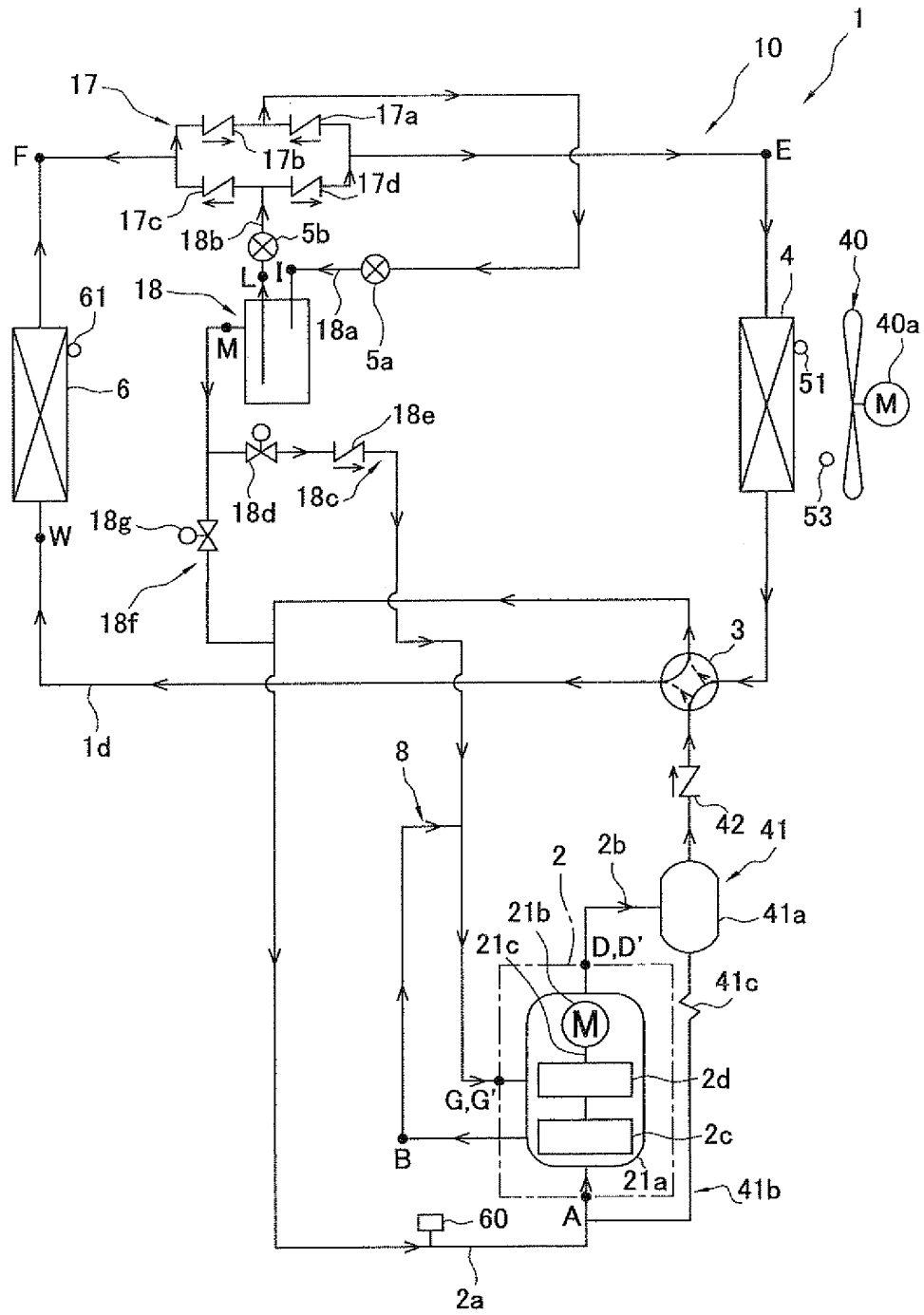


FIG. 5

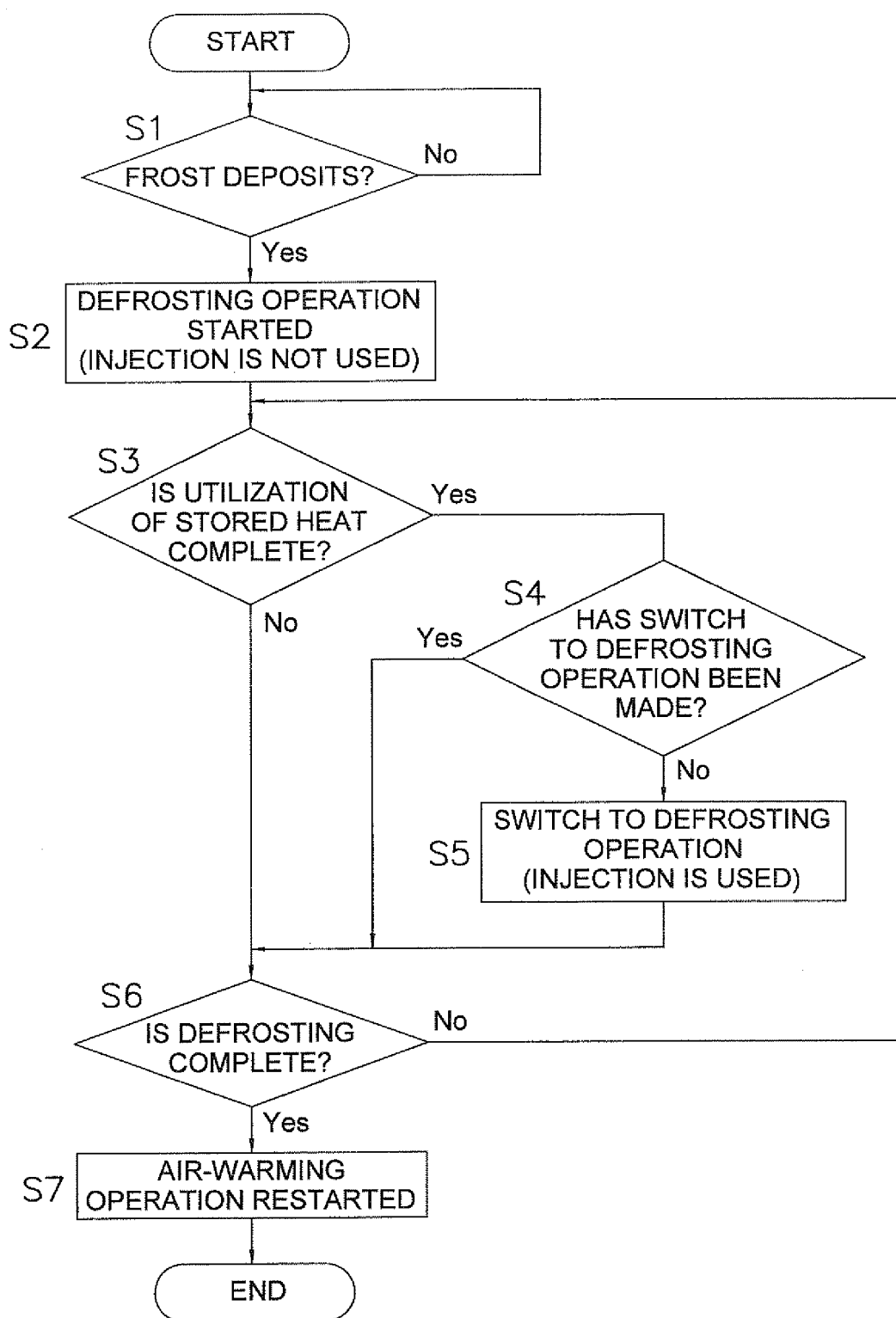


FIG. 6

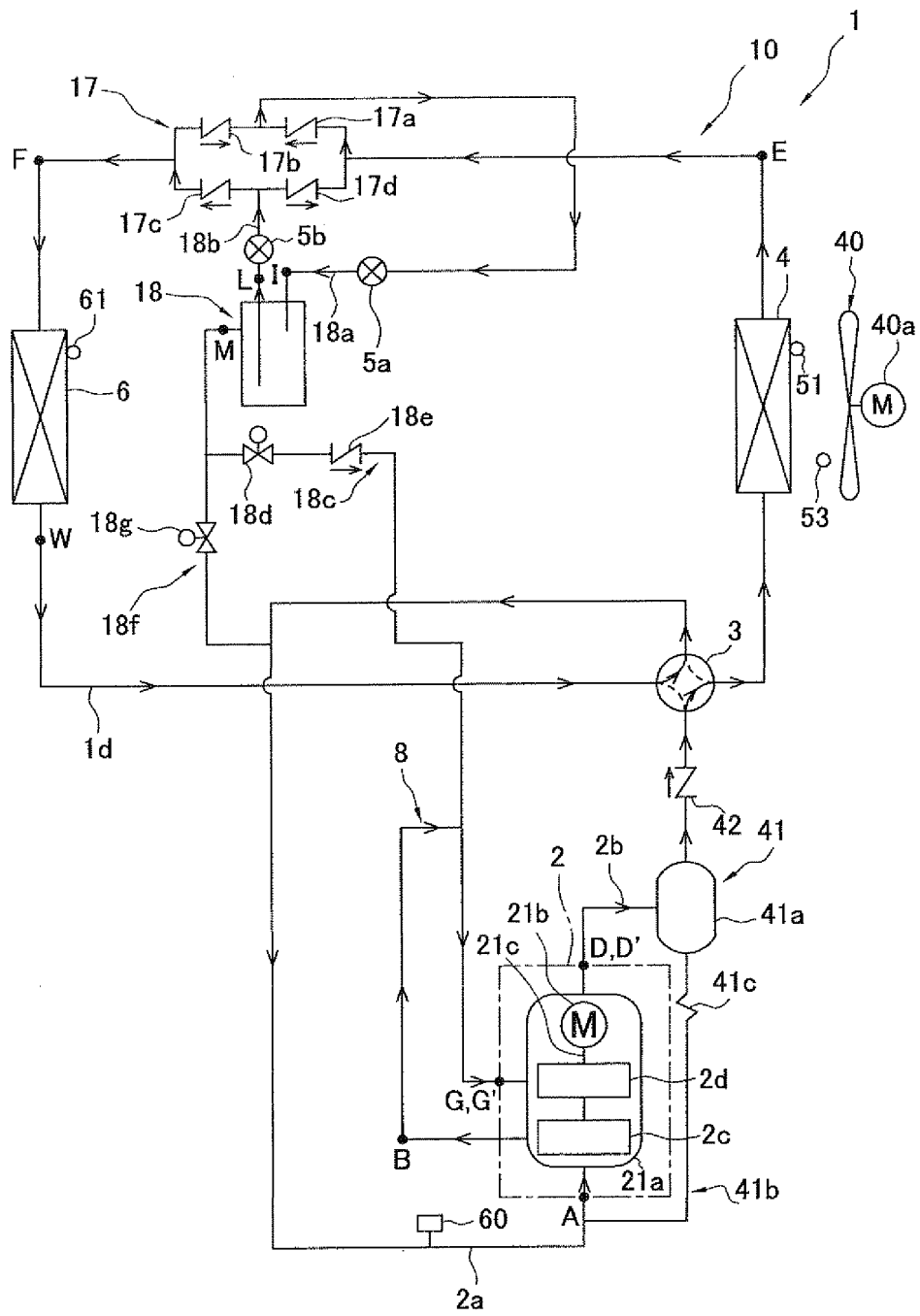


FIG. 7

FIG. 8

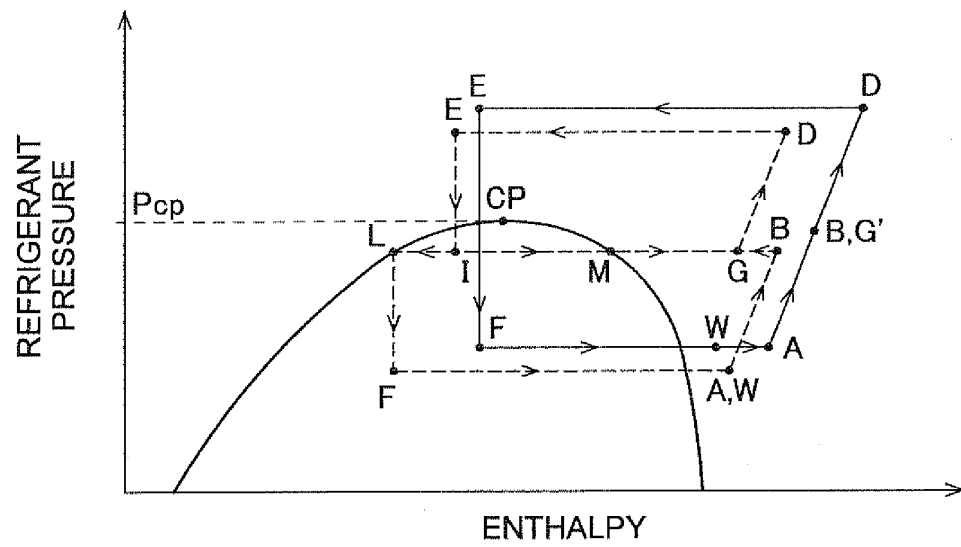
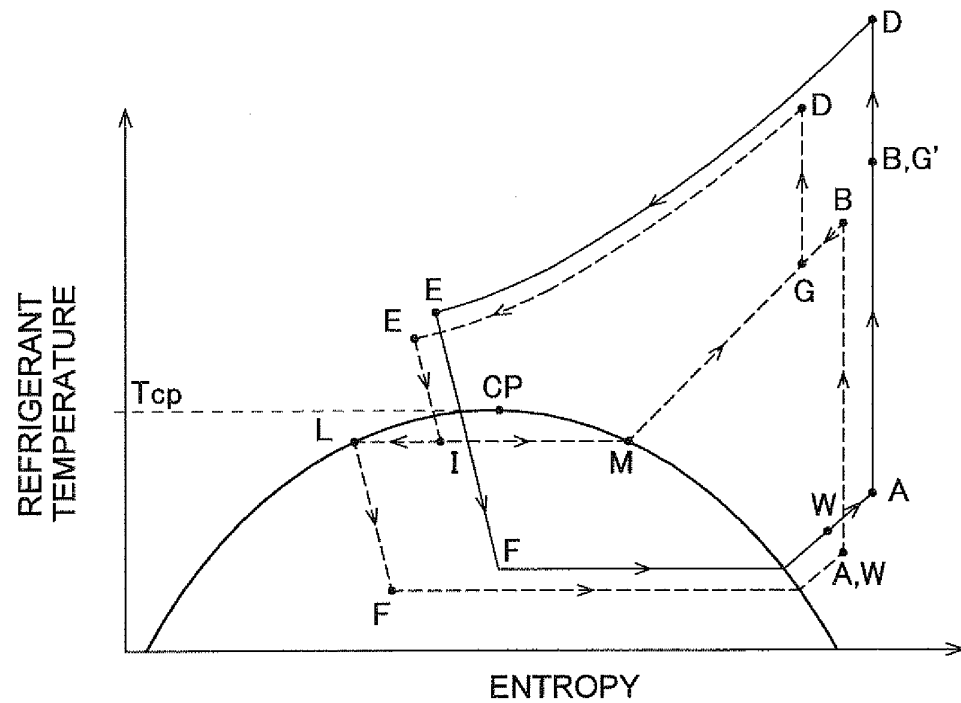


FIG. 9



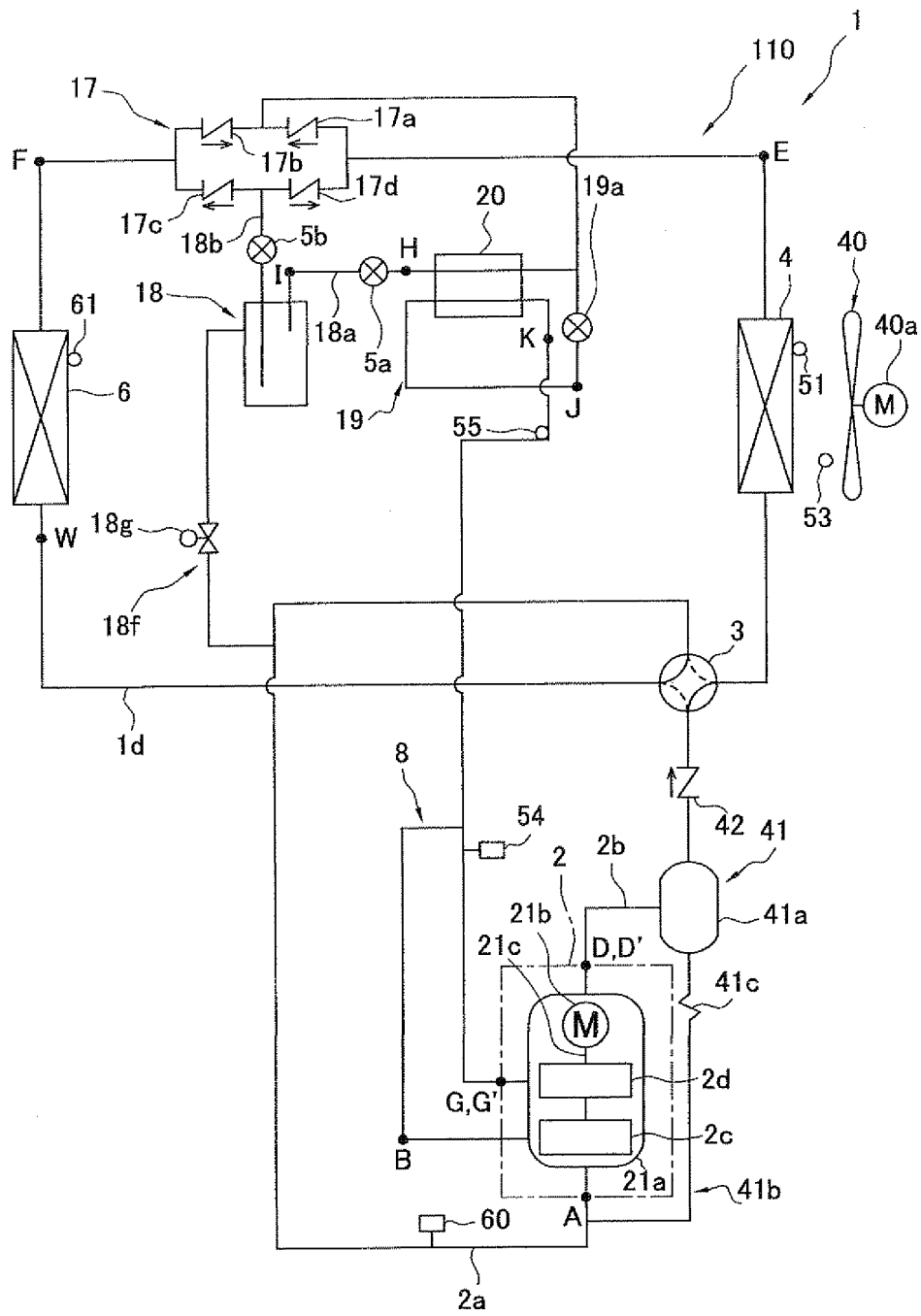


FIG. 10

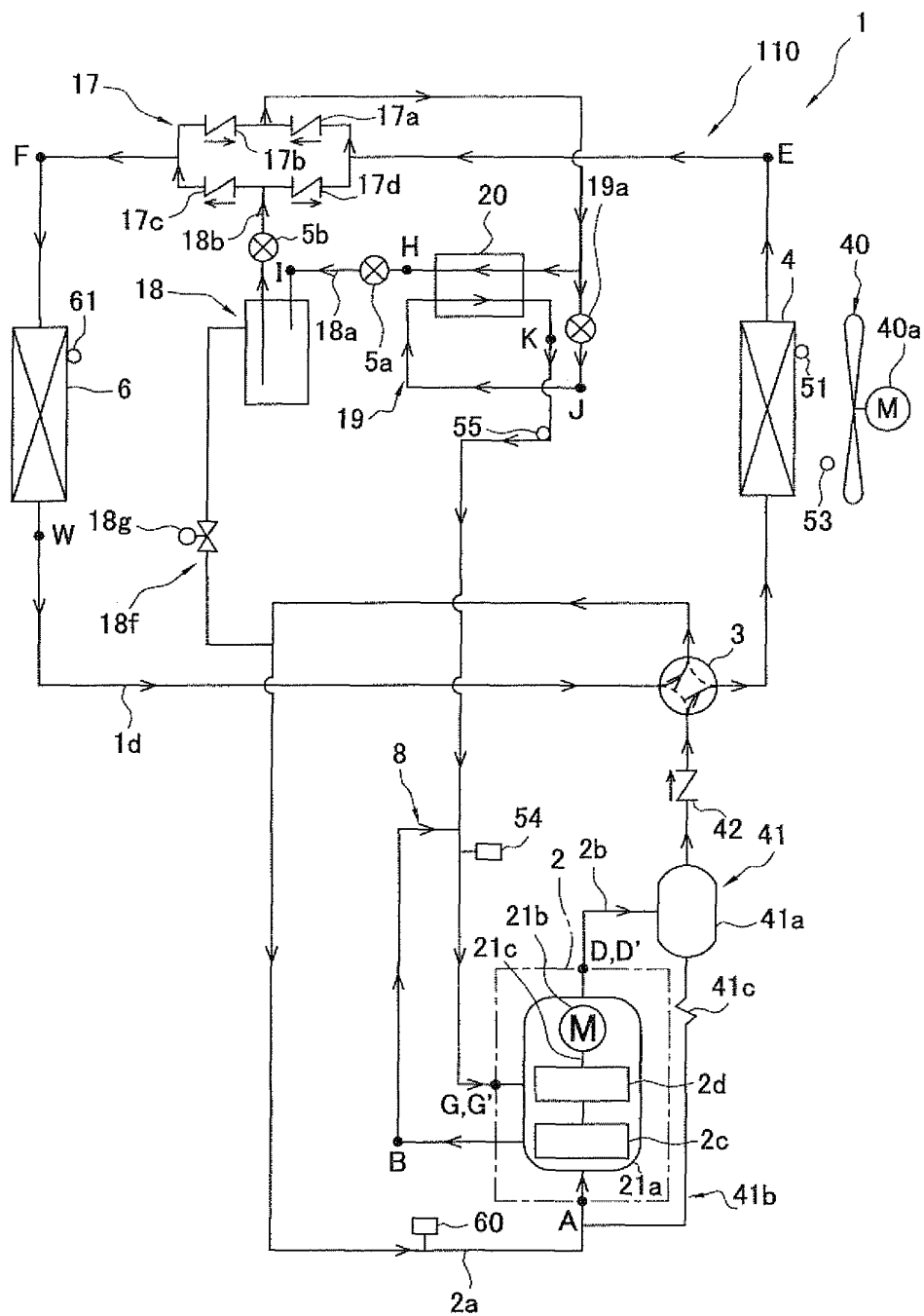


FIG. 11

FIG. 12

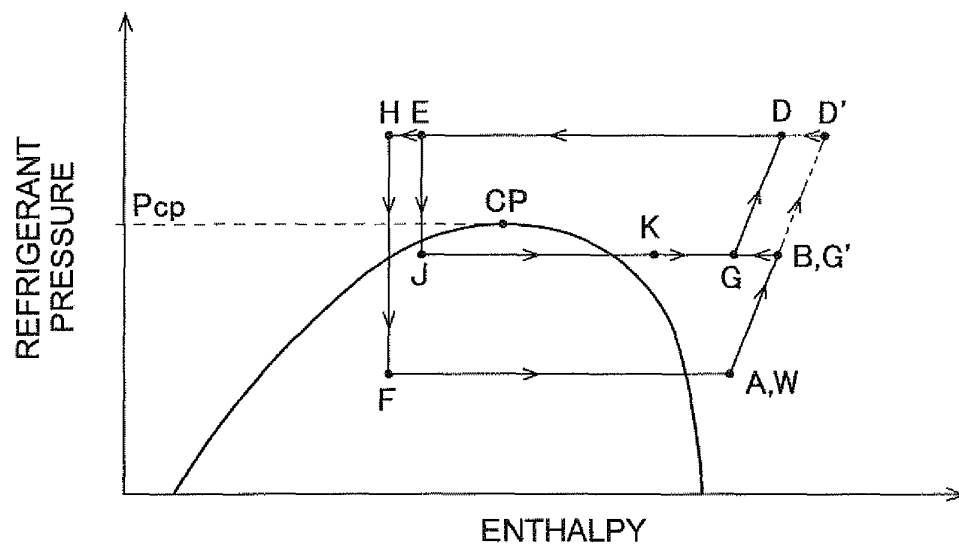
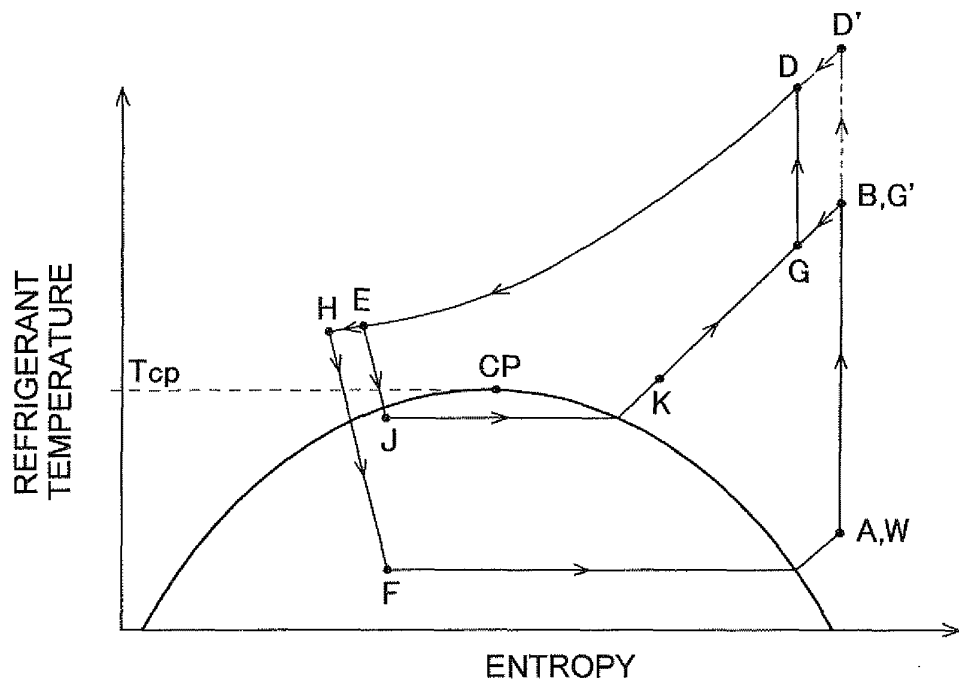


FIG. 13



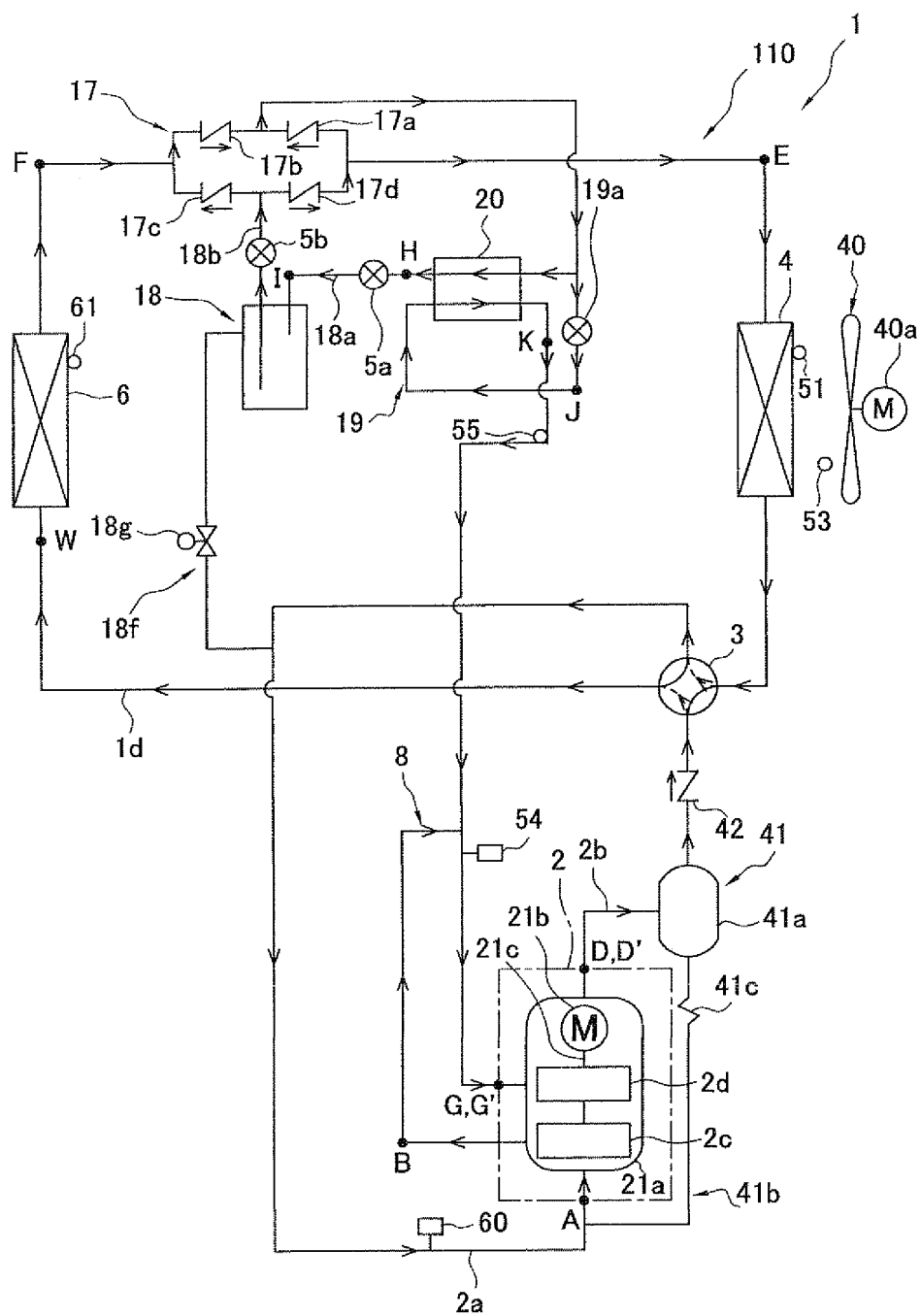


FIG. 14

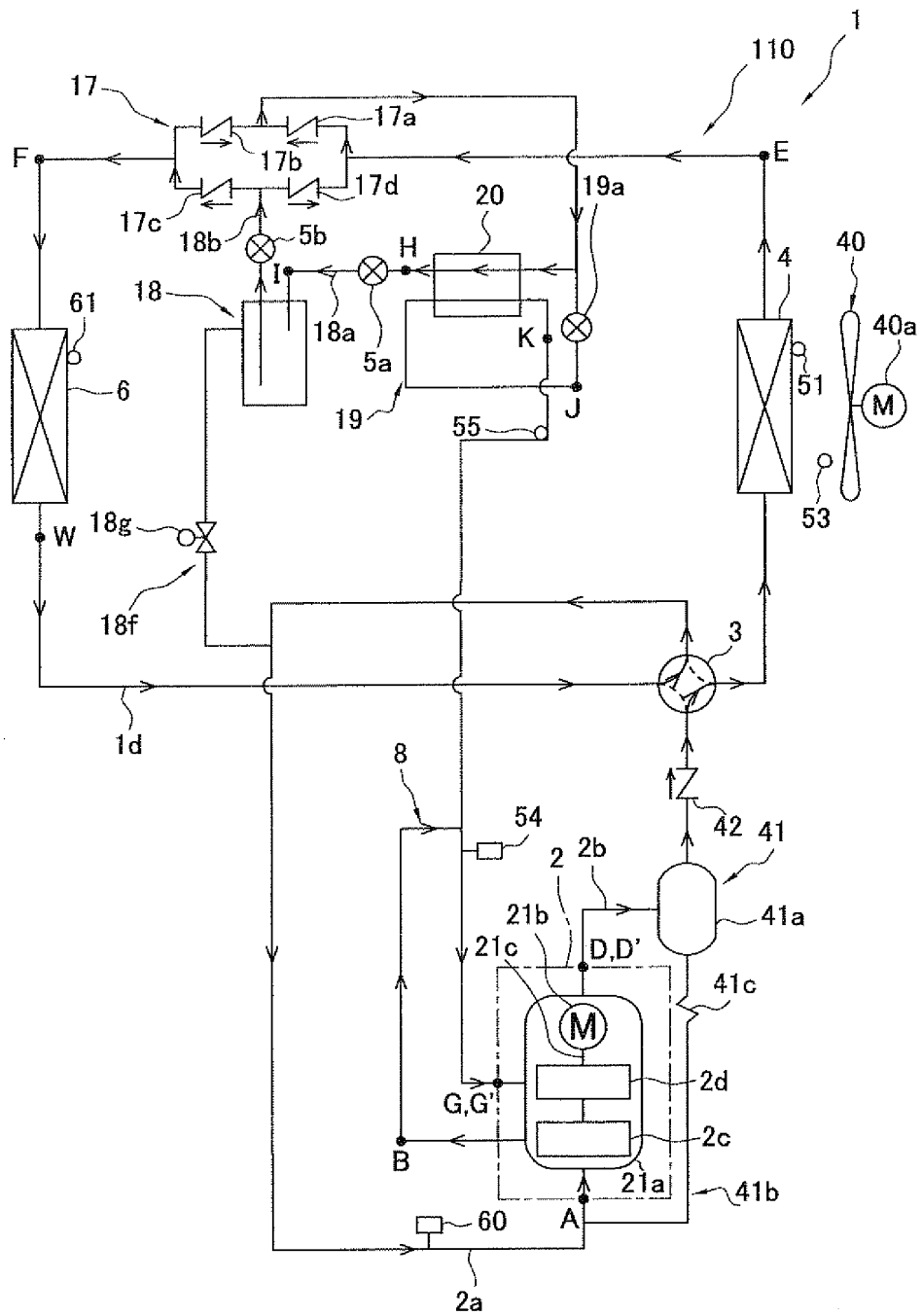


FIG. 15

FIG. 16

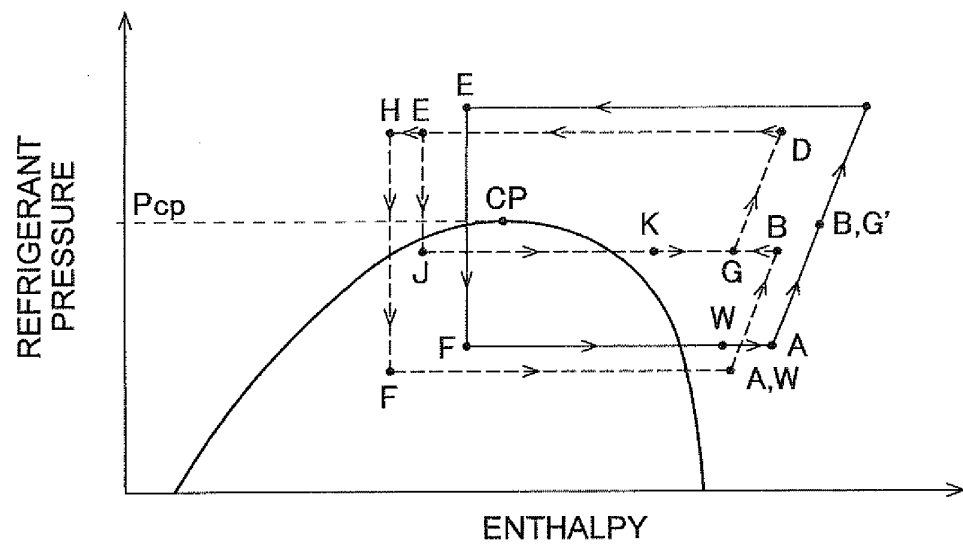
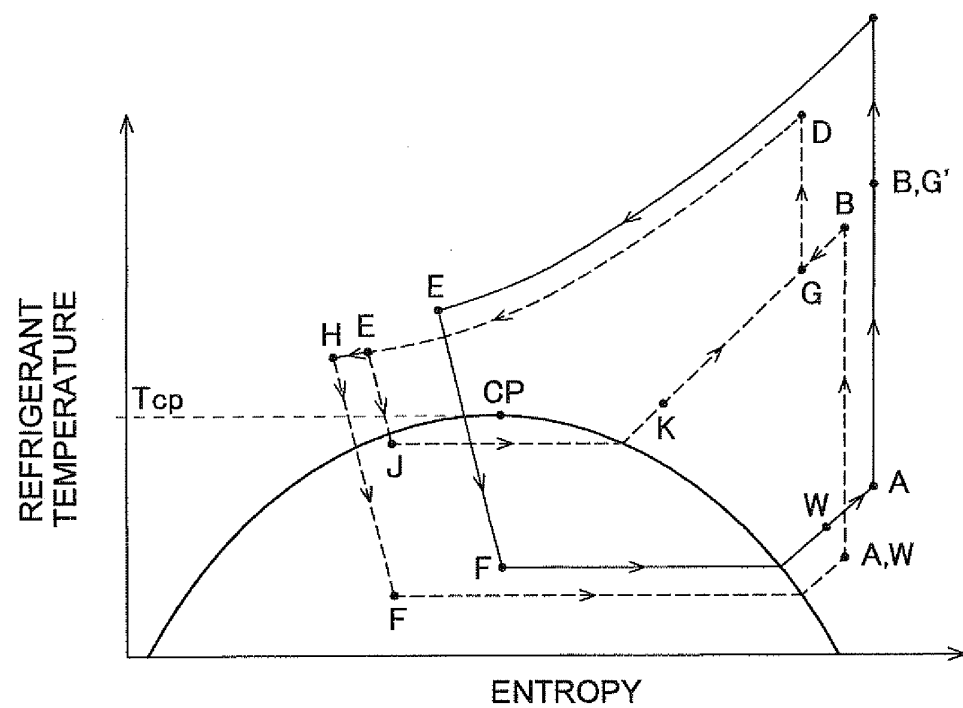


FIG. 17



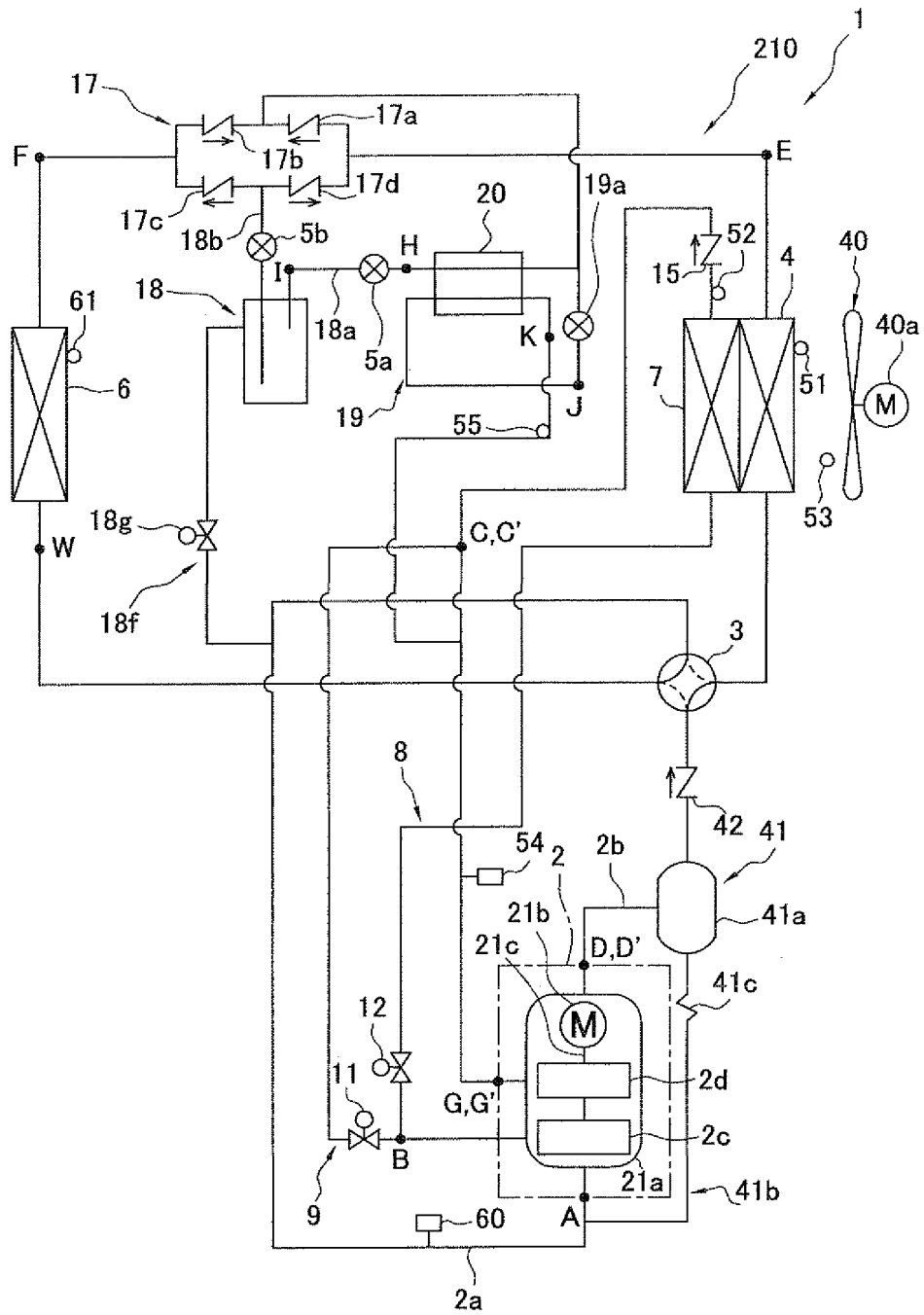


FIG. 18

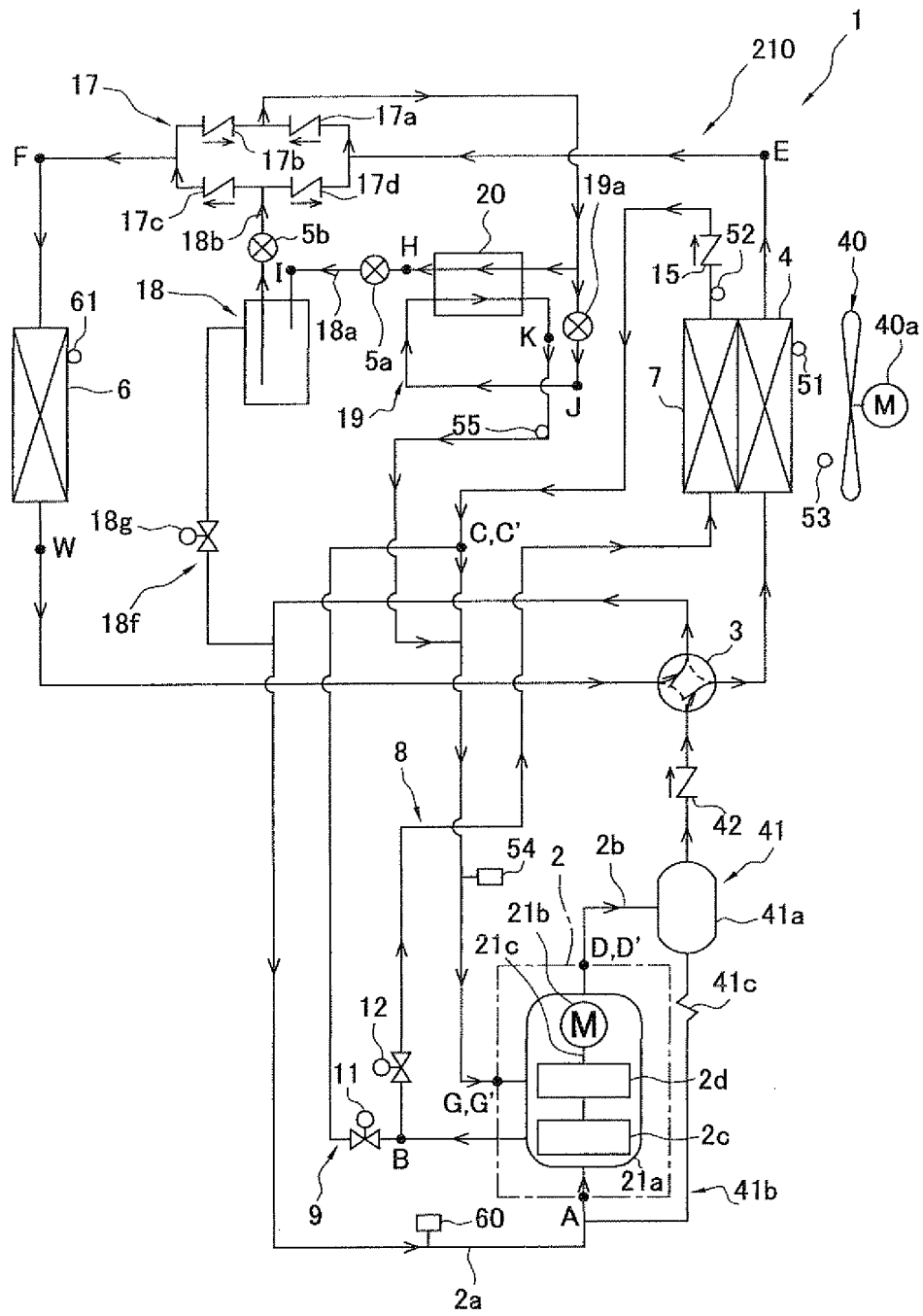


FIG. 19

FIG. 20

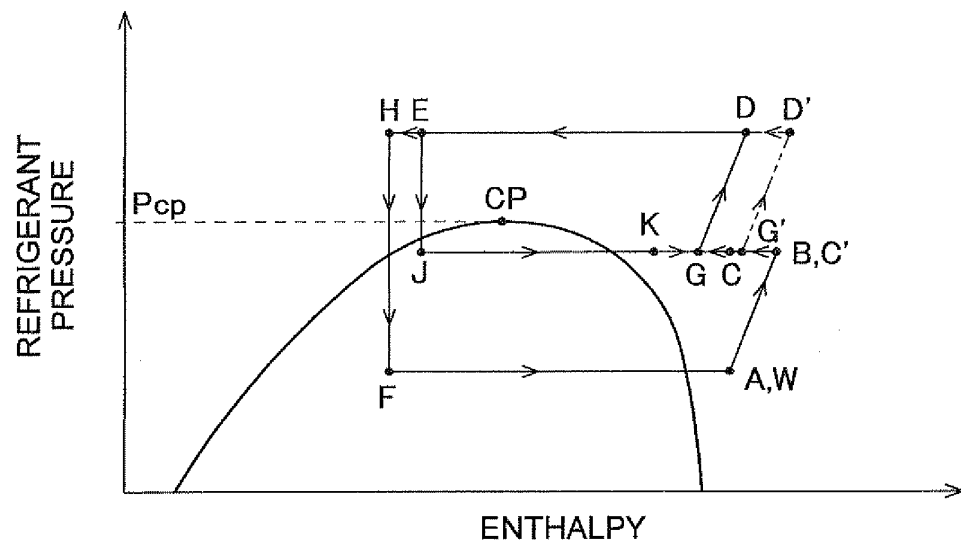
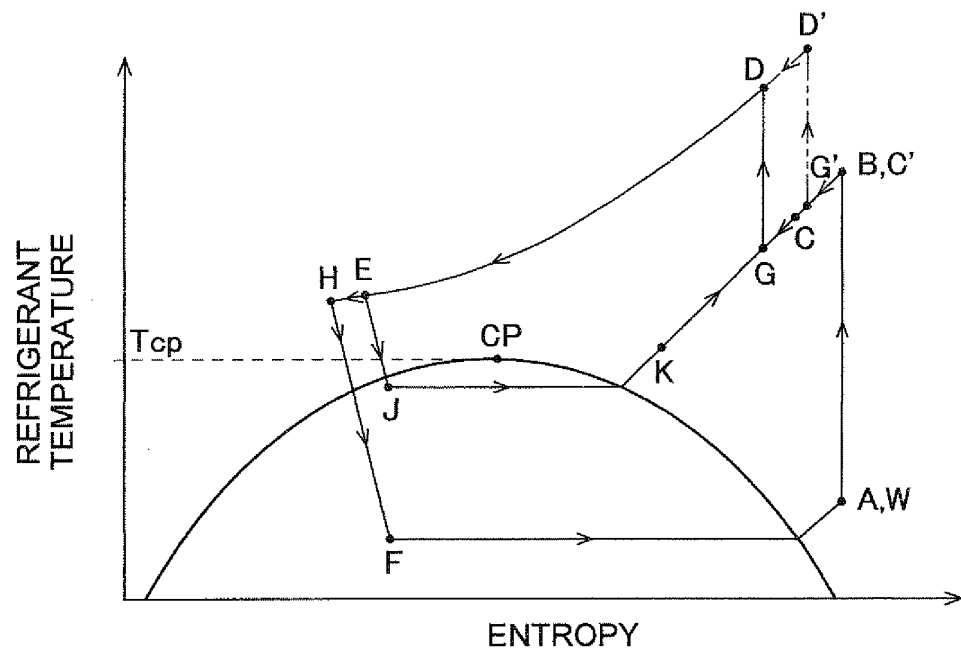


FIG. 21



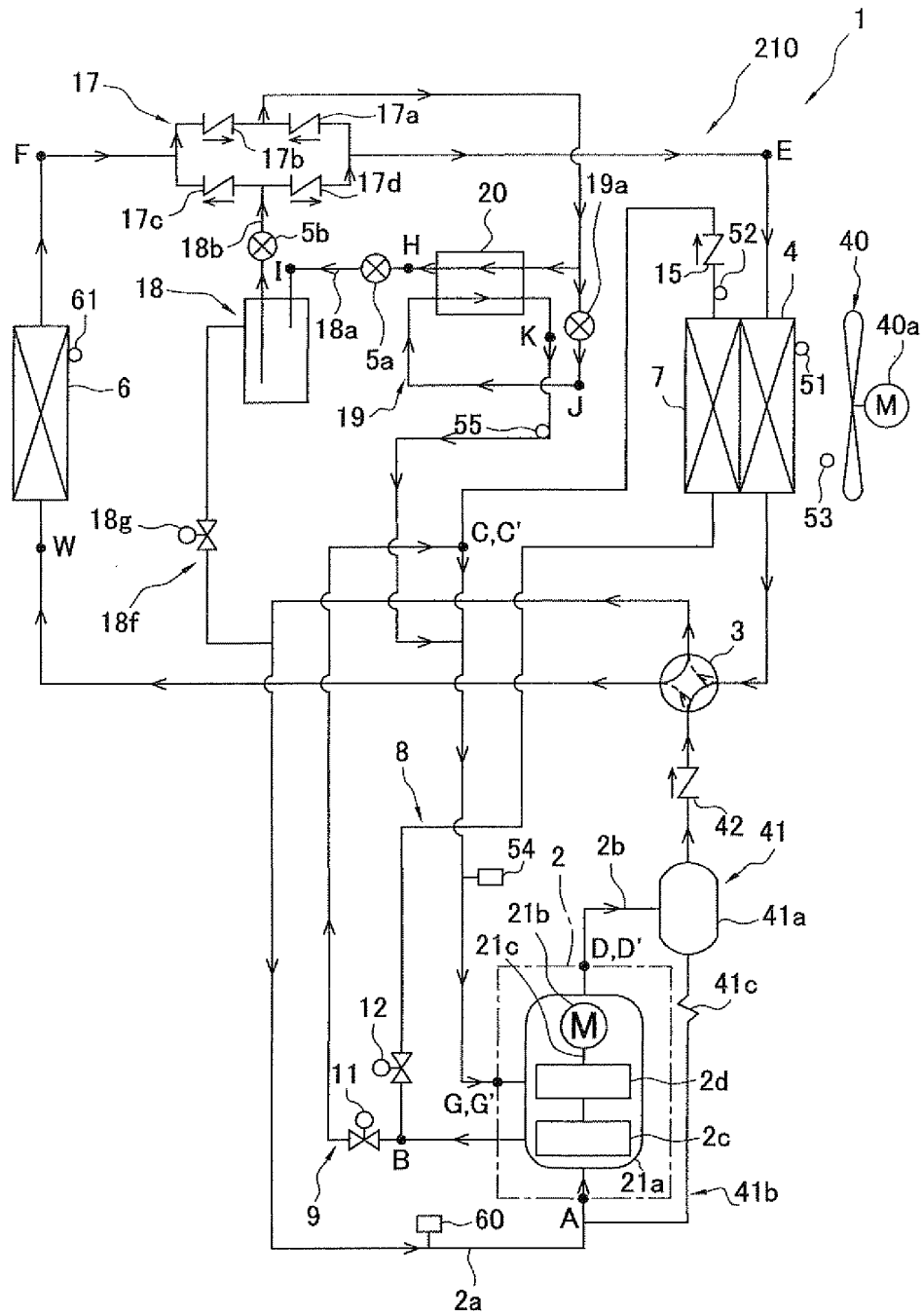


FIG. 22

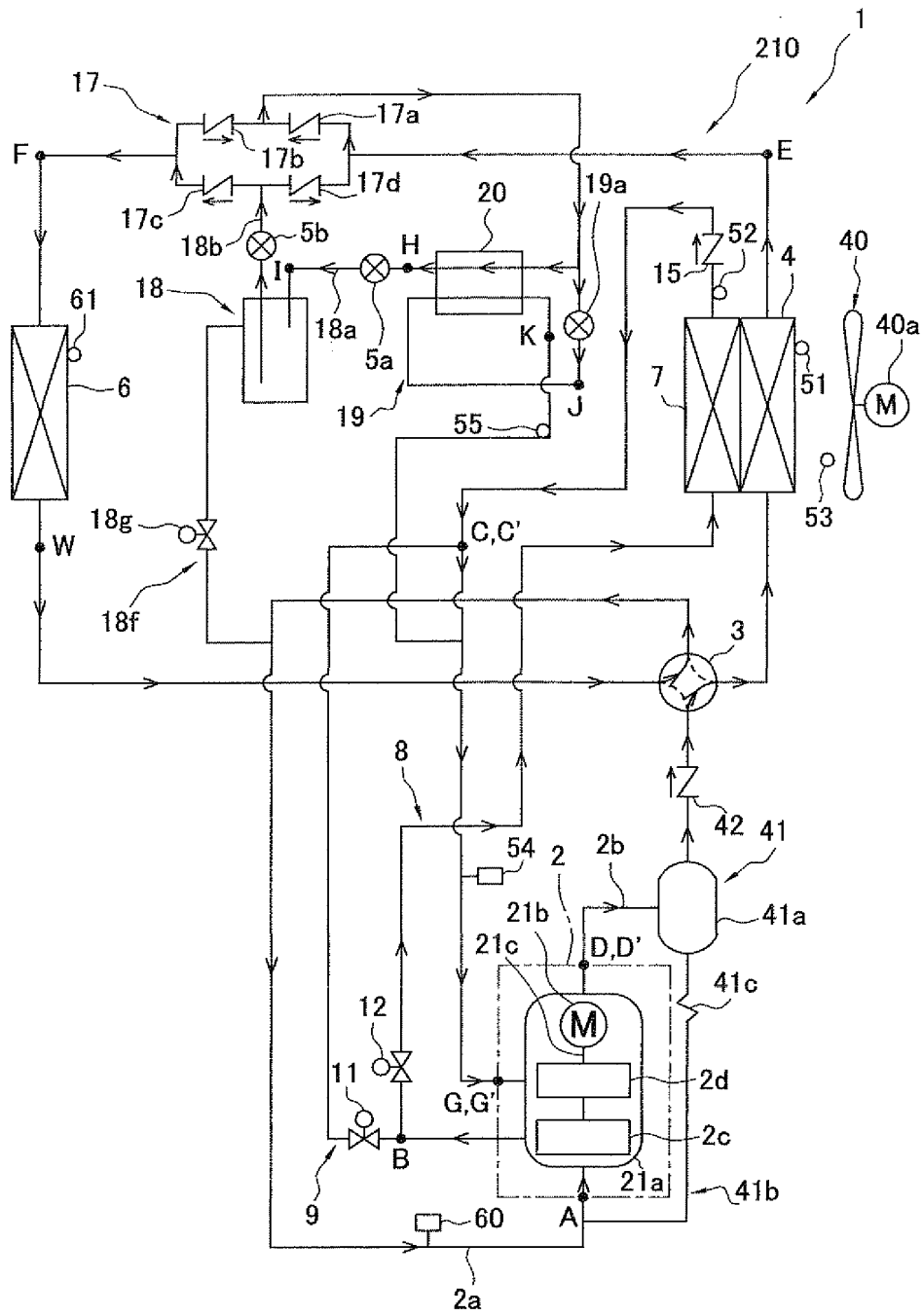


FIG. 23

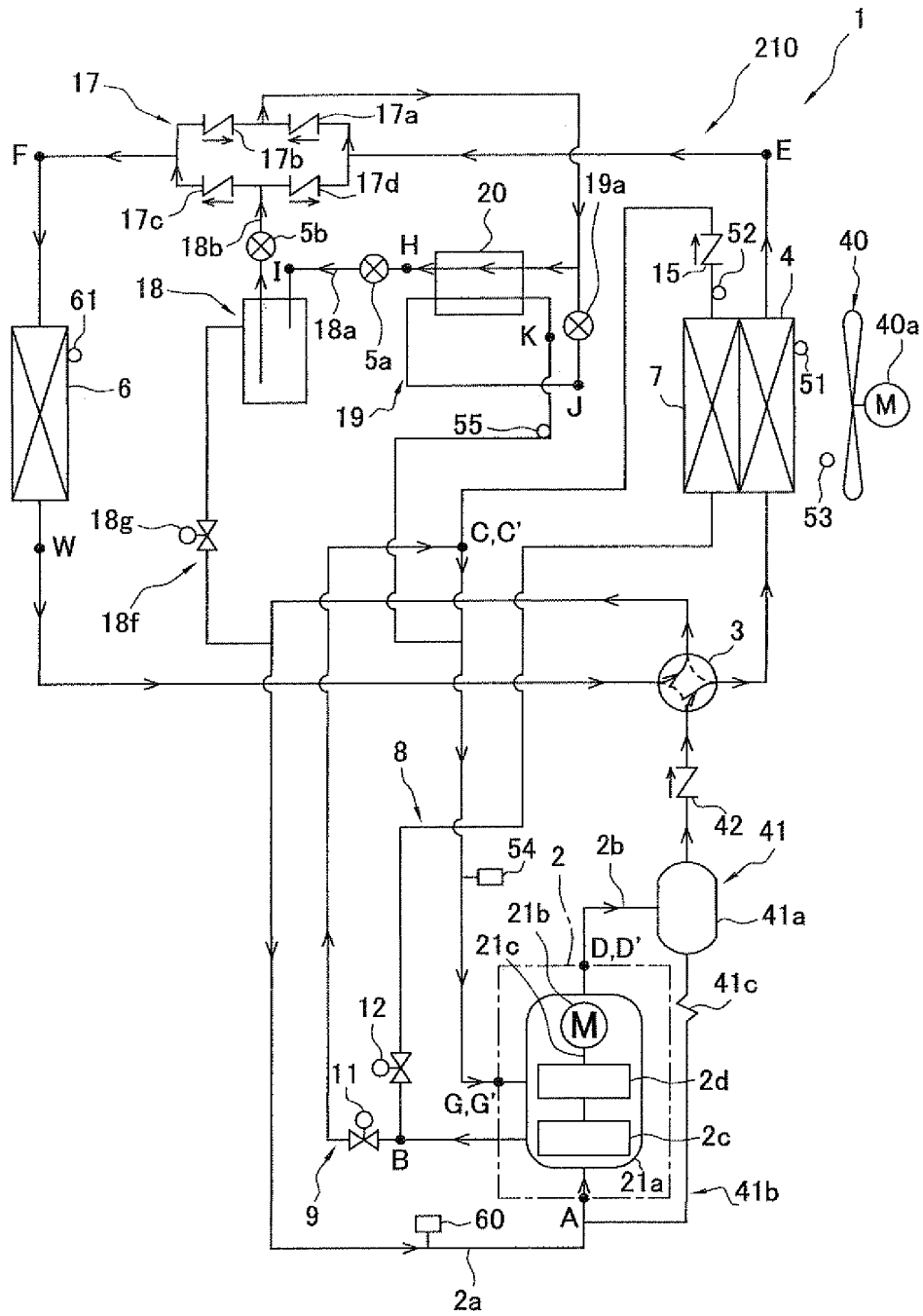


FIG. 24

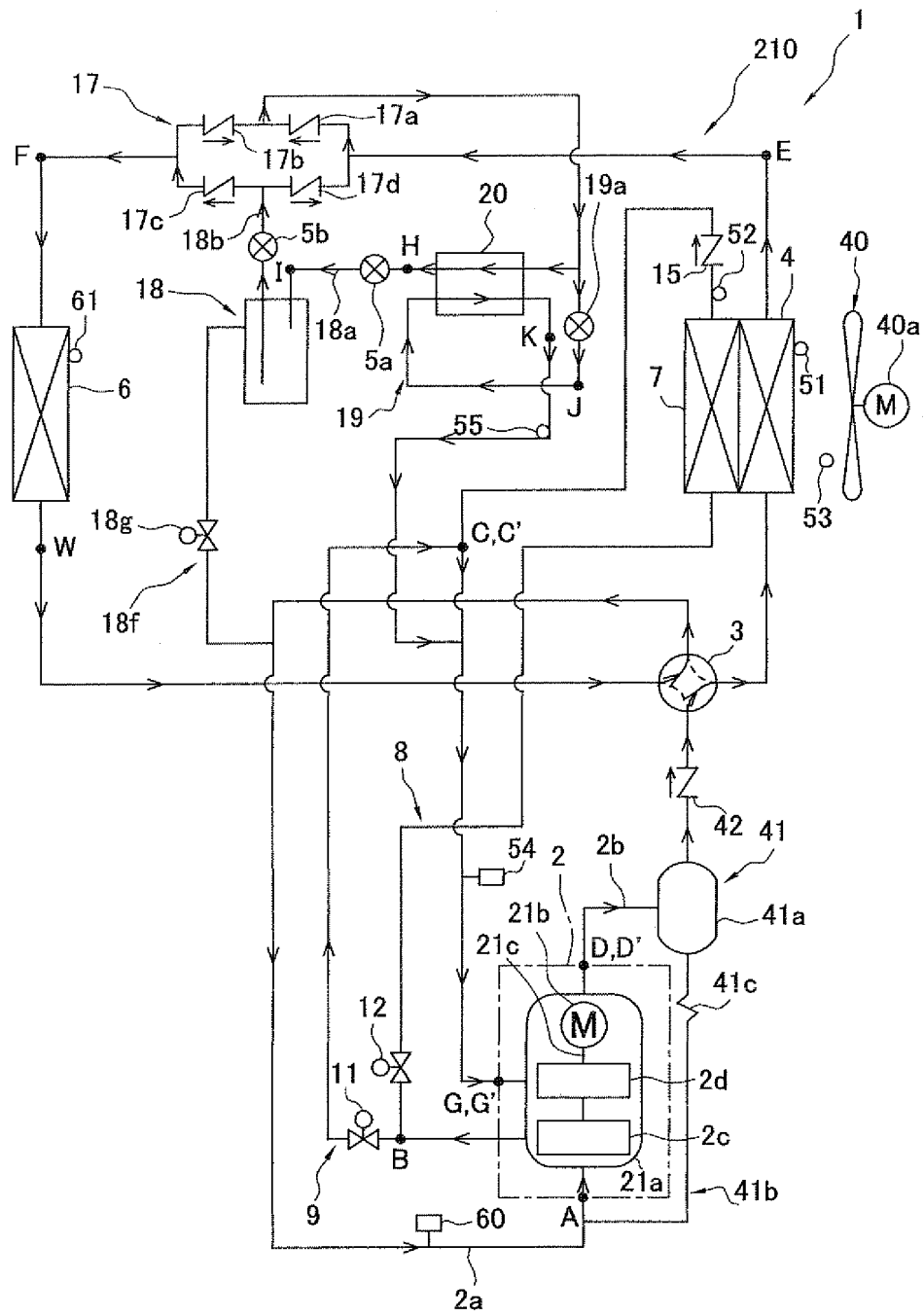


FIG. 25

FIG. 26

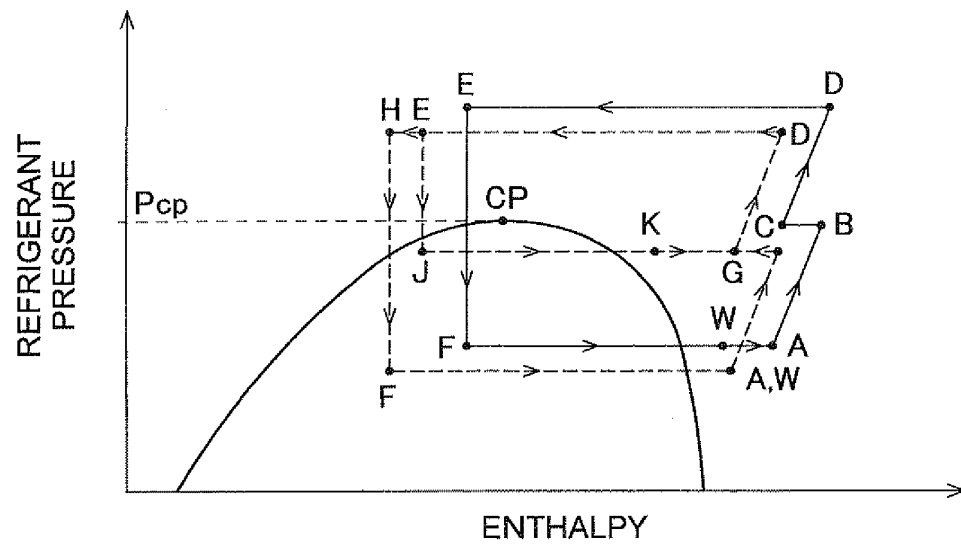
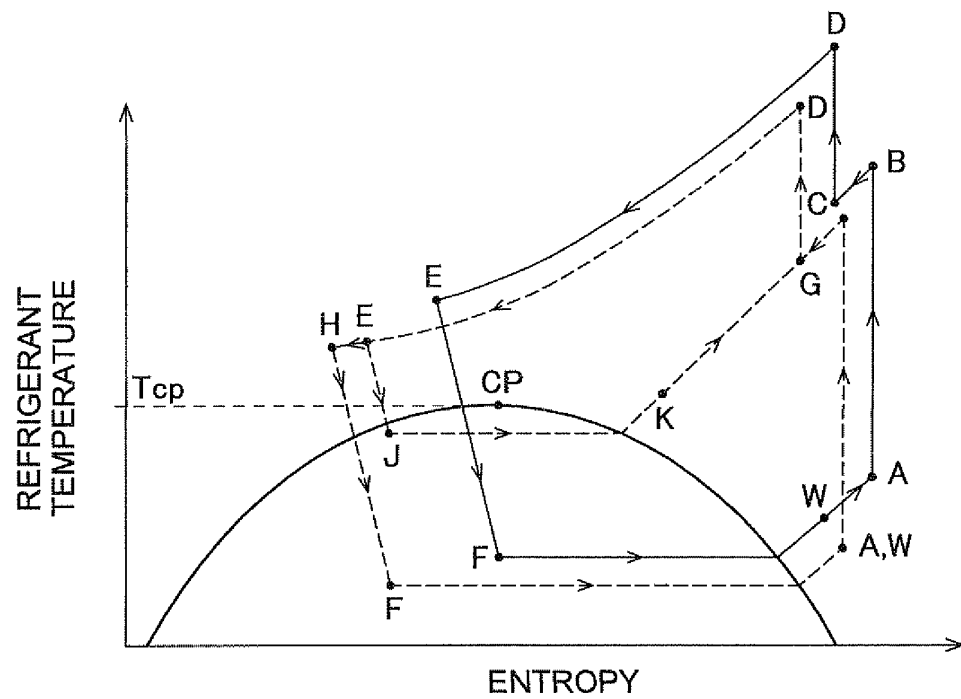


FIG. 27



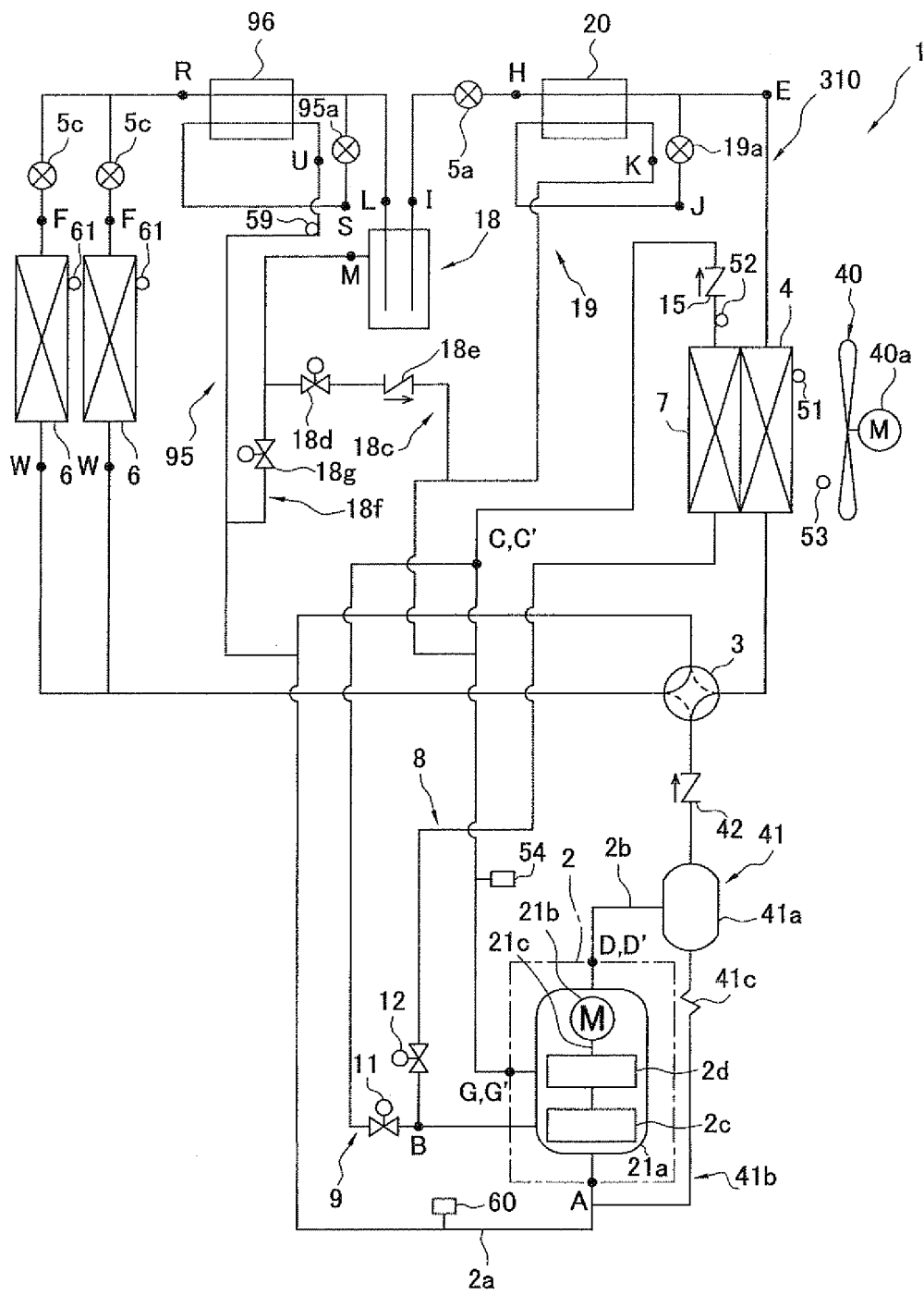


FIG. 28

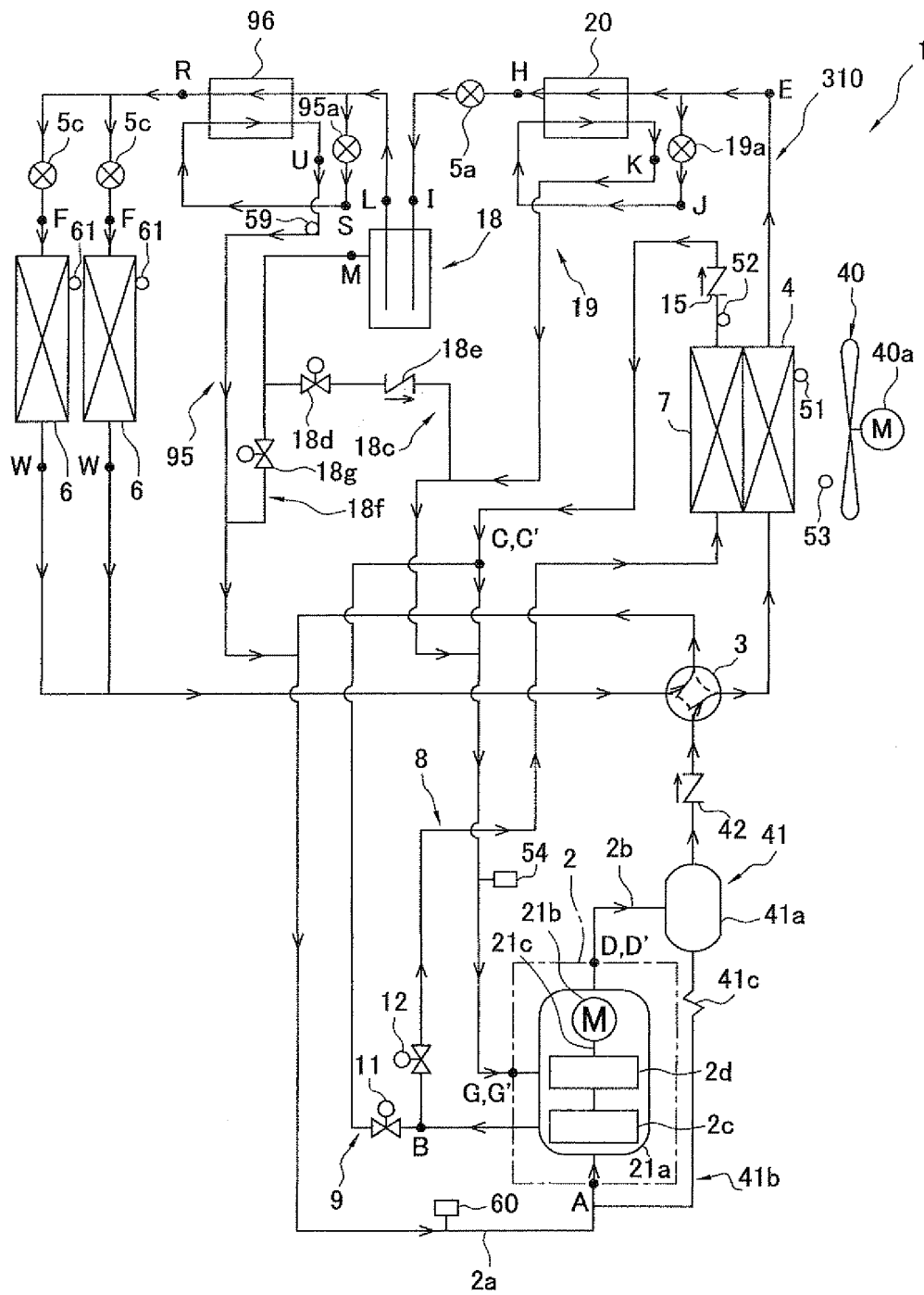


FIG. 29

FIG. 30

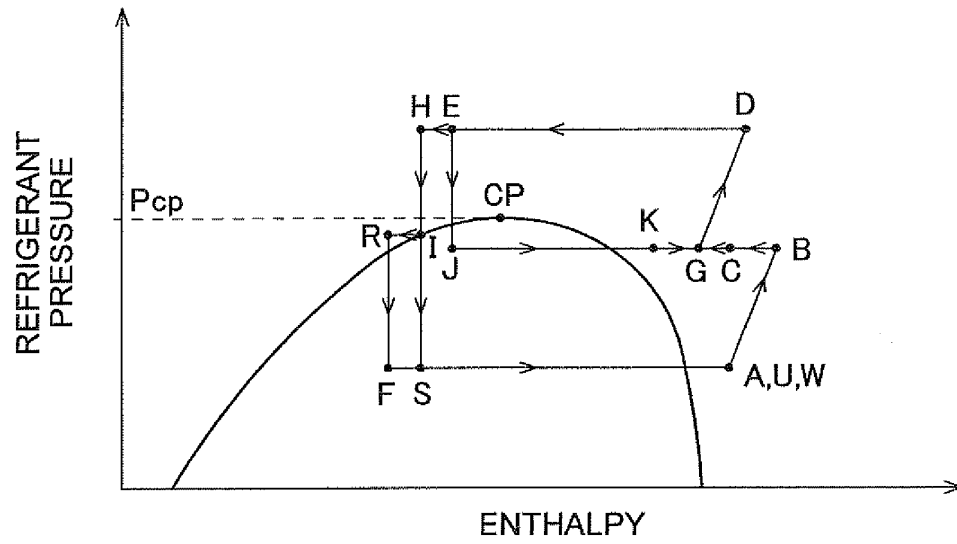
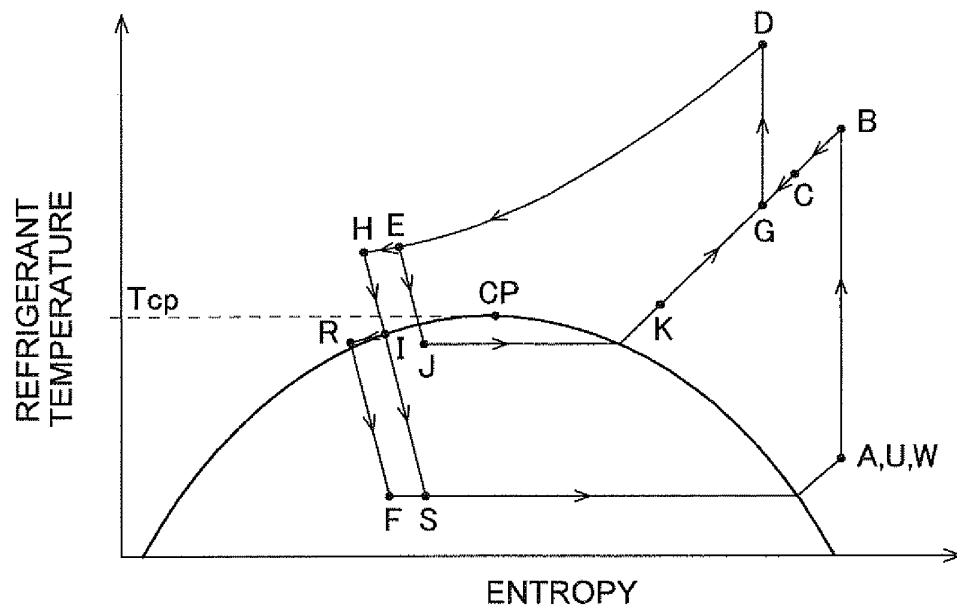


FIG. 31



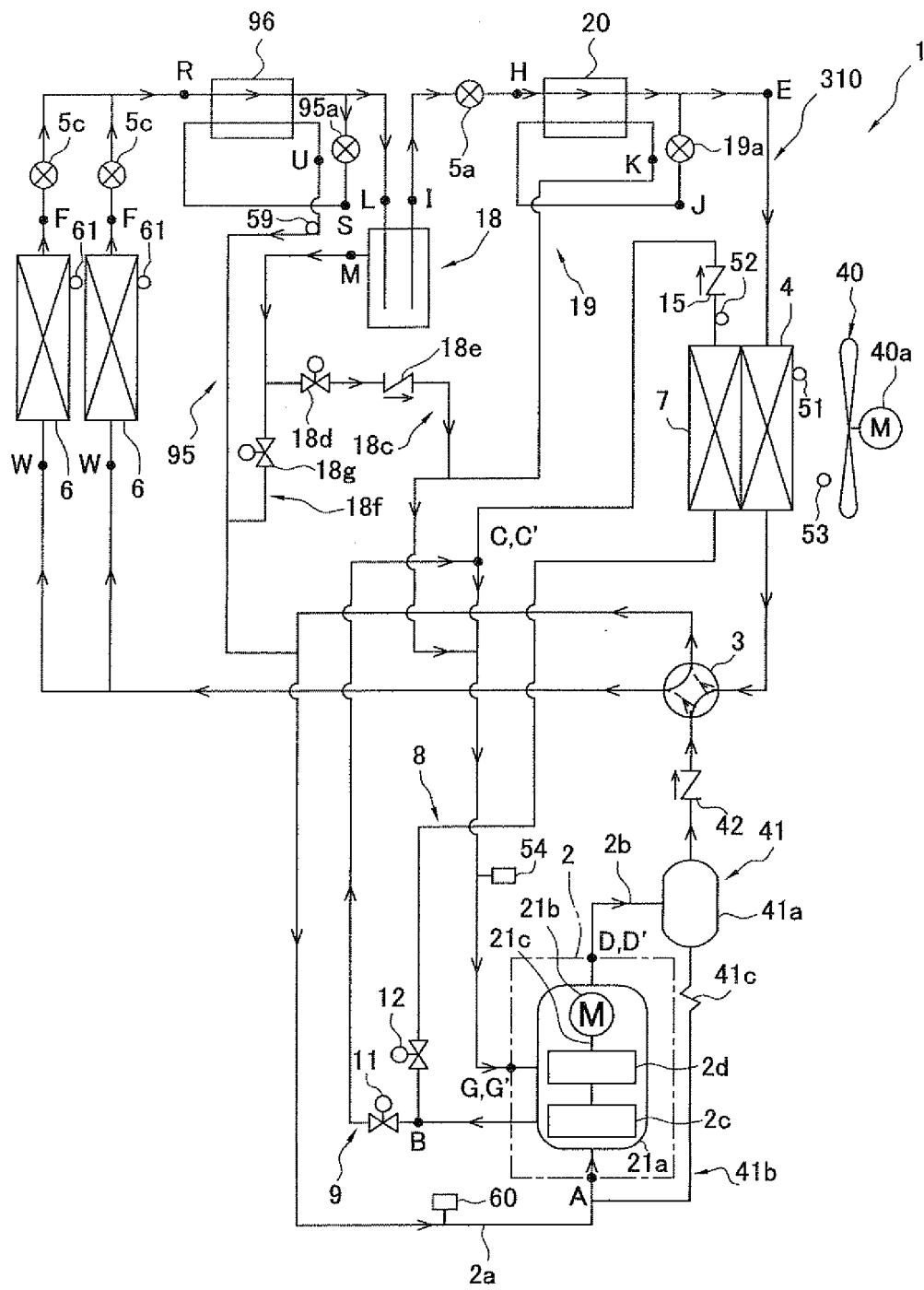


FIG. 32

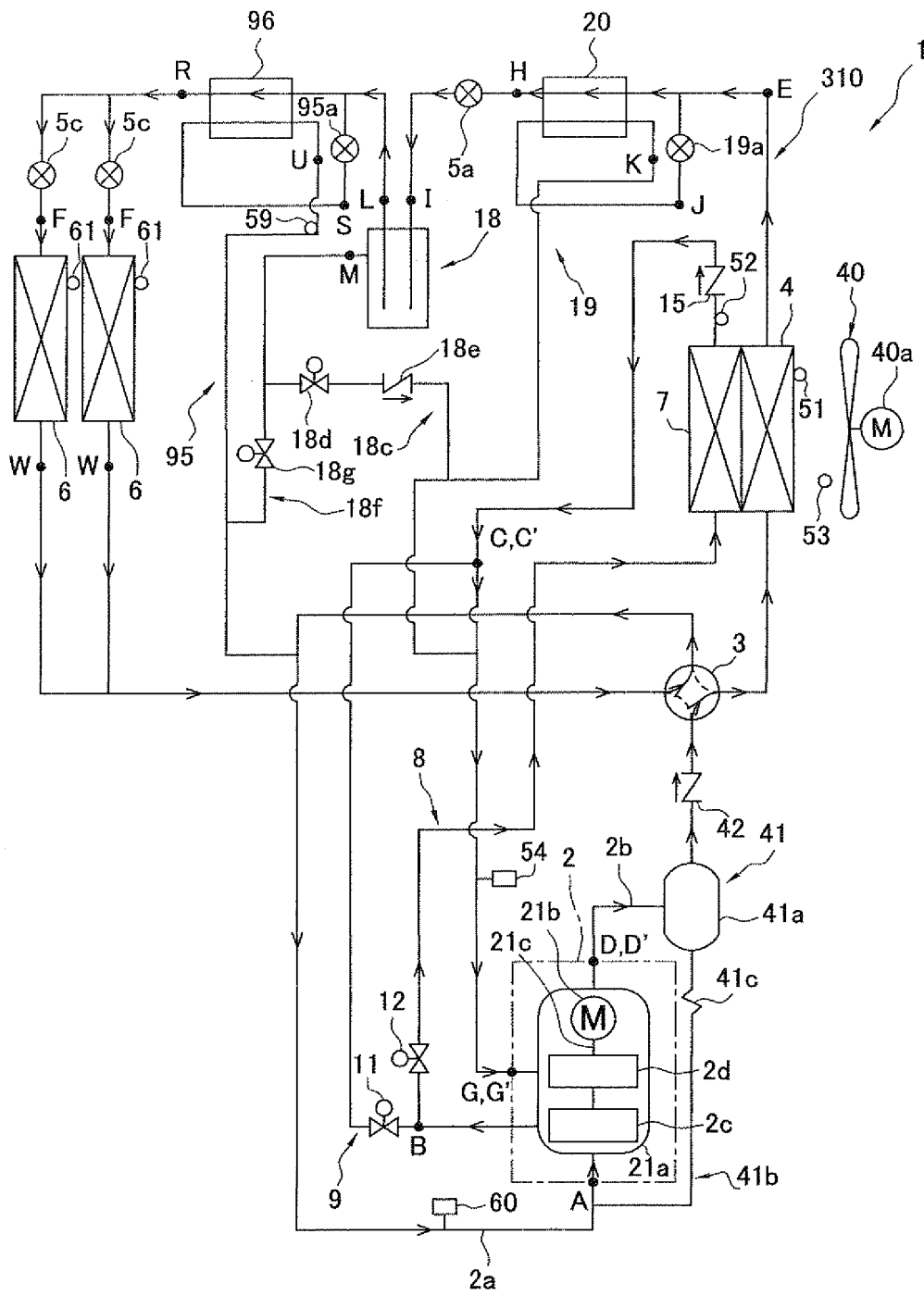


FIG. 33

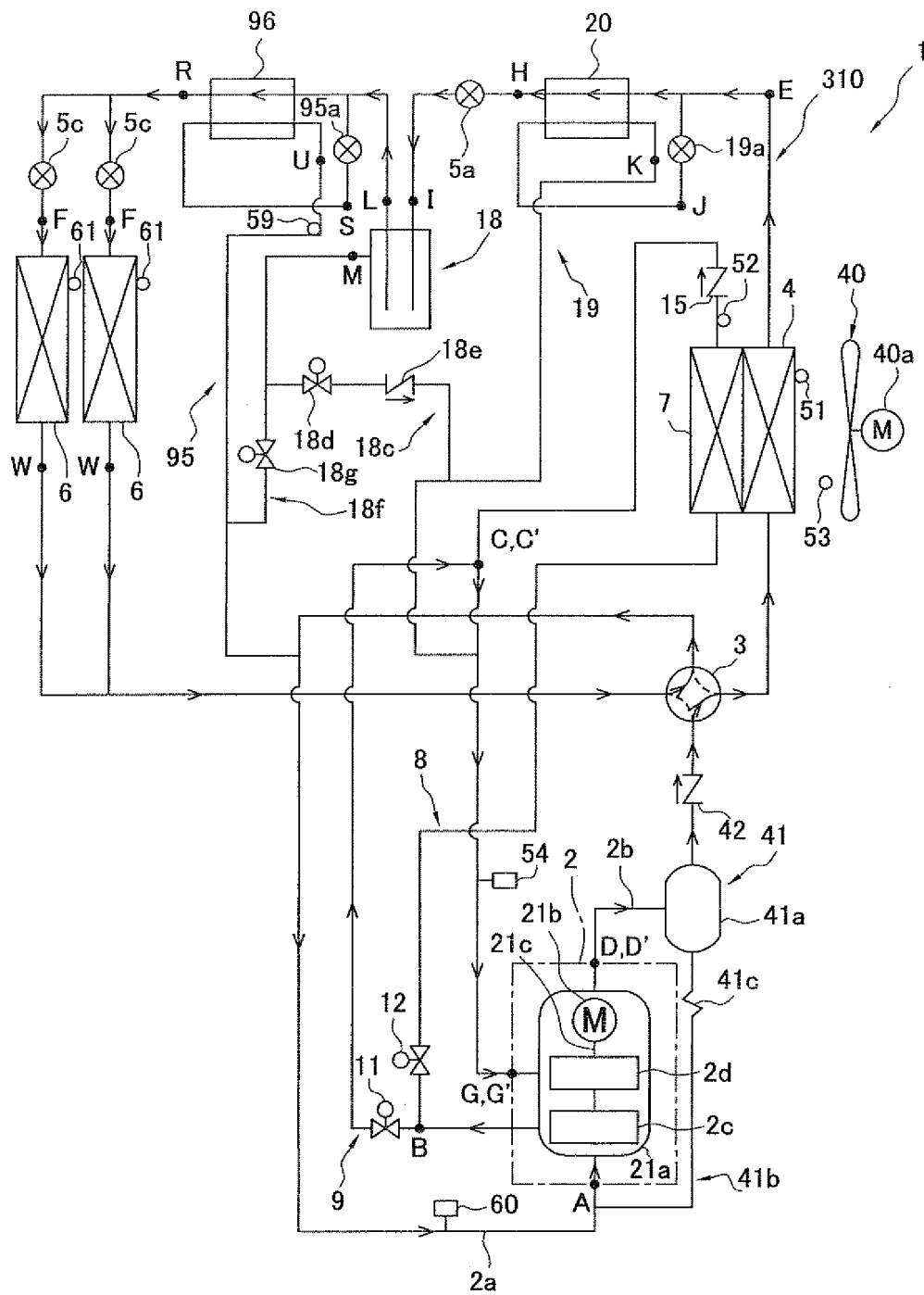


FIG. 34

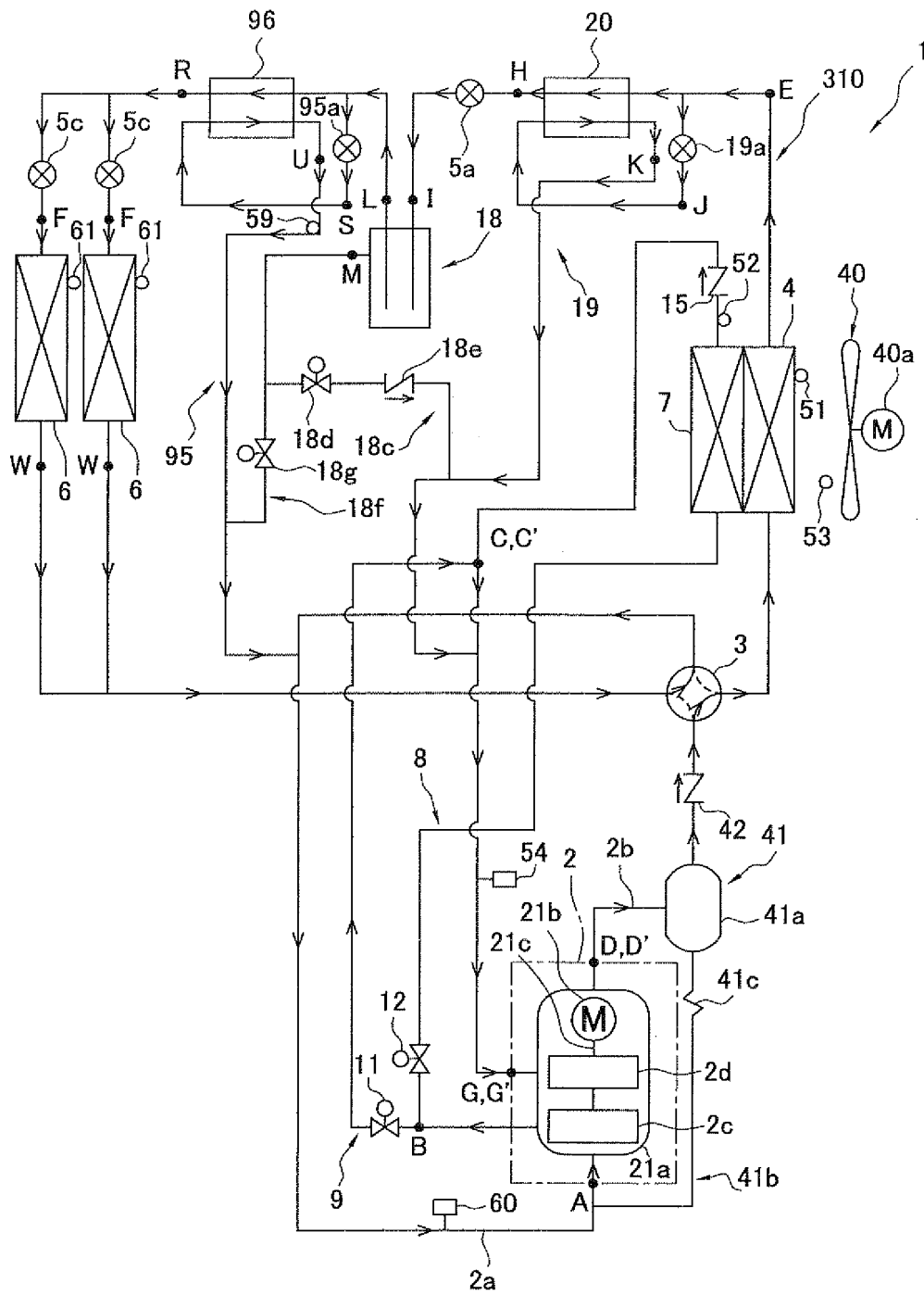


FIG. 35

FIG. 36

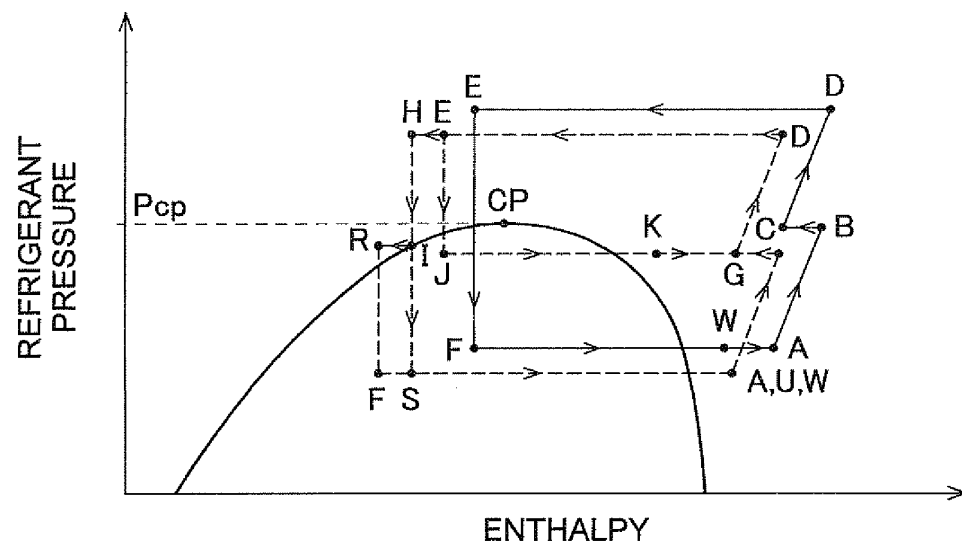
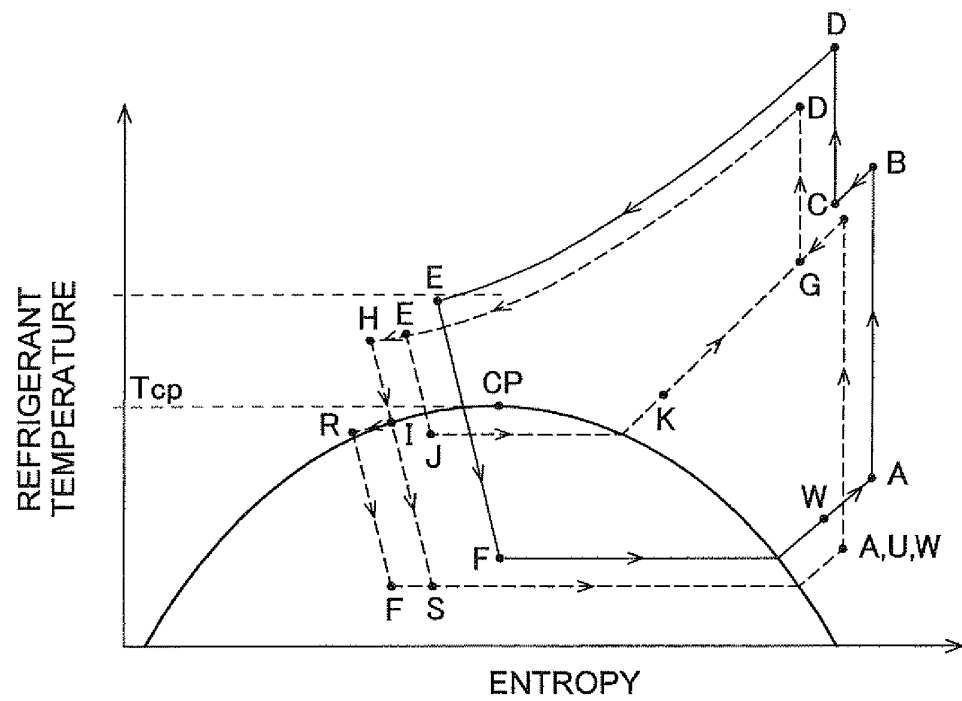


FIG. 37



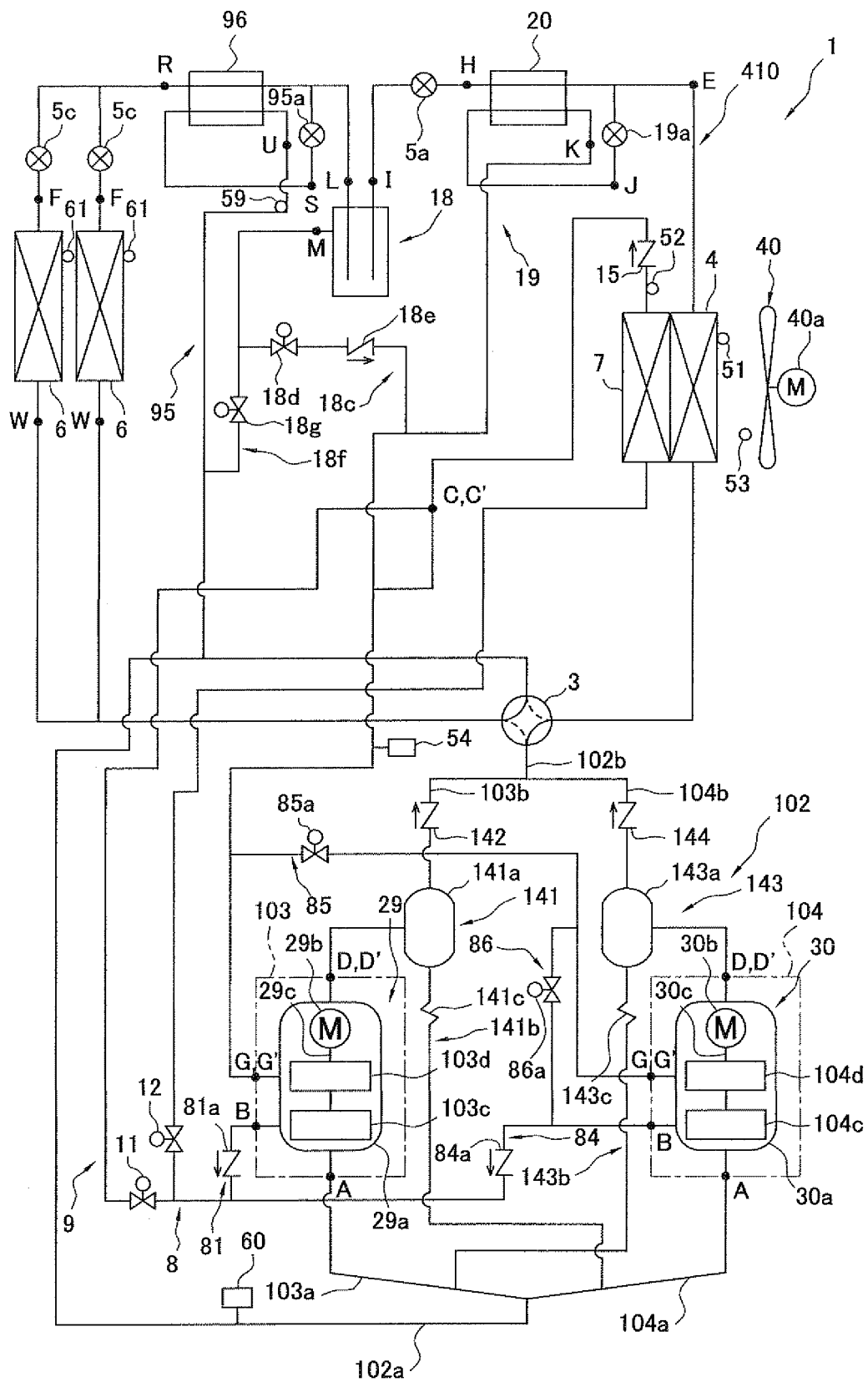


FIG. 38

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/057836

A. CLASSIFICATION OF SUBJECT MATTER

F25B47/02 (2006.01) i, F25B1/00 (2006.01) i, F25B1/10 (2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B47/02, F25B1/00, F25B1/10

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2002-318039 A (Hitachi, Ltd.), 31 October, 2002 (31.10.02), Par. Nos. [0020] to [0027]; Fig. 1 (Family: none)	1-5
Y	JP 2007-232263 A (Daikin Industries, Ltd.), 13 September, 2007 (13.09.07), Par. Nos. [0027] to [0053]; Figs. 1 to 3 & US 2009/0044564 A & EP 1990587 A1 & WO 2007/105440 A1 & KR 10-2008-0090528 A	1-5
Y	JP 63-153377 A (Daikin Industries, Ltd.), 25 June, 1988 (25.06.88), Page 1, right column, line 20 to page 4, lower left column, line 3; Figs. 1 to 3 (Family: none)	2-5

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

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Date of the actual completion of the international search
13 May, 2009 (13.05.09)Date of mailing of the international search report
26 May, 2009 (26.05.09)Name and mailing address of the ISA/
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Form PCT/ISA/210 (second sheet) (April 2007)

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Patent documents cited in the description

- JP 2007232263 A [0002]