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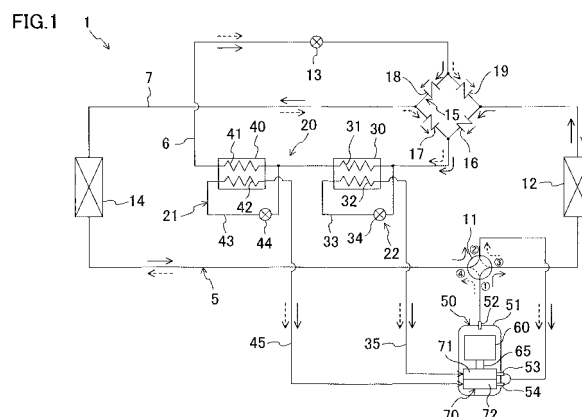
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(54) **REFRIGERATION DEVICE**

(57) In a refrigerant circuit (5) of an air conditioner (1), a single-stage compression refrigeration cycle is performed. In the refrigerant circuit (5), a second heat exchanger (40) is provided downstream a first heat exchanger (30). In the first heat exchanger (30), high-pressure refrigerant of a high-pressure flow path (31) is cooled by exchanging heat with first intermediate-pressure refrigerant of an intermediate-pressure flow path (32). First intermediate-pressure gas refrigerant generated in the first heat exchanger (30) is supplied to a first compression

mechanism (71). Second intermediate-pressure refrigerant having a pressure lower than that of the first intermediate-pressure refrigerant is supplied to an intermediate-pressure flow path (42) of the second heat exchanger (40). In the second heat exchanger (40), high-pressure refrigerant of a high-pressure flow path (41) is further cooled by exchanging heat with the second intermediate-pressure refrigerant of the intermediate-pressure flow path (42). Second intermediate-pressure gas refrigerant generated in the second heat exchanger (40) is supplied to a second compression mechanism (72).



Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigerating apparatus in which a gas injection is performed to supply intermediate-pressure gas refrigerant to a compressor.

BACKGROUND ART

[0002] Conventionally, a refrigerating apparatus has been known, in which a vapor compression refrigeration cycle and a so-called "gas injection" are performed. In the refrigerating apparatus in which the gas injection is performed, intermediate-pressure gas refrigerant is injected to a compression chamber of a compressor in the middle of a compression process.

[0003] For example, Patent Document 1 discloses an air conditioner configured by a refrigerating apparatus in which a gas injection is performed. In such an air conditioner, an intercooler is provided in a refrigerant circuit (see FIG. 1). In the intercooler, high-pressure liquid refrigerant flowing from a condenser (indoor heat exchanger in a heating operation) is cooled by exchanging heat with intermediate-pressure refrigerant which is generated by branching and expanding a part of the high-pressure liquid refrigerant. Then, the high-pressure refrigerant cooled in the intercooler is supplied to an evaporator (outdoor heat exchanger in the heating operation). The intermediate-pressure refrigerant evaporated in the intercooler (intermediate-pressure gas refrigerant) is supplied to a compression chamber of a compressor in the middle of a compression process.

[0004] In addition, Patent Document 2 also discloses an air conditioner configured by a refrigerating apparatus in which a gas injection is performed. In a refrigerant circuit of such an air conditioner, a gas-liquid separator is provided between two expansion valves. Intermediate-pressure refrigerant in a gas-liquid two-phase state, which is expanded when passing through the expansion valve upstream the gas-liquid separator flows into the gas-liquid separator. In the gas-liquid separator, the intermediate-pressure refrigerant flowing into the gas-liquid separator is separated into gas refrigerant and liquid refrigerant. Then, the intermediate-pressure liquid refrigerant in the gas-liquid separator is expanded when passing through the expansion valve downstream the gas-liquid separator, and is sent to an evaporator. The intermediate-pressure gas refrigerant in the gas-liquid separator is supplied to a compression chamber of a compressor in the middle of a compression process.

[0005] Further, Patent Document 3 discloses a refrigerating apparatus in which a multiple-stage compression refrigeration cycle is performed. In a refrigerant circuit of such a refrigerating apparatus, a plurality of compressors are connected in series. Refrigerant discharged from the low-pressure compressor is sucked into the high-pressure compressor, and is further compressed. In addition,

in the refrigerant circuit, intermediate-pressure gas refrigerant is supplied to a pipe connecting between the low-pressure and high-pressure compressors in order to reduce an enthalpy of refrigerant sucked into the high-pressure compressor. Further, FIG. 2 of Patent Document 3 illustrates a refrigerant circuit in which a four-stage compression refrigeration cycle is performed. In such a refrigerant circuit, three types of intermediate-pressure gas refrigerants with different pressures are supplied to pipes connecting the compressors of the four stages together.

CITATION LIST

15 PATENT DOCUMENT

[0006]

PATENT DOCUMENT 1: Japanese Patent Publication No. 2004-183913

PATENT DOCUMENT 2: Japanese Patent Publication No. H11-093874

PATENT DOCUMENT 3: Japanese Patent Publication No. 2002-188865

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0007] In a refrigerant circuit of the refrigerating apparatus in which the gas injection is performed, the compressor compresses low-pressure refrigerant sucked from an evaporator and intermediate-pressure gas refrigerant injected to the compression chamber in the middle of the compression process, and discharges the compressed refrigerant to a condenser. Thus, in the refrigerant circuit, a mass flow rate of refrigerant in the condenser is greater than a mass flow rate of refrigerant in the evaporator.

[0008] A greater mass flow rate of refrigerant in the condenser results in a greater amount of heat released from refrigerant (i.e., a heat dissipation amount of refrigerant) in the condenser. Thus, if a mass flow rate of intermediate-pressure gas refrigerant supplied to the compressor is increased, the mass flow rate of refrigerant in the condenser can be increased without increasing a mass flow rate of low-pressure refrigerant sucked into the compressor from the evaporator. In order to increase the mass flow rate of intermediate-pressure gas refrigerant supplied to the compressor, the pressure of the intermediate-pressure gas refrigerant may be increased to increase the density of the intermediate-pressure gas refrigerant flowing into the compression chamber.

[0009] However, a higher refrigerant pressure results in a higher refrigerant saturation temperature. For such a reason, if the pressure of the intermediate-pressure gas refrigerant generated in the intercooler of Patent Document 1 or the gas-liquid separator of Patent Docu-

ment 2 is increased, an enthalpy of refrigerant sent from the intercooler or the gas-liquid separator to the evaporator is increased. As a result, an amount of heat absorbed by refrigerant (i.e., heat absorption amount of refrigerant) in the evaporator is decreased.

[0010] Thus, in the conventional refrigerating apparatus in which the gas injection is performed, it is difficult to ensure both of the heat dissipation amount of refrigerant in the condenser and the heat absorption amount of refrigerant in the evaporator.

[0011] The present invention has been made in view of the foregoing, and it is an objective of the present invention to ensure both of a heat dissipation amount of refrigerant in a condenser and a heat absorption amount of refrigerant in an evaporator in a refrigerating apparatus in which an gas injection is performed.

SOLUTION TO THE PROBLEM

[0012] A first aspect of the invention is intended for a refrigerating apparatus including a refrigerant circuit (5) including a radiator and an evaporator and performing a refrigeration cycle, and a first compression mechanism (71) and a second compression mechanism (72) each including a compression chamber (85, 95), in which each of the first compression mechanism (71) and the second compression mechanism (72) sucks low-pressure refrigerant into the compression chamber (85, 95), and compresses the low-pressure refrigerant to a high pressure level. The refrigerant circuit (5) includes an enthalpy reducing unit (20) for reducing an enthalpy of refrigerant flowing from the radiator to the evaporator by generating first intermediate-pressure gas refrigerant and second intermediate-pressure gas refrigerant having a pressure lower than that of the first intermediate-pressure gas refrigerant, a first injection path (35) for supplying the first intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (85) of the first compression mechanism (71) in the middle of a compression process, and a second injection path (45) for supplying the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (95) of the second compression mechanism (72) in the middle of a compression process.

[0013] Each of second and third aspects of the invention is intended for a refrigerating apparatus including a refrigerant circuit (5) including a radiator and an evaporator and performing a refrigeration cycle, and a first compression mechanism (71) and a second compression mechanism (72) each including a compression chamber (85, 95), in which the first compression mechanism (71) sucks low-pressure refrigerant into the compression chamber (85) and compresses the low-pressure refrigerant, and the second compression mechanism (72) sucks the refrigerant discharged from the first compression mechanism (71) into the compression chamber (95) and compresses the refrigerant.

[0014] In the second aspect of the invention, the refrigerant circuit (5) includes an enthalpy reducing unit (20) for reducing an enthalpy of refrigerant flowing from the radiator to the evaporator by generating first intermediate-pressure gas refrigerant and second intermediate-pressure gas refrigerant having a pressure lower than that of the first intermediate-pressure gas refrigerant, a first injection path (35) for supplying the first intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (85) of the first compression mechanism (71) in the middle of a compression process, and a second injection path (45) for supplying the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (95) of the second compression mechanism (72) in the middle of a compression process, or to an inlet side of the second compression mechanism (72).

[0015] In the third aspect of the invention, the refrigerant circuit (5) includes an enthalpy reducing unit (20) for reducing an enthalpy of refrigerant flowing from the radiator to the evaporator by generating first intermediate-pressure gas refrigerant and second intermediate-pressure gas refrigerant having a pressure lower than that of the first intermediate-pressure gas refrigerant, a first injection path (35) for supplying the first intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to an inlet side of the second compression mechanism (72), and a second injection path (45) for supplying the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (95) of the second compression mechanism (72) in the middle of a compression process.

[0016] In the refrigerant circuit (5) of the first aspect of the invention, refrigerant circulates to perform a single-stage compression refrigeration cycle. In the refrigerant circuit (5), refrigerant discharged from the compression mechanisms (71, 72) dissipates heat in the radiator. Then, such refrigerant is evaporated by absorbing heat in the evaporator, and is sucked into the compression mechanisms (71, 72). On the other hand, in the refrigerant circuit (5) of each of the second and third aspects of the invention, refrigerant circulates to perform a two-stage compression refrigeration cycle. In the refrigerant circuit (5), refrigerant discharged from the second compression mechanism (72) dissipates heat in the radiator. Then, such refrigerant is evaporated by absorbing heat in the evaporator, and is sucked into the first compression mechanism (71). In the refrigerant circuit (5) of each of the first to third aspects of the invention, after refrigerant dissipates heat in the radiator, and its enthalpy is reduced in the enthalpy reducing unit (20), such refrigerant is supplied to the evaporator.

[0017] In the enthalpy reducing unit (20) of each of the first to third aspects of the invention, the first and second intermediate-pressure gas refrigerants with different pressures are generated. The enthalpy reducing unit (20) reduces the enthalpy of refrigerant flowing from the ra-

diator to the evaporator in the course of generating the two types of intermediate-pressure gas refrigerant. The second intermediate-pressure gas refrigerant has the pressure lower than that of the first intermediate-pressure gas refrigerant, and therefore has a temperature lower than that of the first intermediate-pressure gas refrigerant. Thus, the enthalpy of refrigerant sent from the enthalpy reducing unit (20) to the evaporator is reduced as compared to a case where only the first intermediate-pressure gas refrigerant is generated in the enthalpy reducing unit (20).

[0018] In the refrigerants circuit (5) of the first aspect of the invention, low-pressure refrigerant is sucked into the compression mechanisms (71, 72). The first intermediate-pressure gas refrigerant is injected to the compression chamber (85) of the first compression mechanism (71) in the middle of the compression process through the first injection path (35). The first compression mechanism (71) compresses the low-pressure refrigerant and the first intermediate-pressure gas refrigerants which flow into the compression chamber (85), and discharges the compressed high-pressure refrigerant from the compression chamber (85). Meanwhile, the second intermediate-pressure gas refrigerant is injected to the compression chamber (95) of the second compression mechanism (72) in the middle of the compression process through the second injection path (45). The second compression mechanism (72) compresses the low-pressure refrigerant and the second intermediate-pressure gas refrigerant which flow into the compression chamber (95), and discharges the compressed high-pressure refrigerant from the compression chamber (95).

[0019] In the refrigerant circuit (5) of the second aspect of the invention, refrigerant is compressed in the first compression mechanism (71), and then is further compressed in the second compression mechanism (72). The first intermediate-pressure gas refrigerant is injected to the compression chamber (85) of the first compression mechanism (71) in the middle of the compression process through the first injection path (35). The first compression mechanism (71) compresses the low-pressure refrigerant and the first intermediate-pressure gas refrigerant which flow into the compression chamber (85), and discharges the compressed refrigerant from the compression chamber (85). If the second intermediate-pressure gas refrigerant is injected to the compression chamber (95) of the second compression mechanism (72) in the middle of the compression process through the second injection path (45), the second compression mechanism (72) compresses the refrigerant discharged from the first compression mechanism (71) and sucked into the compression chamber (95), and the second intermediate-pressure gas refrigerant injected to the compression chamber (95) through the second injection path (45), and discharges the compressed high-pressure refrigerant from the compression chamber (95). On the other hand, if the second intermediate-pressure gas refrigerant is injected to the inlet side of the second compression

mechanism (72) through the second injection path (45), the second compression mechanism (72) sucks and compresses the refrigerant discharged from the first compression mechanism (71), and the second intermediate-pressure gas refrigerant supplied through the second injection path (45) in the compression chamber (95), and discharges the compressed high-pressure refrigerant from the compression chamber (95).

[0020] In the refrigerant circuit (5) of the third aspect of the invention, refrigerant is compressed in the first compression mechanism (71), and then is further compressed in the second compression mechanism (72). The first compression mechanism (71) compresses the low-pressure refrigerant flowing into the compression chamber (85), and discharges the compressed refrigerant from the compression chamber (85). The second compression mechanism (72) sucks the refrigerant discharged from the first compression mechanism (71), and the first intermediate-pressure gas refrigerant supplied through the first injection path (35) into the compression chamber (95). In addition, the second intermediate-pressure gas refrigerant is injected to the compression chamber (95) of the second compression mechanism (72) in the middle of the compression process through the second injection path (45). The second compression mechanism (72) compresses the refrigerant sucked into the compression chamber (95), and the second intermediate-pressure gas refrigerant injected to the compression chamber (95) through the second injection path (45), and discharges the compressed high-pressure refrigerant from the compression chamber (95).

[0021] A fourth aspect of the invention is intended for the refrigerating apparatus of any one of the first to third aspects of the invention, in which, in the refrigerant circuit (5), a portion of the refrigerant circuit (5) from an outlet of the radiator to an inlet of the evaporator forms a main path (7); and the enthalpy reducing unit (20) includes a branched path (21) which is connected to the main path (7) and into which a part of refrigerant flowing through the main path (7) flows, an expansion mechanism (22) for expanding the refrigerant flowing into the branched path (21) to generate first intermediate-pressure refrigerant and second intermediate-pressure refrigerant having a pressure lower than that of the first intermediate-pressure refrigerant, a first heat exchanger (30) which is connected to the main path (7) downstream the radiator to exchange heat between the refrigerant flowing through the main path (7) and the first intermediate-pressure refrigerant, which cools the refrigerant flowing through the main path (7), and which generates the first intermediate-pressure gas refrigerant by evaporating the first intermediate-pressure refrigerant, and a second heat exchanger (40) which is connected to the main path (7) between the first heat exchanger (30) and the evaporator to exchange heat between the refrigerant flowing through the main path (7) and the second intermediate-pressure refrigerant, which cools the refrigerant flowing through the main path (7), and which generates the second intermediate-

pressure gas refrigerant by evaporating the second intermediate-pressure refrigerant.

[0022] In the fourth aspect of the invention, the branched path (21), the expansion mechanism (22), the first heat exchanger (30), and the second heat exchanger (40) are provided in the enthalpy reducing unit (20). A part of high-pressure refrigerant flowing out from the radiator to the main path (7) flows into the branched path (21). The high-pressure refrigerant flowing into the branched path (21) is expanded by the expansion mechanism (22). A part of such refrigerant is changed into the first intermediate-pressure refrigerant, and the remaining refrigerant is changed into the second intermediate-pressure refrigerant. The second intermediate-pressure refrigerant has the pressure and temperature lower than those of the first intermediate-pressure refrigerant.

[0023] In the fourth aspect of the invention, in the first heat exchanger (30), heat is exchanged between the first intermediate-pressure refrigerant and the high-pressure refrigerant flowing out from the radiator. In the first heat exchanger (30), the high-pressure refrigerant is cooled by the first intermediate-pressure refrigerant, and the enthalpy of the high-pressure refrigerant is reduced. Meanwhile, the first intermediate-pressure refrigerant is evaporated by absorbing heat from the high-pressure refrigerant, thereby generating the first intermediate-pressure gas refrigerant. The first intermediate-pressure gas refrigerant generated in the first heat exchanger (30) flows into the first injection path (35).

[0024] Further, in the fourth aspect of the invention, in the second heat exchanger (40), heat is exchanged between the second intermediate-pressure refrigerant and the high-pressure refrigerant flowing out from the first heat exchanger (30). In the second heat exchanger (40), the high-pressure refrigerant is cooled by the second intermediate-pressure refrigerant, and the enthalpy of the high-pressure refrigerant is reduced. Meanwhile, the second intermediate-pressure refrigerant is evaporated by absorbing heat from the high-pressure refrigerant, thereby generating the second intermediate-pressure gas refrigerant. The second intermediate-pressure gas refrigerant generated in the second heat exchanger (40) flows into the second injection path (45).

[0025] A fifth aspect of the invention is intended for the refrigerating apparatus of the fourth aspect of the invention, in which the branched path (21) of the enthalpy reducing unit (20) includes a first branched pipe (33) which is connected to the main path (7) between the radiator and the first heat exchanger (30), and which supplies refrigerant flowing from the main path (7) to the first heat exchanger (30), and a second branched pipe (43) which is connected to the main path (7) between the first heat exchanger (30) and the second heat exchanger (40), and which supplies the refrigerant flowing from the main path (7) to the second heat exchanger (40); and the expansion mechanism (22) of the enthalpy reducing unit (20) includes a first expansion valve (34) which is provided in the first branched pipe (33), and which generates the first

intermediate-pressure refrigerant by expanding refrigerant flowing into the first branched pipe (33), and a second expansion valve (44) which is provided in the second branched pipe (43), and which generates the second intermediate-pressure refrigerant by expanding refrigerant flowing into the second branched pipe (43).

[0026] In the fifth aspect of the invention, the branched path (21) includes the first branched pipe (33) and the second branched pipe (43), and the expansion mechanism (22) includes the first expansion valve (34) and the second expansion valve (44). A part of high-pressure refrigerant flowing from the radiator to the first heat exchanger (30) through the main path (7) flows into the first branched pipe (33). The high-pressure refrigerant flowing into the first branched pipe (33) is expanded into the first intermediate-pressure refrigerant when passing through the first expansion valve (34), and then is supplied to the first heat exchanger (30). In the first heat exchanger (30), the supplied first intermediate-pressure refrigerant is evaporated into the first intermediate-pressure gas refrigerant. Meanwhile, a part of high-pressure refrigerant flowing from the first heat exchanger (30) to the second heat exchanger (40) through the main path (7) (i.e., high-pressure refrigerant cooled in the first heat exchanger (30)) flows into the second branched pipe (43). The high-pressure refrigerant flowing into the second branched pipe (43) is expanded into the second intermediate-pressure refrigerant when passing through the second expansion valve (44), and then is supplied to the second heat exchanger (40). In the second heat exchanger (40), the supplied second intermediate-pressure refrigerant is evaporated into the second intermediate-pressure gas refrigerant.

[0027] A sixth aspect of the invention is intended for the refrigerating apparatus of the fourth aspect of the invention, in which the branched path (21) of the enthalpy reducing unit (20) includes a first branched pipe (33) which is connected to the main path (7) between the radiator and the first heat exchanger (30), and which supplies refrigerant flowing from the main path (7) to the first heat exchanger (30), and a second branched pipe (43) which is connected to the first branched pipe (33), and which supplies refrigerant flowing from the first branched pipe (33) to the second heat exchanger (40); and the expansion mechanism (22) of the enthalpy reducing unit (20) includes a first expansion valve (34) which is provided in the first branched pipe (33), and which generates the first intermediate-pressure refrigerant by expanding refrigerant flowing into the first branched pipe (33), and a second expansion valve (44) which is provided in the second branched pipe (43), and which generates the second intermediate-pressure refrigerant by expanding refrigerant flowing into the second branched pipe (43).

[0028] In the sixth aspect of the invention, the branched path (21) includes the first branched pipe (33) and the second branched pipe (43), and the expansion mechanism (22) includes the first expansion valve (34) and the second expansion valve (44). A part of high-pres-

sure refrigerant flowing from the radiator to the first heat exchanger (30) through the main path (7) flows into the first branched pipe (33). A part of the refrigerant flowing into the first branched pipe (33) is supplied to the first heat exchanger (30). The remaining refrigerant flows into the second branched pipe (43), and is supplied to the second heat exchanger (40). The refrigerant supplied to the first heat exchanger (30) through the first branched pipe (33) is expanded into the first intermediate-pressure refrigerant when passing through the first expansion valve (34), and then is supplied to the first heat exchanger (30). In the first heat exchanger (30), the supplied first intermediate-pressure refrigerant is evaporated into the first intermediate-pressure gas refrigerant. Meanwhile, the refrigerant supplied to the second heat exchanger (40) through the second branched pipe (43) is expanded into the second intermediate-pressure refrigerant when passing through the second expansion valve (44), and then is supplied to the second heat exchanger (40). In the second heat exchanger (40), the supplied second intermediate-pressure refrigerant is evaporated into the second intermediate-pressure gas refrigerant.

[0029] A seventh aspect of the invention is intended for the refrigerating apparatus of any one of the first to third aspects of the invention, in which the enthalpy reducing unit (20) includes a first expansion valve (37) for expanding high-pressure refrigerant flowing out from the radiator, a first gas-liquid separator (36) for separating the refrigerant flowing out from the first expansion valve (37) in a gas-liquid two-phase state into gas refrigerant and liquid refrigerant, and supplying the gas refrigerant to the first injection path (35) as the first intermediate-pressure gas refrigerant, a second expansion valve (47) for expanding the liquid refrigerant flowing out from the first gas-liquid separator (36), and a second gas-liquid separator (46) for separating the refrigerant flowing out from the second expansion valve (47) in the gas-liquid two-phase state into gas refrigerant and liquid refrigerant, supplying the gas refrigerant to the second injection path (45) as the second intermediate-pressure gas refrigerant, and supplying the liquid refrigerant to the evaporator.

[0030] In the seventh aspect of the invention, the first expansion valve (37), the first gas-liquid separator (36), the second expansion valve (47), and the second gas-liquid separator (46) are provided in the enthalpy reducing unit (20). In the refrigerant circuit (5), the first expansion valve (37), the first gas-liquid separator (36), the second expansion valve (47), and the second gas-liquid separator (46) are arranged in this order from the radiator to the evaporator.

[0031] In the seventh aspect of the invention, high-pressure refrigerant flowing out from the radiator is expanded into the gas-liquid two-phase state when passing through the first expansion valve (37). Then, such refrigerant flows into the first gas-liquid separator (36), and is separated into liquid refrigerant and gas refrigerant. The gas refrigerant in the first gas-liquid separator (36) flows into the first injection path (35) as the first intermediate-

pressure gas refrigerant. The liquid refrigerant in the first gas-liquid separator (36) is in a saturated state, and the enthalpy of the liquid refrigerant is lower than that of the refrigerant which is sent to the first gas-liquid separator (36) through the first expansion valve (37) in the gas-liquid two-phase state.

[0032] In the seventh aspect of the invention, the liquid refrigerant in the first gas-liquid separator (36) is expanded into the gas-liquid two-phase state when passing through the second expansion valve (47). Then, such refrigerant flows into the second gas-liquid separator (46), and is separated into liquid refrigerant and gas refrigerant. The gas refrigerant in the second gas-liquid separator (46) flows into the second injection path (45) as the second intermediate-pressure gas refrigerant. The liquid refrigerant in the second gas-liquid separator (46) is in the saturated state, and the enthalpy of the liquid refrigerant is lower than that of the refrigerant which is sent to the second gas-liquid separator (46) through the second expansion valve (47) in the gas-liquid two-phase state. The liquid refrigerant in the second gas-liquid separator (46) is supplied to the evaporator.

[0033] An eighth aspect of the invention is intended for the refrigerating apparatus of any one of the first to seventh aspects of the invention, in which the first compression mechanism (71) and the second compression mechanism (72) are provided in a single compressor (50), and the compressor (50) includes a single drive shaft (65) engaged with both of the first compression mechanism (71) and the second compression mechanism (72).

[0034] In the eighth aspect of the invention, both of the first compression mechanism (71) and the second compression mechanism (72) are driven by the single drive shaft (65).

[0035] A ninth aspect of the invention is intended for the refrigerating apparatus of any one of the first to seventh aspects of the invention, in which the first compression mechanism (71) is provided in a first compressor (50a), and the second compression mechanism (72) is provided in a second compressor (50b), and the first compressor (50a) includes a drive shaft (65a) engaged with the first compression mechanism (71), and the second compression mechanism (72) includes a drive shaft (65b) engaged with the second compression mechanism (72).

[0036] In the ninth aspect of the invention, the first compression mechanism (71) is driven by the drive shaft (65a), and the second compression mechanism (72) is driven by the drive shaft (65b).

ADVANTAGES OF THE INVENTION

[0037] The first intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) of the present invention is higher in the pressure and density than the second intermediate-pressure gas refrigerant. In the compressor (50) of the present invention, the second intermediate-pressure gas refrigerant is supplied to the second compression mechanism (72), and the first

intermediate-pressure gas refrigerant having the pressure and density higher than those of the second intermediate-pressure gas refrigerant is supplied to the first compression mechanism (71). Thus, according to the present invention, a mass flow rate of refrigerant discharged from the compressor (50) can be increased as compared to a case where only the second intermediate-pressure gas refrigerant is supplied to the compression mechanism (71, 72). In the present invention, since the first and second intermediate-pressure gas refrigerants are injected to the compression chambers (85, 95) in the middle of the compression process, a mass flow rate of low-pressure refrigerant sucked into the compressor (50) from the evaporator is not increased, and only the mass flow rate of refrigerant discharged from the compressor (50) to the radiator is increased. Thus, according to the present invention, while reducing an increase in energy required for driving the compressor (50), the mass flow rate of refrigerant discharged from the compressor (50) can be increased, and an amount of heat released from refrigerant to a target object such as air in the radiator (i.e., a heat dissipation amount of refrigerant) can be increased.

[0038] In the present invention, not only the first intermediate-pressure gas refrigerant but also the second intermediate-pressure gas refrigerant having the pressure and temperature lower than those of the first intermediate-pressure gas refrigerant are generated in the enthalpy reducing unit (20). Thus, according to the present invention, the enthalpy of refrigerant sent from the enthalpy reducing unit (20) to the evaporator is reduced as compared to the case where only the first intermediate-pressure gas refrigerant is generated in the enthalpy reducing unit (20). Consequently, an amount of heat absorbed from the target object such as air by refrigerant in the evaporator (i.e., a heat absorption amount of refrigerant) can be increased.

[0039] As described above, according to the present invention, an increase in mass flow rate of refrigerant in the radiator results in an increase in heat dissipation amount of refrigerant in the radiator. Further, a reduction in enthalpy of refrigerant flowing into the evaporator results in an increase in heat absorption amount of refrigerant in the evaporator. Thus, according to the present invention, both of the heat dissipation amount of refrigerant in the radiator and the heat absorption amount of refrigerant in the evaporator can be ensured.

[0040] In a refrigerant circuit in which a multiple-stage compression refrigeration cycle is performed, intermediate-pressure gas refrigerant is supplied to each section between compressors. That is, in, e.g., a refrigerant circuit in which a three-stage compression refrigeration cycle is performed, intermediate-pressure gas refrigerant is supplied between a compressor at a first stage and a compressor at a second stage, and between the compressor at the second stage and a compressor at a third stage.

[0041] On the other hand, in the refrigerant circuit of

the present invention, the first and second intermediate-pressure gas refrigerants with different pressures are generated in the enthalpy reducing unit (20). Thus, in the refrigerant circuit of the present invention, employment of a "configuration in which three compression mechanisms are used to perform a three-stage compression refrigeration cycle, the second intermediate-pressure gas refrigerant is supplied between a compression mechanism at a first stage and a compression mechanism at a second stage, and the first intermediate-pressure gas refrigerant is supplied between the compression mechanism at the second stage and a compression mechanism at a third stage" is technically allowed.

[0042] However, if such a configuration is employed in the refrigerant circuit of the present invention, there are problems that operational efficiency of the refrigerating apparatus cannot be sufficiently improved, and a manufacturing cost of the refrigerating apparatus is increased. Such problems will be described below.

[0043] Typically, a three-stage compression refrigeration cycle is performed when only a low COP (coefficient of performance) can be obtained in a two-stage compression refrigerant cycle or a single-stage compression refrigeration cycle due to a large difference between low and high pressure levels of the refrigeration cycle.

[0044] On the other hand, in the present invention, the "configuration in which the enthalpy reducing unit (20) configured to reduce the enthalpy of refrigerant flowing toward the evaporator generates the first and second intermediate-pressure gas refrigerants with different pressures" is employed in order to accomplish the objective which is to "ensure both of the heat dissipation amount of refrigerant in the radiator and the heat absorption amount of refrigerant in the evaporator." That is, in order to accomplish the objective of the present invention, it may be required that the "configuration in which the enthalpy reducing unit (20) generates the first and second intermediate-pressure gas refrigerants" is employed even when the "difference between the low and high pressure levels of the refrigeration cycle is not so large, and a sufficiently high COP can be obtained in the two-stage compression refrigeration cycle or the single-stage compression refrigeration cycle."

[0045] Since the compression mechanism for compressing refrigerant typically includes a plurality of members, a mechanical loss such as a friction loss between the members is caused in the compression mechanism. Thus, the greater number of compression mechanisms results in a greater overall mechanical loss caused in each of the compression mechanisms. In addition, the greater number of compression mechanisms provided in the refrigerating apparatus results in a higher manufacturing cost of the refrigerating apparatus. For such reasons, even when the "difference between the low and high pressure levels of the refrigeration cycle is not so large, and the sufficiently high COP can be obtained in the two-stage compression refrigeration cycle or the single-stage compression refrigeration cycle," if the "config-

uration in which the three compression mechanisms are used to perform the three-stage compression refrigeration cycle" is employed, there are problems that an increase in mechanical loss in the compression mechanism causes degradation of the operational efficiency of the refrigerating apparatus, and an increase in the number of compression mechanisms causes an increase in manufacturing cost of the refrigerating apparatus.

[0046] On the other hand, in the first aspect of the invention, in the refrigerant circuit (5) in which the single-stage compression refrigeration cycle is performed, the first and second intermediate-pressure gas refrigerants generated in the enthalpy reducing unit (20) are sucked into the compression mechanisms (71, 72). In addition, in each of the second and third aspects of the invention, in the refrigerant circuit (5) in which the two-stage compression refrigeration cycle, the first and second intermediate-pressure gas refrigerants generated in the enthalpy reducing unit (20) are sucked into the compression mechanisms (71, 72).

[0047] As described above, according to the present invention, even in the refrigerant circuit (5) in which the single-stage compression refrigeration cycle or the two-stage compression refrigeration cycle is performed, the first and second intermediate-pressure gas refrigerants generated in the enthalpy reducing unit (20) can be sucked into the compression mechanisms (71, 72). Thus, according to the present invention, a situation can be avoided, in which the "three-stage compression refrigeration cycle is performed only for the purpose of processing the first and second intermediate-pressure gas refrigerants generated in the enthalpy reducing unit (20) even through the difference between the low and high pressure levels of the refrigeration cycle is not so large." Consequently, the problems such as the increase in mechanical loss and the increase in manufacturing cost due to the increase in the number of compression mechanisms can be solved.

[0048] In the fourth aspect of the invention, the first heat exchanger (30) and the second heat exchanger (40) are provided in the enthalpy reducing unit (20). In the first heat exchanger (30), high-pressure refrigerant flowing out from the radiator is cooled by the first intermediate-pressure refrigerant. In the second heat exchanger (40), the high-pressure refrigerant cooled in the first heat exchanger (30) is further cooled by the second intermediate-pressure refrigerant. Thus, according to the present invention, the reduction in enthalpy of refrigerant sent from the radiator to the evaporator can be ensured in the course of generating the first and second intermediate-pressure gas refrigerants.

[0049] In the seventh aspect of the invention, the first gas-liquid separator (36) and the second gas-liquid separator (46) are provided in the enthalpy reducing unit (20). The first gas-liquid separator (36) sends only saturated liquid refrigerant having an enthalpy lower than that of refrigerant which is supplied to the first gas-liquid separator (36) through the first expansion valve (37) in the

gas-liquid two-phase state, to the second gas-liquid separator (46). In addition, the second gas-liquid separator (46) sends only saturated liquid refrigerant having an enthalpy lower than that of refrigerant which is supplied to the second gas-liquid separator (46) through the second expansion valve (47) in the gas-liquid two-phase state, to the evaporator. Thus, according to the present invention, the reduction in enthalpy of refrigerant sent from the radiator to the evaporator can be ensured in the course of generating the first and second intermediate-pressure gas refrigerants.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050]

[FIG. 1] FIG. 1 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a first embodiment.

[FIG. 2] FIG. 2 is a longitudinal sectional view of a compressor of the first embodiment.

[FIG. 3] FIGS. 3 are cross-sectional views of a main section of the compressor of the first embodiment. FIG. 3(A) is a cross-sectional view of a first compression mechanism, and FIG. 3(B) is a cross-sectional view of a second compression mechanism.

[FIG. 4] FIG. 4 is a Mollier diagram (pressure-enthalpy diagram) illustrating a refrigeration cycle performed in a refrigerant circuit of the first embodiment.

[FIG. 5] FIG. 5 is a refrigerant circuit diagram illustrating a "configuration of an air conditioner of a second embodiment.

[FIG. 6] FIG. 6 is a Mollier diagram (pressure-enthalpy diagram) illustrating a refrigeration cycle performed in a refrigerant circuit of the second embodiment.

[FIG. 7] FIG. 7 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a first variation of the second embodiment.

[FIG. 8] FIG. 8 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a second variation of the second embodiment.

[FIG. 9] FIG. 9 is a Mollier diagram (pressure-enthalpy diagram) illustrating a refrigeration cycle performed in a refrigerant circuit of the second variation of the second embodiment.

[FIG. 10] FIG. 10 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a third embodiment.

[FIG. 11] FIG. 11 is a Mollier diagram (pressure-enthalpy diagram) illustrating a refrigeration cycle performed in a refrigerant circuit of the third embodiment.

[FIG. 12] FIG. 12 is a schematic perspective view illustrating a configuration of a heat exchange member of a first variation of other embodiment.

[FIG. 13] FIG. 13 is a schematic side view illustrating the configuration of the heat exchange member of

the first variation of the other embodiment.

[FIG. 14] FIG. 14 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a second variation of the other embodiment.

[FIG. 15] FIG. 15 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a third variation of the other embodiment.

[FIG. 16] FIG. 16 is a Mollier diagram (pressure-enthalpy diagram) illustrating a refrigeration cycle performed in a refrigerant circuit of the third variation of the other embodiment.

[FIG. 17] FIG. 17 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a fourth variation of the other embodiment.

[FIG. 18] FIG. 18 is a Mollier diagram (pressure-enthalpy diagram) illustrating a refrigeration cycle performed in a refrigerant circuit of the fourth variation of the other embodiment.

[FIG. 19] FIG. 19 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of the fourth variation of the other embodiment.

[FIG. 20] FIG. 20 is a refrigerant circuit diagram illustrating a configuration of an air conditioner of a fifth variation of the other embodiment.

[FIG. 21] FIG. 21 is another refrigerant circuit diagram illustrating the configuration of the air conditioner of the fifth variation of the other embodiment.

[FIG. 22] FIG. 22 is another refrigerant circuit diagram illustrating the configuration of the air conditioner of the fifth variation of the other embodiment.

DESCRIPTION OF EMBODIMENTS

[0051] Embodiments of the present invention will be described below in detail with reference to the drawings.

[0052] «First Embodiment of the Invention»

A first embodiment of the present invention will be described. The present embodiment is intended for an air conditioner (1) configured by a refrigerating apparatus.

[0053] <configuration of Refrigerant Circuit>

The air conditioner (1) of the present embodiment includes a refrigerant circuit (5). The refrigerant circuit (5) is a closed circuit filled with refrigerant, and refrigerant circulates to perform a vapor compression refrigeration cycle. The refrigerant circuit (5) is filled with zeotropic refrigerant mixture containing 2, 3, 3, 3-tetrafluoro-1-propene (HFO-1234yf) which is a high-boiling component and HFC-32 (difluoromethane) which is a low-boiling component.

[0054] As illustrated in FIG. 1, the refrigerant circuit (5) includes a compressor (50), a four-way valve (11), and an outdoor heat exchanger (12), a bridge circuit (15), and an indoor heat exchanger (14). A discharge pipe (52) of the compressor (50) is connected to a first port of the four-way valve (11), and suction pipes (53, 54) of the compressor (50) are connected to a second port of the four-way valve (11). A gas inlet/outlet end of the outdoor heat exchanger (12) is connected to a third port of the

four-way valve (11), and a liquid inlet/outlet end of the outdoor heat exchanger (12) is connected to the bridge circuit (15). A gas inlet/outlet end of the indoor heat exchanger (14) is connected to a fourth port of the four-way valve (11), and a liquid inlet/outlet end of the indoor heat exchanger (14) is connected to the bridge circuit (15).

[0055] The compressor (50) is a hermetic rotary compressor. In the compressor (50), a main body (70) including a first compression mechanism (71) and a second compression mechanism (72), an electric motor (60) for driving the main body (70), and a drive shaft (65) connecting between the main body (70) and the electric motor (60) are accommodated in a casing (51). The compressor (50) will be described in detail later.

[0056] The four-way valve (11) is switchable between a first state (state indicated by a solid line in FIG. 1) in which the first port is communicated with the third port, and the second port is communicated with the fourth port; and a second state (state indicated by a dashed line in FIG. 1) in which the first port is communicated with the fourth port, and the second port is communicated with the third port. In the outdoor heat exchanger (12), heat is exchanged between outdoor air and refrigerant. In the indoor heat exchanger (14), heat is exchanged between room air and refrigerant.

[0057] The bridge circuit (15) includes four check valves (16-19). In the bridge circuit (15), an outlet side of the first check valve (16) and an outlet side of the second check valve (17) are connected together, and an inlet side of the second check valve (17) and an outlet side of the third check valve (18) are connected together. In addition, an inlet side of the third check valve (18) and an inlet side of the fourth check valve (19) are connected together, and an outlet side of the fourth check valve (19) and an inlet side of the first check valve (16) are connected together. Further, in the bridge circuit (15), the liquid inlet/outlet end of the outdoor heat exchanger (12) is connected between the fourth check valve (19) and the first check valve (16), and the liquid inlet/outlet end of the indoor heat exchanger (14) is connected between the second check valve (17) and the third check valve (18).

[0058] A one-way circulation pipe line (6) is provided in the refrigerant circuit (5). An inlet end of the one-way circulation pipe line (6) is connected to the bridge circuit (15) between the first check valve (16) and the second check valve (17), and an outlet end of the one-way circulation pipe line (6) is connected to the bridge circuit (15) between the third check valve (18) and the fourth check valve (19). In the one-way circulation pipe line (6), refrigerant constantly flows from the inlet end toward the outlet end. In the refrigerant circuit (5), a main path (7) is formed by the pipe connecting between the liquid inlet/outlet end of the outdoor heat exchanger (12) and the bridge circuit (15), the pipe connecting between the liquid inlet/outlet end of the indoor heat exchanger (14) and the bridge circuit (15), the bridge circuit (15), and the one-way circulation pipe line (6).

[0059] A first heat exchanger (30), a second heat ex-

changer (40), and a main expansion valve (13) are connected to the one-way circulation pipe line (6) in this order from the inlet end toward the outlet end. The main expansion valve (13) is a so-called "electronic expansion valve." Each of the first heat exchanger (30) and the second heat exchanger (40) includes a high-pressure flow path (31, 41) and an intermediate-pressure flow path (32, 42), and is configured so that heat is exchanged between refrigerant flowing through the high-pressure flow path (31, 41) and refrigerant flowing through the intermediate-pressure flow path (32, 42). The high-pressure flow paths (31, 41) of the first heat exchanger (30) and the second heat exchanger (40) are connected to the one-way circulation pipe line (6).

[0060] A first branched pipe (33) and a first injection pipe (35) are connected to the intermediate-pressure flow path (32) of the first heat exchanger (30). One end of the first branched pipe (33) is connected to the one-way circulation pipe line (6) upstream the first heat exchanger (30), and the other end of the first branched pipe (33) is connected to an inlet end of the intermediate-pressure flow path (32) of the first heat exchanger (30). A first expansion valve (34) which is a so-called "electronic expansion valve" is provided in the first branched pipe (33). The first expansion valve (34) expands high-pressure refrigerant flowing into the first branched pipe (33) from the one-way circulation pipe line (6) to generate first intermediate-pressure refrigerant. One end of the first injection pipe (35) is connected to an outlet end of the intermediate-pressure flow path (32) of the first heat exchanger (30), and the other end of the first injection pipe (35) is connected to the first compression mechanism (71) of the compressor (50).

[0061] A second branched pipe (43) and a second injection pipe (45) are connected to the intermediate-pressure flow path (42) of the second heat exchanger (40). One end of the second branched pipe (43) is connected to the one-way circulation pipe line (6) between the first heat exchanger (30) and the second heat exchanger (40), and the other end of the second branched pipe (43) is connected to an inlet side of the intermediate-pressure flow path (42) of the second heat exchanger (40). A second expansion valve (44) which is a so-called "electronic expansion valve" is provided in the second branched pipe (43). The second expansion valve (44) expands high-pressure refrigerant flowing into the second branched pipe (43) from the one-way circulation pipe line (6) to generate second intermediate-pressure refrigerant. One end of the second injection pipe (45) is connected to an outlet side of the intermediate-pressure flow path (42) of the second heat exchanger (40), and the other end of the second injection pipe (45) is connected to the second compression mechanism (72) of the compressor (50).

[0062] In the refrigerant circuit (5) of the present embodiment, the first heat exchanger (30), the first branched pipe (33), the first expansion valve (34), the second heat exchanger (40), the second branched pipe (43), and the

second expansion valve (44) form an enthalpy reducing unit (20) configured to reduce an enthalpy of refrigerant flowing through the one-way circulation pipe line (6). In addition, in the refrigerant circuit (5), the first branched pipe (33) and the second branched pipe (43) form a branched path (21), and the first expansion valve (34) and the second expansion valve (44) form an expansion mechanism (22). Further, in the refrigerant circuit (5), the first injection pipe (35) forms a first injection path, and the second injection pipe (45) forms a second injection path.

[0063] <Configuration of Compressor>

As illustrated in FIG. 2, the compressor (50) includes the casing (51), the main body (70), the electric motor (60), and the drive shaft (65). The casing (51) is formed in an elongated hollow cylindrical shape which is closed at both ends. The electric motor (60) is arranged above the main body (70) in the casing (51). In a top portion of the casing (51), the discharge pipe (52) is provided so as to penetrate the casing (51).

[0064] The electric motor (60) includes a stator (61) and a rotor (62). The stator (61) is fixed to a portion of a body section of the casing (51) closer to the top. The rotor (62) is arranged inside the stator (61).

[0065] The drive shaft (65) includes a main shaft portion (68), a first eccentric portion (66), and a second eccentric portion (67). A portion of the main shaft portion (68) closer to its upper end is connected to the rotor (62). The first eccentric portion (66) and the second eccentric portion (67) are formed closer to a lower end of the main shaft portion (68). The first eccentric portion (66) is arranged above the second eccentric portion (67). An outer diameter of each of the first eccentric portion (66) and the second eccentric portion (67) is larger than an outer diameter of the main shaft portion (68), and each of the first eccentric portion (66) and the second eccentric portion (67) is eccentric to the center of the main shaft portion (68). An eccentric direction of one of the first eccentric portion (66) and the second eccentric portion (67) relative to the center of the main shaft portion (68) is opposite to an eccentric direction of the remaining one of the first eccentric portion (66) and the second eccentric portion (67). An oil supply path (69) upwardly extending from the lower end of the main shaft portion (68) is formed in the main shaft portion (68).

[0066] The main body (70) includes a front heat (73), a first cylinder (81), a middle plate (75), a second cylinder (91), and a rear head (74), and forms a swing piston type rotary fluid machine. The rear head (74), the second cylinder (91), the middle plate (75), the first cylinder (81), and the front heat (73) are stacked in the main body (70) in this order from the bottom to the top, and are fastened together with bolts which are not shown in the figure.

[0067] As illustrated in FIGS. 3(A) and 3(B), a first piston (82) is accommodated in the first cylinder (81), and a second piston (92) is accommodated in the second cylinder (91). The piston (82, 92) is formed in a slightly-thick cylindrical shape with a low height. The first eccen-

tric portion (66) is inserted into the first piston (82), and the second eccentric portion (67) is inserted into the second piston (92). A flat plate-like blade (83, 93) protruding from an outer circumferential surface of the piston (82, 92) is integrally formed with the piston (82, 92). The blade (83) integrally formed with the first piston (82) is supported by the first cylinder (81) through a pair of bushes (84). The blade (93) integrally formed with the second piston (92) is supported by the second cylinder (91) through a pair of bushes (94).

[0068] In the first cylinder (81) sandwiched between the front heat (73) and the middle plate (75), a first compression chamber (85) is formed between an inner circumferential surface of the first cylinder (81) and an outer circumferential surface of the first piston (82). The first compression chamber (85) is divided into low-pressure and high-pressure sides by the blade (83). In the second cylinder (91) sandwiched between the middle plate (75) and the rear head (74), a second compression chamber (95) is formed between an inner circumferential surface of the second cylinder (91) and an outer circumferential surface of the second piston (92). The second compression chamber (95) is divided into low-pressure and high-pressure sides by the blade (93).

[0069] A first suction port (86) is formed in the first cylinder (81). In addition, a second suction port (96) is formed in the second cylinder (91). In the cylinder (81, 91), the suction port (86, 96) penetrates the cylinder (81, 91) in a radial direction. The suction port (86, 96) opens onto the inner circumferential surface of the cylinder (81, 91) near the right side of the blade (83, 93) as viewed in FIGS. 3(A) and 3(B). The suction pipe (53) is inserted into the first suction port (86), and the suction pipe (54) is inserted into the second suction port (96). The suction pipe (53, 54) extends to an outside of the casing (51).

[0070] A first discharge port (87) is formed in the front heat (73). The first discharge port (87) penetrates the front heat (73). The first discharge port (87) opens onto a front surface (lower surface) of the front heat (73) near the left side of the blade (83) as viewed in FIG. 3(A). A first discharge valve (88) configured to open/close the first discharge port (87) is provided in the front heat (73).

[0071] A second discharge port (97) is formed in the rear head (74). The second discharge port (97) penetrates the rear head (74). The second discharge port (97) opens onto a front surface (upper surface) of the rear head (74) near the left side of the blade (93) as viewed in FIG. 3(B). A second discharge valve (98) configured to open/close the second discharge port (97) is provided in the rear head (74).

[0072] A first injection port (89) is formed in the middle plate (75). One end of the first injection port (89) opens onto an upper surface of the middle plate (75), and the other end of the first injection port (89) opens onto an outer surface of the middle plate (75). The one end of the first injection port (89) opens onto the upper surface of the middle plate (75) in a portion facing the first compression chamber (85). The first injection pipe (35) is

inserted into the other end of the first injection port (89).

[0073] A second injection port (99) is formed in the rear head (74). One end of the second injection port (99) opens onto the front surface (upper surface) of the rear head (74), and the other end of the second injection port (99) opens onto an outer surface of the rear head (74). The one end of the second injection port (99) opens onto the front surface of the rear head (74) in a portion facing the second compression chamber (95). The second injection pipe (45) is injected into the other end of the second injection port (99).

[0074] In the main body (70) of the compressor (50) of the present embodiment, the front heat (73), the first cylinder (81), the middle plate (75), the first piston (82), and the blade (83) form the first compression mechanism (71) defining the first compression chamber (85). In addition, in the main body (70), the rear head (74), the second cylinder (91), the middle plate (75), the second piston (92), and the blade (93) form the second compression mechanism (72) defining the second compression chamber (95).

[0075] Operation

The air conditioner (1) of the present embodiment switches between cooling and heating operations.

[0076] <Cooling Operation of Air Conditioner>

A process in the air conditioner (1) during the cooling operation will be described with reference to FIG. 1. In the cooling operation, the four-way valve (11) is set to the first state (state indicated by the solid line in FIG. 1), and degrees of opening of the first expansion valve (34), the second expansion valve (44), and the main expansion valve (13) are adjusted as necessary. When driving the compressor (50) in such a state, refrigerant circulates in the refrigerant circuit (5) as indicated by solid arrows in FIG. 1, thereby performing the vapor compression refrigeration cycle. At this point, the outdoor heat exchanger (12) is operated as a condenser (i.e., a radiator), and the indoor heat exchanger (14) is operated as an evaporator.

[0077] Refrigerant discharged from the compressor (50) flows into the outdoor heat exchanger (12) through the four-way valve (11). Such refrigerant dissipates heat to outdoor air, and is condensed. Subsequently, the refrigerant flows into the one-way circulation pipe line (6) through the first check valve (16) of the bridge circuit (15).

[0078] A part of the high-pressure refrigerant flowing into the one-way circulation pipe line (6) flows into the first branched pipe (33), and the remaining refrigerant flows into the high-pressure flow path (31) of the first heat exchanger (30). The high-pressure refrigerant flowing into the first branched pipe (33) is expanded into first intermediate-pressure refrigerant when passing through the first expansion valve (34), and then flows into the intermediate-pressure flow path (32) of the first heat exchanger (30). In the first heat exchanger (30), the high-pressure refrigerant flowing through the high-pressure flow path (31) is cooled, and the first intermediate-pressure refrigerant flowing through the intermediate-pres-

sure flow path (32) is evaporated into first intermediate-pressure gas refrigerant. The first intermediate-pressure gas refrigerant is sent to the compressor (50) through the first injection pipe (35).

[0079] A part of the high-pressure refrigerant flowing out from the high-pressure flow path (31) of the first heat exchanger (30) flows into the second branched pipe (43), and the remaining refrigerant flows into the high-pressure flow path (41) of the second heat exchanger (40). The high-pressure refrigerant flowing into the second branched pipe (43) is expanded into second intermediate-pressure refrigerant when passing through the second expansion valve (44), and then flows into the intermediate-pressure flow path (42) of the second heat exchanger (40). In the second heat exchanger (40), the high-pressure refrigerant flowing through the high-pressure flow path (41) is cooled, and the second intermediate-pressure refrigerant flowing through the intermediate-pressure flow path (42) is evaporated into second intermediate-pressure gas refrigerant. The second intermediate-pressure gas refrigerant is sent to the compressor (50) through the second injection pipe (45).

[0080] The high-pressure refrigerant flowing out from the high-pressure flow path (41) of the second heat exchanger (40) is expanded into low-pressure refrigerant when passing through the main expansion valve (13). The low-pressure refrigerant flows into the indoor heat exchanger (14) through the third check valve (18) of the bridge circuit (15). Such refrigerant absorbs heat from room air, and is evaporated. Subsequently, the refrigerant is sucked into the main body (70) of the compressor (50) through the four-way valve (11). In the indoor heat exchanger (14), the room air is cooled by exchanging heat with the refrigerant, and the cooled room air is sent back to a room.

[0081] <Heating Operation of Air Conditioner>

A process in the air conditioner (1) during the heating operation will be described with reference to FIG. 1. In the heating operation, the four-way valve (11) is set to the second state (state indicated by the dashed line in FIG. 1), and the degrees of opening of the first expansion valve (34), the second expansion valve (44), and the main expansion valve (13) are adjusted as necessary. When driving the compressor (50) in such a state, refrigerant circulates in the refrigerant circuit (5) as indicated by dashed arrows in FIG. 1, thereby performing the vapor compression refrigeration cycle. At this point, in the refrigerant circuit (5), the indoor heat exchanger (14) is operated as the condenser (i.e., the radiator), and the outdoor heat exchanger (12) is operated as the evaporator.

[0082] Refrigerant discharged from the compressor (50) flows into the indoor heat exchanger (14) through the four-way valve (11). Such refrigerant dissipates heat to room air, and is condensed. Subsequently, the refrigerant flows into the one-way circulation pipe line (6) through the second check valve (17) of the bridge circuit (15). In the indoor heat exchanger (14), the room air is heated by exchanging heat with the refrigerant, and the

heated room air is sent back to the room.

[0083] A part of the high-pressure refrigerant flowing into the one-way circulation pipe line (6) flows into the first branched pipe (33), and the remaining refrigerant flows into the high-pressure flow path (31) of the first heat exchanger (30). The high-pressure refrigerant flowing into the first branched pipe (33) is expanded into first intermediate-pressure refrigerant when passing through the first expansion valve (34), and then flows into the intermediate-pressure flow path (32) of the first heat exchanger (30). In the first heat exchanger (30), the high-pressure refrigerant flowing through the high-pressure flow path (31) is cooled, and the first intermediate-pressure refrigerant flowing through the intermediate-pressure flow path (32) is evaporated into first intermediate-pressure gas refrigerant. The first intermediate-pressure gas refrigerant is sent to the compressor (50) through the first injection pipe (35).

[0084] A part of the high-pressure refrigerant flowing out from the high-pressure flow path (31) of the first heat exchanger (30) flows into the second branched pipe (43), and the remaining refrigerant flows into the high-pressure flow path (41) of the second heat exchanger (40). The high-pressure refrigerant flowing into the second branched pipe (43) is expanded into second intermediate-pressure refrigerant when passing through the second expansion valve (44), and then flows into the intermediate-pressure flow path (42) of the second heat exchanger (40). In the second heat exchanger (40), the high-pressure refrigerant flowing through the high-pressure flow path (41) is cooled, and the second intermediate-pressure refrigerant flowing through the intermediate-pressure flow path (42) is evaporated into second intermediate-pressure gas refrigerant. The second intermediate-pressure gas refrigerant is sent to the compressor (50) through the second injection pipe (45).

[0085] The high-pressure refrigerant flowing out from the high-pressure flow path (41) of the second heat exchanger (40) is expanded into low-pressure refrigerant when passing through the main expansion valve (13). The low-pressure refrigerant flows into the outdoor heat exchanger (12) through the fourth check valve (19) of the bridge circuit (15). Such refrigerant absorbs heat from outdoor air, and is evaporated. Subsequently, the refrigerant is sucked into the main body (70) of the compressor (50) through the four-way valve (11).

[0086] <Operation of Compressor>

An operation of the compressor (50) will be described with reference to FIGS. 2, 3(A), and 3(B). As described above, the main body (70) of the compressor (50) sucks low-pressure refrigerant from either one of the outdoor heat exchanger (12) and the indoor heat exchanger (14), which is operated as the evaporator. A half of the low-pressure refrigerant flowing into the compressor (50) is sucked into the first compression chamber (85) of the first compression mechanism (71), and the remaining half of the low-pressure refrigerant is sucked into the second compression chamber (95) of the second compres-

sion mechanism (72).

[0087] In the first compression mechanism (71), the low-pressure refrigerant is sucked into the first compression chamber (85) through the first suction port (86). In the completely-closed first compression chamber (85) which is blocked from the first suction port (86), the refrigerant is compressed as the first piston (82) moves. In such a state, first intermediate-pressure gas refrigerant is injected into the completely-closed first compression chamber (85) through the first injection pipe (35) and the first injection port (89). As described above, the low-pressure refrigerant is sucked into the first compression chamber (85) through the first suction port (86), and the first intermediate-pressure gas refrigerant is sucked into the first compression chamber (85) through the first injection port (89). The first compression mechanism (71) compresses the refrigerant sucked into the first compression chamber (85), and discharges the compressed high-pressure refrigerant to an internal space of the casing (51) through the first discharge port (87).

[0088] In the second compression mechanism (72), low-pressure refrigerant is sucked into the second compression chamber (95) through the second suction port (96). In the completely-closed second compression chamber (95) which is blocked from the second suction port (96), the refrigerant is compressed as the second piston (92) moves. In such a state, second intermediate-pressure gas refrigerant is injected to the completely-closed second compression chamber (95) through the second injection pipe (45) and the second injection port (99). As described above, the low-pressure refrigerant is sucked into the second compression chamber (95) through the second suction port (96), and the second intermediate-pressure gas refrigerant is sucked into the second compression chamber (95) through the second injection port (99). The second compression mechanism (72) compresses the refrigerant sucked into the second compression chamber (95), and discharges the compressed high-pressure refrigerant to the internal space of the casing (51) through the second discharge port (97).

[0089] The high-pressure refrigerant is discharged from each of the first compression mechanism (71) and the second compression mechanism (72) to the internal space of the casing (51). The high-pressure refrigerant discharged from the compression mechanism (71, 72) upwardly flows through the internal space of the casing (51), and is sent to the outside of the casing (51) through the discharge pipe (52).

[0090] Although not shown in the figure, refrigerant oil is accumulated in a bottom portion of the internal space of the casing (51). The refrigerant oil flows into the oil supply path (69) opening at a lower end of the drive shaft (65). Then, the refrigerant oil is supplied to the compression mechanisms (71, 72), and is used for lubrication of sliding portions of the compression mechanisms (71, 72).

[0091] <Refrigeration Cycle>

The refrigeration cycle performed in the refrigerant circuit (5) will be described with reference to a Mollier diagram

(pressure-enthalpy diagram) of FIG. 4. In the description below, the "evaporator" means either one of the outdoor heat exchanger (12) and the indoor heat exchanger (14), which is operated as the evaporator (i.e., the indoor heat exchanger (14) in the cooling operation, and the outdoor heat exchanger (12) in the heating operation), and the "condenser" means either one of the outdoor heat exchanger (12) and the indoor heat exchanger (14), which is operated as the condenser (i.e., the outdoor heat exchanger (12) in the cooling operation, and the indoor heat exchanger (14) in the heating operation).

[0092] Refrigerant in a state at a point D (gas refrigerant having a pressure P_H) is discharged from the compressor (50). The refrigerant in the state at the point D is changed to a state at a point E by dissipating heat to air in the condenser, and then flows into the one-way circulation pipe line (6). A mass flow rate of high-pressure refrigerant flowing from the condenser to the one-way circulation pipe line (6) is " m_c ."

[0093] A part of the high-pressure refrigerant flowing into the one-way circulation pipe line (6) flows into the first branched pipe (33), and the remaining refrigerant flows into the high-pressure flow path (31) of the first heat exchanger (30). A mass flow rate of high-pressure refrigerant flowing into the first branched pipe (33) is " m_{i1} ." The high-pressure refrigerant flowing into the first branched pipe (33) is expanded when passing through the first expansion valve (34), and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M1} . Then, such refrigerant is changed to first intermediate-pressure refrigerant in a state at a point F (in a gas-liquid two-phase state).

[0094] In the first heat exchanger (30), the high-pressure refrigerant flowing through the high-pressure flow path (31) is cooled, and the first intermediate-pressure refrigerant flowing through the intermediate-pressure flow path (32) is evaporated into first intermediate-pressure gas refrigerant. The high-pressure refrigerant changed to a state at a point H due to reduction of the enthalpy flows out from the high-pressure flow path (31) of the first heat exchanger (30). Meanwhile, the first intermediate-pressure gas refrigerant in a state at a point G flows out from the intermediate-pressure flow path (32) of the first heat exchanger (30). The first intermediate-pressure gas refrigerant having the pressure P_{M1} is sent to the compressor (50) through the first injection pipe (35). A mass flow rate of the first intermediate-pressure gas refrigerant supplied to the compressor (50) is " m_{i1} ."

[0095] A part of the high-pressure refrigerant in the state at the point H, which flows out from the high-pressure flow path (31) of the first heat exchanger (30) flows into the second branched pipe (43), and the remaining refrigerant flows into the high-pressure flow path (41) of the second heat exchanger (40). A mass flow rate of the high-pressure refrigerant flowing into the second branched pipe (43) is " m_{i2} ." The high-pressure refrigerant flowing into the second branched pipe (43) is expanded when passing through the second expansion valve (44),

and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M2} . Then, such refrigerant is changed to second intermediate-pressure refrigerant in a state at a point I (in the gas-liquid two-phase state). The second intermediate-pressure refrigerant in the state at the point I is lower in any of a pressure, a specific enthalpy, and a temperature than the first intermediate-pressure refrigerant in the state at the point F. The second intermediate-pressure refrigerant flows into the intermediate-pressure flow path (32) of the second heat exchanger (40).

[0096] In the second heat exchanger (40), the high-pressure refrigerant flowing through the high-pressure flow path (41) is cooled, and the second intermediate-pressure refrigerant flowing through the intermediate-pressure flow path (42) is evaporated into second intermediate-pressure gas refrigerant. The high-pressure refrigerant changed to a state at a point K due to the reduction of the enthalpy flows out from the high-pressure flow path (41) of the second heat exchanger (40). Meanwhile, the second intermediate-pressure gas refrigerant in a state at a point J flows out from the intermediate-pressure flow path (42) of the second heat exchanger (40). The second intermediate-pressure gas refrigerant having the pressure P_{M2} is sent to the compressor (50) through the second injection pipe (45). A mass flow rate of the second intermediate-pressure gas refrigerant supplied to the compressor (50) is " m_{i2} ."

[0097] The high-pressure refrigerant in the state at the point K, which flows out from the high-pressure flow path (41) of the second heat exchanger (40) is expanded when passing through the main expansion valve (13), and the pressure of the high-pressure refrigerant is decreased from P_H to P_L . Then, such refrigerant is changed to low-pressure refrigerant in a state at a point L (in the gas-liquid two-phase state). The low-pressure refrigerant flows into the evaporator, and absorbs heat from air. After such refrigerant is evaporated into refrigerant in a state at a point A, the refrigerant is sucked into the compressor (50). In the compressor (50), the refrigerant in the state at the point A is sucked into the first compression chamber (85) of the first compression mechanism (71) and the second compression chamber (95) of the second compression mechanism (72). A mass flow rate of the low-pressure refrigerant sucked into the compressor (50) from the evaporator is " m_e ."

[0098] In the first compression mechanism (71) of the compressor (50), the refrigerant sucked into the first compression chamber (85) is compressed, and the refrigerant in the first compression chamber (85) is changed from the state at the point A to a state at a point B. Meanwhile, the first intermediate-pressure gas refrigerant in the state at the point G is injected to the completely-closed first compression chamber (85) in the middle of a compression process through the first injection port (89). In the first compression chamber (85), the refrigerant which flows into the first compression chamber (85) in the state at the point A and is being compressed, and the first

intermediate-pressure gas refrigerant in the state at the point G, which flows into the first compression chamber (85) through the first injection port (89) are mixed together, and the refrigerant mixture is compressed into the refrigerant in the state at the point D.

[0099] In the second compression mechanism (72) of the compressor (50), the refrigerant sucked into the second compression chamber (95) is compressed, and the refrigerant in the second compression chamber (95) is changed from the state at the point A to a state at a point B'. Meanwhile, the second intermediate-pressure gas refrigerant in the state at the point J is injected to the completely-closed second compression chamber (95) in the middle of the compression process through the second injection port (99). In the second compression chamber (95), the refrigerant which flows into the second compression chamber (95) in the state at the point A and is being compressed, and the second intermediate-pressure gas refrigerant in the state at the point J, which flows into the second compression chamber (95) through the second injection port (99) are mixed together, and the refrigerant mixture is compressed into the refrigerant in the state at the point D.

[0100] As described above, the main body (70) of the compressor (50) sucks and compresses the low-pressure refrigerant (the mass flow rate m_e) sent from the evaporator, the first intermediate-pressure gas refrigerant (the mass flow rate m_{i1}) supplied through the first injection pipe (35), and the second intermediate-pressure gas refrigerant (the mass flow rate m_{i2}) supplied through the second injection pipe (45). Thus, a mass flow rate m_c of high-pressure refrigerant discharged from the compressor (50) to the condenser is equal to a sum of the mass flow rates of the low-pressure refrigerant, the first intermediate-pressure gas refrigerant, and the second intermediate-pressure gas refrigerant which are sucked into the main body (70) of the compressor (50) ($m_c = m_e + m_{i1} + m_{i2}$).

Advantages of First Embodiment

[0101] In the refrigerant circuit (5) of the air conditioner (1) of the present embodiment, the first intermediate-pressure gas refrigerant is generated in the first heat exchanger (30), and the second intermediate-pressure gas refrigerant is generated in the second heat exchanger (40). The first intermediate-pressure gas refrigerant is higher in the pressure and the density than the second intermediate-pressure gas refrigerant. In addition, in the refrigerant circuit (5) of the air conditioner (1) of the present embodiment, the second intermediate-pressure gas refrigerant is supplied to the second compression mechanism (72) of the compressor (50), whereas the first intermediate-pressure gas refrigerant having the pressure and density higher than those of the second intermediate-pressure gas refrigerant is supplied to the first compression mechanism (71) of the compressor (50). Thus, according to the present embodiment, the

mass flow rate m_c of refrigerant discharged from the compressor (50) can be increased as compared to a case where only the second intermediate-pressure gas refrigerant is supplied to the compression mechanism (71, 72).

[0102] In the air conditioner (1) of the present embodiment, the first intermediate-pressure gas refrigerant is injected to the first compression chamber (85) of the first compression mechanism (71) in the middle of the compression process, and the second intermediate-pressure gas refrigerant is injected to the second compression chamber (95) of the second compression mechanism (72) in the middle of the compression process. Thus, only the mass flow rate m_c of refrigerant discharged from the compressor (50) to the condenser can be increased without increasing the mass flow rate m_e of low-pressure refrigerant sucked into the compressor (50) from the evaporator. That is, according to the present embodiment, the mass flow rate of refrigerant discharged from the compressor (50) can be increased without increasing a rotational speed of the compression mechanism (71, 72) provided in the compressor (50) (i.e., a rotational speed of the drive shaft (65) for driving the piston (82, 92) of the compression mechanism (71, 72)). Consequently, while reducing an increase in electric power consumed by the electric motor (60) of the compressor (50), the mass flow rate of refrigerant discharged from the compressor (50) can be increased, and an amount of heat released to air from refrigerant (i.e., a heat dissipation amount of refrigerant) in the condenser can be increased.

[0103] In the refrigerant circuit (5) of the air conditioner (1) of the present embodiment, high-pressure refrigerant is cooled by exchanging heat with the first intermediate-pressure refrigerant in the first heat exchanger (30), and the high-pressure refrigerant cooled in the first heat exchanger (30) is further cooled by exchanging heat with the second intermediate-pressure refrigerant (i.e., refrigerant having the pressure and temperature lower than those of the first intermediate-pressure refrigerant) in the second heat exchanger (40). Thus, according to the present embodiment, the enthalpy of refrigerant flowing into the evaporator can be reduced as compared to a case where high-pressure refrigerant sent from the condenser to the evaporator exchanges heat only with the first intermediate-pressure refrigerant. Consequently, an amount of heat absorbed from air by refrigerant (i.e., a heat absorption amount of refrigerant) in the evaporator can be increased.

[0104] As described above, according to the present embodiment, the increase in mass flow rate of refrigerant in the condenser results in the increase in heat dissipation amount of refrigerant in the condenser. Further, the reduction in enthalpy of refrigerant flowing into the evaporator results in the increase in heat absorption amount of refrigerant in the evaporator. That is, according to the present embodiment, both of the heat dissipation amount of refrigerant in the condenser and the heat absorption amount of refrigerant in the evaporator can be ensured. Thus, according to the present embodiment, while reduc-

ing the increase in power consumption of the air conditioner (1), a heating capacity (i.e., an amount of heat released from refrigerant to room air in the indoor heat exchanger (14) operated as the condenser) of the air conditioner (1) can be increased, and a cooling capacity (i.e., an amount of heat absorbed from room air by refrigerant in the indoor heat exchanger (14) operated as the evaporator) of the air conditioner (1) can be also increased.

[0105] In the refrigerant circuit (5) of the air conditioner (1) of the present embodiment, the enthalpy of refrigerant flowing into the evaporator can be reduced as described above. Thus, while maintaining the heat absorption amount of refrigerant in the evaporator, the mass flow rate of refrigerant in the evaporator can be decreased. When decreasing the mass flow rate of refrigerant in the evaporator, a flow velocity of refrigerant in the evaporator is reduced, and a pressure loss of refrigerant during a passage through the evaporator is reduced. When reducing the pressure loss of refrigerant in the evaporator, the pressure of low-pressure refrigerant sucked into the compressor (50) is increased by an amount equivalent to the reduction in the pressure loss in the evaporator, and the power consumption by the electric motor (60) of the compressor (50) is reduced. Thus, according to the present embodiment, while maintaining the heat dissipation amount of refrigerant in the evaporator, the power consumption of the compressor (50) can be reduced. Consequently, a coefficient of performance (COP) of the air conditioner (1) in the cooling operation can be improved.

[0106] In a refrigerant circuit in which a multiple-stage compression refrigeration cycle is performed, intermediate-pressure gas refrigerant is supplied to each section between compressors. That is, in, e.g., a refrigerant circuit in which a three-stage compression refrigeration cycle is performed, intermediate-pressure gas refrigerant is supplied between, a compressor at a first stage and a compressor at a second stage, and between the compressor at the second stage and a compressor at a third stage.

[0107] On the other hand, in the refrigerant circuit (5) of the present embodiment, the first and second intermediate-pressure gas refrigerants with different pressures are generated in the enthalpy reducing unit (20). Thus, in the refrigerant circuit of the present embodiment, employment of a "configuration in which three compression mechanisms are used to perform a three-stage compression refrigeration cycle, the second intermediate-pressure gas refrigerant is supplied between a compression mechanism at a first stage and a compression mechanism at a second stage, and the first intermediate-pressure gas refrigerant is supplied between the compression mechanism at the second stage and a compression mechanism at a third stage" is technically allowed.

[0108] However, if such a configuration is employed in the refrigerant circuit of the present embodiment, there are problems that operational efficiency of the air conditioner cannot be sufficiently improved, and a manufac-

turing cost of the air conditioner is increased. Such problems will be described below.

[0109] Typically, a three-stage compression refrigeration cycle is performed when only a low COP (coefficient of performance) can be obtained in a two-stage compression refrigerant cycle or a single-stage compression refrigeration cycle due to a large difference between low and high pressure levels of the refrigeration cycle. The low and high pressure levels of the refrigeration cycle performed in a refrigerant circuit of an air conditioner are values corresponding to a temperature inside a room where a person is present or an outdoor temperature. It is less likely that the room temperature or the outdoor temperature shows an extremely high value or an extremely low value, and therefore the difference between the low and high pressure levels of the refrigeration cycle performed in the refrigerant circuit of the air conditioner is not extremely increased under normal conditions.

[0110] Since the compression mechanism for compressing refrigerant includes a plurality of members, a mechanical loss such as a friction loss between the members is caused in the compression mechanism. Thus, the greater number of compression mechanisms results in a greater overall mechanical loss caused in each of the compression mechanisms. In addition, the greater number of compression mechanisms provided in the air conditioner results in a higher manufacturing cost of the air conditioner. For such reasons, even when the "difference between the low and high pressure levels of the refrigeration cycle is not so large, and a sufficiently high COP can be obtained in the single-stage compression refrigeration cycle," if the "configuration in which the three compression mechanisms are used to perform the three-stage compression refrigeration cycle" is employed, there are problems that an increase in mechanical loss in the compression mechanism causes degradation of the operational efficiency of the air conditioner, and an increase in the number of compression mechanisms causes an increase in manufacturing cost of the air conditioner.

[0111] On the other hand, in the refrigerant circuit (5) of the air conditioner (1) of the present embodiment, in which the single-stage compression refrigeration cycle is performed, the first intermediate-pressure gas refrigerant and the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) are sucked into the first compression mechanism (71) and the second compression mechanism (72), respectively. That is, according to the present embodiment, both of the first and second intermediate-pressure gas refrigerants with different pressures can be sucked into the compressor (50) in which a single-stage compression is performed. Thus, according to the present embodiment, while using the two compression mechanisms (71, 72), the first and second intermediate-pressure gas refrigerants with different pressures can be processed, thereby solving the problems such as the increase in mechanical loss of the compressor (50) and the increase in manu-

facturing cost of the air conditioner (1) due to the increase in the number of compression mechanisms.

[0112] «Second Embodiment of the Invention»

A second embodiment of the present invention will be described. In the present embodiment, the configuration of the refrigerant circuit (5) is changed in the air conditioner (1) of the first embodiment. Differences between a refrigerant circuit (5) of the present embodiment and the refrigerant circuit (5) of the first embodiment will be described.

[0113] As illustrated in FIG. 5, the refrigerant circuit (5) of the present embodiment is different from the refrigerant circuit (5) of the first embodiment in a connection position of a second branched pipe (43). Specifically, in the refrigerant circuit (5) of the present embodiment, one end of the second branched pipe (43) is connected to a first branched pipe (33) between a first expansion valve (34) and a first heat exchanger (30). The refrigerant circuit (5) of the present embodiment is similar to the refrigerant circuit (5) of the first embodiment in that the other end of the second branched pipe (43) is connected to a second heat exchanger (40).

[0114] A refrigeration cycle performed in the refrigerant circuit (5) of the present embodiment will be described. Differences between such a refrigeration cycle and the refrigeration cycle performed in the refrigerant circuit (5) of the first embodiment will be described below. In the description below, an "evaporator" means either one of an outdoor heat exchanger (12) and an indoor heat exchanger (14), which is operated as an evaporator, and a "condenser" means either one of the outdoor heat exchanger (12) and the indoor heat exchanger (14), which is operated as a condenser.

[0115] As illustrated in a Mollier diagram (pressure-enthalpy diagram) of FIG. 6, the refrigeration cycle performed in the refrigerant circuit (5) of the present embodiment is different from the refrigeration cycle performed in the refrigerant circuit (5) of the first embodiment in a state change of refrigerant flowing through the first branched pipe (33) and the second branched pipe (43).

[0116] Specifically, in the refrigerant circuit (5) of the present embodiment, a part of high-pressure refrigerant (refrigerant in a state at a point D) flowing into a one-way circulation pipe line (6) through a bridge circuit (15) flows into the first branched pipe (33). The high-pressure refrigerant flowing into the first branched pipe (33) is expanded when passing through the first expansion valve (34), and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M1} . Then, such refrigerant is changed to first intermediate-pressure refrigerant in a state at a point F. A part of the first intermediate-pressure refrigerant flows into an intermediate-pressure flow path (32) of the first heat exchanger (30), and the remaining refrigerant flows into the second branched pipe (43). The first intermediate-pressure refrigerant flowing into the intermediate-pressure flow path (32) of the first heat exchanger (30) is evaporated into first intermediate-pressure gas refrigerant by absorbing heat from high-pres-

sure refrigerant flowing through a high-pressure flow path (31) of the first heat exchanger (30), and is supplied to a first compression mechanism (71) of a compressor (50). The high-pressure refrigerant flowing through the high-pressure flow path (31) of the first heat exchanger (30) is changed to a state at a point H due to reduction of an enthalpy.

[0117] Meanwhile, the first intermediate-pressure refrigerant flowing into the second branched pipe (43) is expanded when passing through a second expansion valve (44), and the pressure of the first intermediate-pressure refrigerant is decreased from P_{M1} to P_{M2} . Then, such refrigerant is changed to second intermediate-pressure refrigerant in a state at a point I. All of the second intermediate-pressure refrigerant flows into an intermediate-pressure flow path (42) of the second heat exchanger (40). The second intermediate-pressure refrigerant flowing into the intermediate-pressure flow path (42) of the second heat exchanger (40) is evaporated into second intermediate-pressure gas refrigerant by absorbing heat from high-pressure refrigerant flowing through a high-pressure flow path (41) of the second heat exchanger (40), and is supplied to a second compression mechanism (72) of the compressor (50). The high-pressure refrigerant flowing through the high-pressure flow path (41) of the second heat exchanger (40) is changed to a state at a point K due to the reduction of the enthalpy.

[0118] First Variation of Second Embodiment

As illustrated in FIG. 7, in the refrigerant circuit (5) of the present embodiment, one end of the second branched pipe (43) may be connected to the first branched pipe (33) upstream the first expansion valve (34).

[0119] In a refrigerant circuit (5) of the present variation, a refrigeration cycle illustrated in the Mollier diagram of FIG. 6 is performed. In the refrigerant circuit (5), a part of high-pressure refrigerant (refrigerant in a state at a point E in FIG. 6) flowing into the first branched pipe (33) from the one-way circulation pipe line (6) is sent to the first expansion valve (34), and the remaining refrigerant flows into the second branched pipe (43). The high-pressure refrigerant sent to the first expansion valve (34) is expanded when passing through the first expansion valve (34), and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M1} . Then, such refrigerant is changed to first intermediate-pressure refrigerant in the state at the point F in FIG. 6, and flows into the first heat exchanger (30). Meanwhile, the high-pressure refrigerant flowing into the second branched pipe (43) is expanded when passing through the second expansion valve (44), and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M2} . Then, such refrigerant is changed to second intermediate-pressure refrigerant in the state at the point I in FIG. 6, and flows into the second heat exchanger (40).

Second Variation of Second Embodiment

[0120] As illustrated in FIG. 8, in the refrigerant circuit

(5) of the present embodiment, a gas-liquid separator (23) may be provided in the middle of the first branched pipe (33), and one end of the second branched pipe (43) may be connected to the gas-liquid separator (23).

[0121] Specifically, in a refrigerant circuit (5) of the present variation, the first branched pipe (33) is divided into an upstream section (33a) and a downstream section (33b). One end of the upstream section (33a) of the first branched pipe (33) is connected to the one-way circulation pipe line (6) upstream the first heat exchanger (30), and the other end of the upstream section (33a) is connected to an inlet of the gas-liquid separator (23). The first expansion valve (34) is provided in the upstream section (33a) of the first branched pipe (33). On the other hand, one end of the downstream section (33b) of the first branched pipe (33) is connected to a gas refrigerant outlet of the gas-liquid separator (23), and the other end of the downstream section (33b) is connected to the intermediate-pressure flow path (32) of the first heat exchanger (30). One end of the second branched pipe (43) is connected to a liquid refrigerant outlet of the gas-liquid separator (23), and the other end of the second branched pipe (43) is connected to the intermediate-pressure flow path (42) of the second heat exchanger (40).

[0122] In the refrigerant circuit (5) of the present variation, a refrigeration cycle illustrated in a Mollier diagram of FIG. 9 is performed. In the refrigerant circuit (5), high-pressure refrigerant (refrigerant in the state at the point E) flowing into the upstream section (33a) of the first branched pipe (33) from the one-way circulation pipe line (6) is expanded when passing through the first expansion valve (34), and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M1} . Then, such refrigerant is changed to first intermediate-pressure refrigerant in the state at the point F, and flows into the gas-liquid separator (23). The first intermediate-pressure refrigerant flowing into the gas-liquid separator (23) is separated into saturated liquid refrigerant in a state at a point F' and saturated gas refrigerant in a state at a point F".

[0123] The saturated gas refrigerant in the state at the point F" flows into the intermediate-pressure flow path (32) of the first heat exchanger (30) through the downstream section (33b) of the first branched pipe (33), and is changed to first intermediate-pressure gas refrigerant in a state at a point G by absorbing heat from high-pressure refrigerant flowing through the high-pressure flow path (31) of the first heat exchanger (30). The high-pressure refrigerant flowing through the high-pressure flow path (31) of the first heat exchanger (30) is cooled to the state at the point H by the refrigerant flowing through the intermediate-pressure flow path (32).

[0124] Meanwhile, the saturated liquid refrigerant in the state at the point F' flows into the second branched pipe (43). The refrigerant flowing into the second branched pipe (43) is expanded when passing through the second expansion valve (44), and the pressure of the refrigerant is decreased from P_{M1} to P_{M2} . Then, such refrigerant is changed to second intermediate-pressure

refrigerant in the state at the point I, and flows into the second heat exchanger (40). In the second heat exchanger (40), the second intermediate-pressure refrigerant flowing through the intermediate-pressure flow path (42) is evaporated into second intermediate-pressure gas refrigerant in a state at a point J by absorbing heat from high-pressure refrigerant flowing through the high-pressure flow path (41). The high-pressure refrigerant flowing through the high-pressure flow path (41) of the second heat exchanger (40) is cooled to the state at the point K by the refrigerant flowing through the intermediate-pressure flow path (42).

[0125] «Third Embodiment of the Invention»

A third embodiment of the present invention will be described. In the present embodiment, the configuration of the refrigerant circuit (5) is changed in the air conditioner (1) of the first embodiment. Differences between a refrigerant circuit (5) of the present embodiment and the refrigerant circuit (5) of the first embodiment will be described.

[0126] As illustrated in FIG. 10, in the refrigerant circuit (5) of the present embodiment, the first branched pipe (33), the second branched pipe (43), the first heat exchanger (30), and the second heat exchanger (40) of the first embodiment are omitted. In the refrigerant circuit (5) of the present embodiment, a first expansion valve (37), a first gas-liquid separator (36), a second expansion valve (47), and a second gas-liquid separator (46) are provided in a one-way circulation pipe line (6).

[0127] In the refrigerant circuit (5) of the present embodiment, the first expansion valve (37), the first gas-liquid separator (36), the second expansion valve (47), and the second gas-liquid separator (46) are arranged in this order from an inlet end of the one-way circulation pipe line (6) to an outlet end of the one-way circulation pipe line (6). In the refrigerant circuit (5) of the present embodiment, the inlet end of the one-way circulation pipe line (6) is connected to an inlet of the first gas-liquid separator (36) through the first expansion valve (37). A gas refrigerant outlet of the first gas-liquid separator (36) is connected to a first injection pipe (35), and a liquid refrigerant outlet of the first gas-liquid separator (36) is connected to an inlet of the second gas-liquid separator (46) through the second expansion valve (47). A gas refrigerant outlet of the second gas-liquid separator (46) is connected to a second injection pipe (45), and a liquid refrigerant outlet of the second gas-liquid separator (46) is connected to a main expansion valve (13).

[0128] A refrigeration cycle performed in the refrigerant circuit (5) of the present embodiment will be described. Differences between such a refrigeration cycle and the refrigeration cycle performed in the refrigerant circuit (5) of the first embodiment will be described below. In the description below, an "evaporator" means either one of an outdoor heat exchanger (12) and an indoor heat exchanger (14), which is operated as an evaporator, and a "condenser" means either one of the outdoor heat exchanger (12) and the indoor heat exchanger (14),

which is operated as a condenser.

[0129] As illustrated in a Mollier diagram of FIG. 11, the refrigeration cycle performed in the refrigerant circuit (5) of the present embodiment is different from the refrigeration cycle performed in the refrigerant circuit (5) of the first embodiment in a state change of refrigerant flowing through the one-way circulation pipe line (6) of the refrigerant circuit (5).

[0130] Specifically, in the refrigerant circuit (5) of the present embodiment, high-pressure refrigerant (refrigerant in a state at a point D) flowing into the one-way circulation pipe line (6) through a bridge circuit (15) is expanded when passing through the first expansion valve (37), and the pressure of the high-pressure refrigerant is decreased from P_H to P_{M1} . Then, such refrigerant is changed to refrigerant in a state at a point F (in a gas-liquid two-phase state), and flows into the first gas-liquid separator (36). The refrigerant flowing into the first gas-liquid separator (36) is separated into saturated liquid refrigerant in a state at a point F' and saturated gas refrigerant in a state at a point F". The saturated liquid refrigerant in the state at the point F' flows out from the first gas-liquid separator (36) to the second expansion valve (47). The saturated gas refrigerant in the state at the point F" is supplied to a first compression mechanism (71) of a compressor (50) through the first injection pipe (35).

[0131] The saturated liquid refrigerant in the state at the point F', which flows out from the first gas-liquid separator (36) is expanded when passing through the second expansion valve (47), and the pressure of the saturated liquid refrigerant is decreased from P_{M1} to P_{M2} . Then, such refrigerant is changed to refrigerant in a state at a point I (in the gas-liquid two-phase state), and flows into the second gas-liquid separator (46). The refrigerant flowing into the second gas-liquid separator (46) is separated into saturated liquid refrigerant in a state at a point I' and saturated gas refrigerant in a state at a point I". The saturated liquid refrigerant in the state at the point I' flows out from the second gas-liquid separator (46) to the main expansion valve (13). The saturated gas refrigerant in the state at the point I" is supplied to a second compression mechanism (72) of the compressor (50) through the second injection pipe (45).

[0132] The saturated liquid refrigerant in the state at the point I', which flows out from the second gas-liquid separator (46) is expanded when passing through the main expansion valve (13), and the pressure of the saturated liquid refrigerant is decreased from P_{M2} to P_L . Then, such refrigerant is changed to refrigerant in a state at a point L (in the gas-liquid two-phase state). The low-pressure refrigerant in the state at the point L is supplied to the evaporator after passing through the main expansion valve (13).

[0133] «Other Embodiment»

First Variation

In the first and second embodiments, the first heat exchanger (30) and the second heat exchanger (40) may form a single heat exchange member (100).

[0134] As illustrated in FIGS. 12 and 13, the heat exchange member (100) is integrally formed by bonding four flat pipes (101-104) and six headers (111-116) together by, e.g., brazing.

[0135] The flat pipe (101-104) is formed so as to have an oval cross section. A plurality of fluid paths extending one end of the flat pipe (101-104) to the other end of the flat pipe (101-104) are formed in the flat pipe (101-104).

[0136] In the heat exchange member (100), the first flat pipe (101) and the fourth flat pipe (104) are stacked so that axial directions of the first flat pipe (101) and the fourth flat pipe (104) are parallel to each other, and flat portions of outer surfaces of the first flat pipe (101) and the fourth flat pipe (104) closely contact each other. In addition, in the heat exchange member (100), the second flat pipe (102) and the third flat pipe (103) are stacked so that axial directions of the second flat pipe (102) and the third flat pipe (103) are parallel to each other, and flat portions of outer surfaces of the second flat pipe (102) and the third flat pipe (103) closely contact each other.

[0137] The header (111-116) is formed in a hollow cylindrical shape which is closed at both ends. The header (111-116) is arranged so that an axial direction of the header (111-116) is perpendicular to the axial direction of the flat pipe (101-104).

[0138] The first header (111) is connected to one end of the first flat pipe (101). The second header (112) is connected to the other end of the first flat pipe (101). One end of the second flat pipe (102) is connected to the second header (112) from a side opposite to the first flat pipe (101). The other end of the second flat pipe (102) is connected to the third header (113).

[0139] One end of the third flat pipe (103) is connected to the fourth header (114). The other end of the third flat pipe (103) is connected to the fifth header (115). One end of the fourth flat pipe (104) is connected to the fifth header (115) from a side opposite to the third flat pipe (103). Further, an internal space of the fifth header (115) is divided into a portion communicated only with the third flat pipe (103) and a portion communicated only with the fourth flat pipe (104). The other end of the fourth flat pipe (104) is connected to the sixth header (116).

[0140] Pipes forming the refrigerant circuit (5) are connected to the heat exchange member (100) (see FIG. 13). The one-way circulation pipe line (6) extending from the bridge circuit (15) is connected to the four-way valve (11). An inlet end of the second branched pipe (43) is connected to the second header (112). The one-way circulation pipe line (6) extending toward the main expansion valve (13) is connected to the third header (113). An outlet end of the second branched pipe (43) is connected to the fourth header (114). The second injection pipe (45) is connected to the portion of the fifth header (115), which is communicated with the third flat pipe (103). An outlet end of the first branched pipe (33) is connected to the portion of the fifth header (115), which is connected to the fourth flat pipe (104). The first injection pipe (35) is connected to the sixth header (116).

[0141] In the heat exchange member (100), the first flat pipe (101), the fourth flat pipe (104), the first header (111), the second header (112), the fifth header (115), and the sixth header (116) form the first heat exchanger (30). Specifically, in the heat exchange member (100), the fluid paths of the first flat pipe (101) serve as the high-pressure flow path (31) of the first heat exchanger (30), and the fluid paths of the fourth flat pipe (104) serve as the intermediate-pressure flow path (32) of the first heat exchanger (30). Since the first flat pipe (101) and the fourth flat pipe (104) are bonded together with the first flat pipe (101) and the fourth flat pipe (104) being stacked in the heat exchange member (100), heat is exchanged between refrigerant flowing through the high-pressure flow path (31) and refrigerant flowing through the intermediate-pressure flow path (32).

[0142] In addition, in the heat exchange member (100), the second flat pipe (102), the third flat pipe (103), the second header (112), the third header (113), the fourth header (114), and the fifth header (115) form the second heat exchanger (40). Specifically, in the heat exchange member (100), the fluid paths of the second flat pipe (102) serve as the high-pressure flow path (41) of the second heat exchanger (40), and the fluid paths of the third flat pipe (103) serve as the intermediate-pressure flow path (42) of the second heat exchanger (40). Since the second flat pipe (102) and the third flat pipe (103) are bonded together with the second flat pipe (102) and the third flat pipe (103) being stacked in the heat exchange member (100), heat is exchanged between refrigerant flowing through the high-pressure flow path (41) and refrigerant flowing through the intermediate-pressure flow path (42).

[0143] Second Variation

In each of the first to third embodiments, the first compression mechanism (71) and the second compression mechanism (72) may be provided in separate compressors (50a, 50b). Differences of the refrigerant circuit (5) of the first embodiment, to which the present variation is applied, from the refrigerant circuit (5) of the first embodiment will be described.

[0144] As illustrated in FIG. 14, in the refrigerant circuit (5) of the present variation, the first compressor (50a) and the second compressor (50b) are provided. The first compressor (50a) is a hermetic compressor including a first compression mechanism (71). In a casing (51a) of the first compressor (50a), the first compression mechanism (71), an electric motor (60a), and a drive shaft (65a) connecting between the first compression mechanism (71) and the electric motor (60a) are accommodated. A discharge pipe (52a) is provided in the casing (51a) of the first compressor (50a), and a first suction pipe (53) is connected to the first compression mechanism (71). On the other hand, the second compressor (50b) is a hermetic compressor including a second compression mechanism (72). In a casing (51b) of the second compressor (50b), the second compression mechanism (72), an electric motor (60b), a drive shaft (65b) connecting the second compression mechanism (72) and the electric

motor (60b) are accommodated. A discharge pipe (52b) is provided in the casing (51b) of the second compressor (50b), and a second suction pipe (54) is connected to the second compression mechanism (72).

[0145] In the refrigerant circuit (5) of the present variation, both of the discharge pipe (52a) of the first compressor (50a) and the discharge pipe (52b) of the second compressor (50b) are connected to the first port of the four-way valve (11). In addition, in the refrigerant circuit (5), both of the first suction pipe (53) of the first compressor (50a) and the second suction pipe (54) of the second compressor (50b) are connected to the second port of the four-way valve (11). The first injection pipe (35) is connected to the first injection port (89) of the first compression mechanism (71) provided in the first compressor (50a). The second injection pipe (45) is connected to the second injection port (99) of the second compression mechanism (72) provided in the second compressor (50b).

[0146] Note that each of the first compression mechanism (71) and the second compression mechanism (72) of the present variation may be a rotary fluid machine including a pair of cylinders and a pair of pistons, or a rotary fluid machine including a plurality of cylinders and a plurality of pistons.

[0147] Third Variation

In each of the first to third embodiments, the compressor (50) may be configured to perform a two-stage compression. Differences of the refrigerant circuit (5) of the first embodiment, to which the present variation is applied, from the refrigerant circuit (5) of the first embodiment will be described.

[0148] As illustrated in FIG. 15, the compressor (50) of the present variation includes a single suction pipe (55). The suction pipe (55) penetrates the casing (51), and one end of the suction pipe (55) is connected to the second suction port (96) of the second compression mechanism (72). In addition, a connection path (57) is provided in the compressor (50). The connection path (57) allows a communication between the second discharge port (97) of the second compression mechanism (72) and the first suction port (86) of the first compression mechanism (71). Note that the connection path (57) may be defined by a pipe exposed to the outside of the casing (51), or may be defined by a space formed inside the main body (70) of the compressor (50). As in the first embodiment, in the compressor (50) of the present variation, the first injection pipe (35) is connected to the first injection port (89) of the first compression mechanism (71), and the second injection pipe (45) is connected to the second injection port (99) of the second compression mechanism (72).

[0149] An operation of the compressor (50) of the present variation will be described with reference to FIG. 16. FIG. 16 is a Mollier diagram illustrating a two-stage compression refrigeration cycle performed in the refrigerant circuit (5) of the present variation.

[0150] Low-pressure refrigerant in a state at a point A

is sucked into the compressor (50) of the present variation. The low-pressure refrigerant flowing into the suction pipe (55) of the compressor (50) is sucked into the second compression chamber (95) of the second compression mechanism (72). In the second compression mechanism (72), the low-pressure refrigerant sucked into the second compression chamber (95) is compressed, and the refrigerant in the second compression chamber (95) is changed from the state at the point A to a state at a point B₁. Second intermediate-pressure gas refrigerant in a state at a point J is injected to the second compression mechanism (72) through the second injection pipe (45). In the second compression chamber (95) of the second compression mechanism (72), the refrigerant which flows into the second compression chamber (95) in the state at the point A and is being compressed, and the second intermediate-pressure gas refrigerant flowing into the second compression chamber (95) through the second injection pipe (45) are mixed together, and the refrigerant mixture is compressed into a state at a point M. The second compression mechanism (72) discharges the refrigerant compressed into refrigerant in the state at the point M.

[0151] The refrigerant discharged from the second compression mechanism (72) is sucked into the first compression mechanism (71) through the connection path (57). In the first compression mechanism (71), the refrigerant sucked into the first compression chamber (85) is compressed, and the refrigerant in the first compression chamber (85) is changed from the state at the point M to a state at a point C₁. First intermediate-pressure gas refrigerant in a state at a point G is injected to the first compression mechanism (71) through the first injection pipe (35). In the first compression chamber (85) of the first compression mechanism (71), the refrigerant which flows into the first compression chamber (85) in the state at the point M and is being compressed, and the first intermediate-pressure gas refrigerant flowing into the first compression chamber (85) through the first injection pipe (35) are mixed together, and the refrigerant mixture is compressed into refrigerant in a state at a point D. The first compression mechanism (71) discharges the refrigerant compressed into the state at the point D. The refrigerant discharged from the first compression mechanism (71) is sent to the outside of the casing (51) through the discharge pipe (52).

[0152] As described above, the compressor (50) of the present variation sucks and compresses the low-pressure refrigerant (the mass flow rate m_e) sent from the evaporator, the first intermediate-pressure gas refrigerant (the mass flow rate m_{i1}) supplied through the first injection pipe (35), and the second intermediate-pressure gas refrigerant (the mass flow rate m_{i2}) supplied through the second injection pipe (45). Thus, the mass flow rate m_c of high-pressure refrigerant discharged from the compressor (50) to the condenser is equal to a sum of the mass flow rates of the low-pressure refrigerant, the first intermediate-pressure gas refrigerant, and the

second intermediate-pressure gas refrigerant which are sucked into the compressor (50) ($m_c = m_e + m_{i1} + m_{i2}$).

[0153] In the refrigerant circuit (5) of the air conditioner (1) of the present variation, in which the two-state compression refrigeration cycle is performed, the first and second intermediate-pressure gas refrigerants generated in the enthalpy reducing unit (20) are sucked into the compressor (50). That is, according to the present variation, both of the first and second intermediate-pressure gas refrigerants with different pressures can be sucked into the compressor (50) performing the two-stage compression. Thus, according to the present variation, while using the two compression mechanisms (71, 72), the first and second intermediate-pressure gas refrigerants with different pressures can be processed, thereby solving the problems such as the increase in mechanical loss of the compressor (50) and the increase in manufacturing cost of the air conditioner (1) due to the increase in the number of compression mechanisms.

[0154] Fourth Variation

In the refrigerant circuit (5) of the third variation, a connection position of the first injection pipe (35) or the second injection pipe (45) to the compressor (50) may be changed. Differences of the refrigerant circuit (5) illustrated in FIG. 15, to which the present variation is applied, from the refrigerant circuit (5) illustrated in FIG. 15 will be described.

[0155] As illustrated in FIG. 17, the first injection pipe (35) may be connected not to the first compression mechanism (71) but to the connection path (57). In such a case, in the first compression mechanism (71), the first injection port (89) is omitted. Note that the refrigerant circuit (5) of the present variation is similar to the refrigerant circuit (5) illustrated in FIG. 15 in that the second injection pipe (45) is connected to the second compression mechanism (72).

[0156] An operation of the compressor (50) of the present variation will be described with reference to FIG. 18. FIG. 18 is a Mollier diagram illustrating a two-stage compression refrigeration cycle performed in the refrigerant circuit (5) of the present variation.

[0157] In the refrigerant circuit (5) illustrated in FIG. 17, low-pressure refrigerant in a state at a point A is sucked into the compressor (50). The low-pressure refrigerant flowing into the suction pipe (55) of the compressor (50) is sucked into the second compression chamber (95) of the second compression mechanism (72). In the second compression mechanism (72), the low-pressure refrigerant sucked into the second compression chamber (95) is compressed, and the refrigerant in the second compression chamber (95) is changed from the state at the point A to a state at a point B₁. Second intermediate-pressure gas refrigerant in a state at a point J is injected to the second compression mechanism (72) through the second injection pipe (45). In the second compression chamber (95) of the second compression mechanism (72), the refrigerant which flows into the second compression chamber (95) in the state at the

point A and is being compressed, and the second intermediate-pressure gas refrigerant flowing into the second compression chamber (95) through the second injection pipe (45) are mixed together, and the refrigerant mixture is compressed into refrigerant in a state at a point C₁. The second compression mechanism (72) discharges the refrigerant compressed into the state at the point C₁.

[0158] The refrigerant discharged from the second compression mechanism (72) flows into the connection path (57). First intermediate-pressure gas refrigerant in a state at a point G is injected to the connection path (57) through the first injection pipe (35). In the connection path (57), the refrigerant in the state at the point C₁ and the first intermediate-pressure gas refrigerant in the state at the point G are mixed into refrigerant in a state at a point C₂. The first compression mechanism (71) sucks the refrigerant in the state indicated by the point C₂ through the connection path (57).

[0159] In the first compression mechanism (71), the refrigerant sucked into the first compression chamber (85) is compressed, and the refrigerant in the first compression chamber (85) is changed from the state at the point C₂ to a state at a point D. The first compression mechanism (71) discharges the refrigerant compressed into the state at the point D. The refrigerant discharged from the first compression mechanism (71) is sent to the outside of the casing (51) through the discharge pipe (52).

[0160] As illustrated in FIG. 19, the second injection pipe (45) may be connected not to the second compression mechanism (72) but to the connection path (57). In such a case, in the second compression mechanism (72), the second injection port (99) is omitted. Note that the refrigerant circuit (5) of the present variation is similar to the refrigerant circuit (5) illustrated in FIG. 15 in that the first injection pipe (35) is connected to the first compression mechanism (71).

[0161] An operation of the compressor (50) of the present variation will be described with reference to FIG. 18.

[0162] In the refrigerant circuit (5) illustrated in FIG. 18, low-pressure refrigerant in the state at the point A is sucked into the compressor (50). The low-pressure refrigerant flowing into the suction pipe (55) of the compressor (50) is sucked into the second compression chamber (95) of the second compression mechanism (72), and is compressed. Then, such refrigerant is changed from the state at the point A to the state at the point B₁. The second compression mechanism (72) discharges the refrigerant changed to the state at the point B₁.

[0163] The refrigerant discharged from the second compression mechanism (72) flows into the connection path (57). Second intermediate-pressure gas refrigerant in the state at the point J is injected to the connection path (57) through the second injection pipe (45). In the connection path (57), the refrigerant in the state at the point B₁ and the second intermediate-pressure gas refrigerant in the state at the point J are mixed into refrigerant

erant in a state at a point B_2 . The first compression mechanism (71) sucks the refrigerant in the state at the point B_2 through the connection path (57).

[0164] In the first compression mechanism (71), the refrigerant sucked into the first compression chamber (85) is compressed, and the refrigerant in the first compression chamber (85) is changed from the state at the point B_2 to the state at the point C_1 . First intermediate-pressure gas refrigerant in the state at the point G is injected to the first compression mechanism (71) through the first injection pipe (35). In the first compression chamber (85) of the first compression mechanism (71), the refrigerant which flows into the first compression chamber (85) in the state at the point B_2 and is being compressed, and the first intermediate-pressure gas refrigerant flowing into the first compression chamber (85) through the first injection pipe (35) are mixed together, and the refrigerant mixture is compressed into refrigerant in the state at the point D. The first compression mechanism (71) discharges the refrigerant compressed into the state at the point D. The refrigerant discharged from the first compression mechanism (71) is sent to the outside of the casing (51) through the discharge pipe (52).

[0165] Fifth Variation

In each of the third and fourth variations, the first compression mechanism (71) and the second compression mechanism (72) may be provided in separate compressors (50a, 50b).

[0166] First, differences of the refrigerant circuit (5) of the second variation illustrated in FIG. 15, to which the present variation is applied, from the refrigerant circuit (5) illustrated in FIG. 15 will be described.

[0167] As illustrated in FIG. 20, if the present variation is applied to the refrigerant circuit (5) illustrated in FIG. 15, the first compressor (50a) and the second compressor (50b) are provided in the refrigerant circuit (5). The first compressor (50a) is the hermetic compressor including the first compression mechanism (71). In the casing (51a) of the first compressor (50a), the first compression mechanism (71), the electric motor (60a), and the drive shaft (65a) connecting the first compression mechanism (71) and the electric motor (60a) are accommodated. The discharge pipe (52a) is provided in the casing (51a) of the first compressor (50a), and the suction pipe (53) is connected to the first compression mechanism (71). On the other hand, the second compressor (50b) is the hermetic compressor including the second compression mechanism (72). In the casing (51b) of the second compressor (50b), the second compression mechanism (72), the electric motor (60b), and the drive shaft (65b) connecting the second compression mechanism (72) and the electric motor (60b) are accommodated. The discharge pipe (52b) is provided in the casing (51b) of the second compressor (50b), and the suction pipe (54) is connected to the second compression mechanism (72).

[0168] In the refrigerant circuit (5) of the present variation, the discharge pipe (52a) of the first compressor (50a) is connected to the first port of the four-way valve

(11), and the suction pipe (54) of the second compressor (50b) is connected to the second port of the four-way valve (11). The discharge pipe (52b) of the second compressor (50b) and the first suction pipe (53) of the first compressor (50a) are connected together by a connection pipe (58). The first injection pipe (35) is connected to the first injection port (89) of the first compression mechanism (71) provided in the first compressor (50a). The second injection pipe (45) is connected to the second injection port (99) of the second compression mechanism (72) provided in the second compressor (50b).

[0169] Next, the refrigerant circuit (5) of the second variation illustrated in FIG. 17, to which the present variation is applied will be described with reference to FIG. 21. The refrigerant circuit (5) illustrated in FIG. 21 is different from the refrigerant circuit (5) illustrated in FIG. 20 only in a connection position of the first injection pipe (35).

[0170] Specifically, in the refrigerant circuit (5) illustrated in FIG. 21, the first injection pipe (35) is connected not to the first compression mechanism (71) but to the connection pipe (58). In the first compression mechanism (71), the first injection port (89) is omitted. In the refrigerant circuit (5), the second compression mechanism (72) of the second compressor (50b) compresses and discharges low-pressure refrigerant sucked through the suction pipe (54) and second intermediate-pressure gas refrigerant flowing through the second injection pipe (45). The first compression mechanism (71) of the first compressor (50a) sucks the refrigerant discharged from the second compressor (50b) and first intermediate-pressure gas refrigerant flowing into the connection pipe (58) from the first injection pipe (35), and compresses and discharges the sucked refrigerant.

[0171] Finally, the refrigerant circuit (5) of the second variation illustrated in FIG. 19, to which the present variation is applied will be described with reference to FIG. 22. The refrigerant circuit (5) illustrated in FIG. 22 is different from the refrigerant circuit (5) illustrated in FIG. 20 only in a connection position of the second injection pipe (45).

[0172] Specifically, in the refrigerant circuit (5) illustrated in FIG. 22, the second injection pipe (45) is connected not to the second compression mechanism (72) but to the connection pipe (58). In the second compression mechanism (72), the second injection port (99) is omitted. In the refrigerant circuit (5), the second compression mechanism (72) of the second compressor (50b) compresses and discharges low-pressure refrigerant sucked through the suction pipe (54). The first compression mechanism (71) of the first compressor (50a) sucks the refrigerant discharged from the second compressor (50b) and second intermediate-pressure gas refrigerant flowing into the connection pipe (58) from the second injection pipe (45) through the suction pipe (53). Further, first intermediate-pressure gas refrigerant is injected to the first compression mechanism (71) through the first injection pipe (35). The first compressor (50a) compresses and discharges the refrigerant discharged from the

second compressor (50b), the second intermediate-pressure gas refrigerant, and the first intermediate-pressure gas refrigerant.

[0173] Note that each of the first compression mechanism (71) and the second compression mechanism (72) of the present variation may be a rotary fluid machine including a pair of cylinders and a pair of pistons, or a rotary fluid machine including a plurality of cylinders and a plurality of pistons.

[0174] The foregoing embodiments have been set forth merely for purposes of preferred examples in nature, and are not intended to limit the scope, applications, and use of the invention.

INDUSTRIAL APPLICABILITY 15

[0175] As described above, the present invention is useful for the refrigerating apparatus in which the gas injection is performed to supply intermediate-pressure gas refrigerant to the compressor. 20

DESCRIPTION OF REFERENCE CHARACTERS

[0176] 25

1	Air Conditioner (Refrigerating Apparatus)	
5	Refrigerant Circuit	
7	Main Path	
20	Enthalpy Reducing Unit	
21	Branched Path	30
22	Expansion Mechanism	
30	First Heat Exchanger	
33	First Branched Pipe	
34	First Expansion Valve	
35	First Injection Pipe (First Injection Path)	35
36	First Gas-Liquid Separator	
37	First Expansion Valve	
40	Second Heat Exchanger	
43	Second Branched Pipe	
44	Second Expansion Valve	40
45	Second Injection Pipe (Second Injection Path)	
46	Second Gas-Liquid Separator	
47	Second Expansion Valve	
50	Compressor	
65	Drive Shaft	45
71	First Compression Mechanism	
72	Second Compression Mechanism	
85	First Compression Chamber (Compression Chamber)	
95	Second Compression Chamber (Compression Chamber)	50

Claims 55

1. A refrigerating apparatus, comprising:
a refrigerant circuit (5) including a radiator and

an evaporator and performing a refrigeration cycle; and

a first compression mechanism (71) and a second compression mechanism (72) each including a compression chamber (85, 95), wherein each of the first compression mechanism (71) and the second compression mechanism (72) sucks low-pressure refrigerant into the compression chamber (85, 95), and compresses the low-pressure refrigerant to a high pressure level, and

the refrigerant circuit (5) includes an enthalpy reducing unit (20) for reducing an enthalpy of refrigerant flowing from the radiator to the evaporator by generating first intermediate-pressure gas refrigerant and second intermediate-pressure gas refrigerant having a pressure lower than that of the first intermediate-pressure gas refrigerant,

a first injection path (35) for supplying the first intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (85) of the first compression mechanism (71) in the middle of a compression process, and

a second injection path (45) for supplying the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (95) of the second compression mechanism (72) in the middle of a compression process.

2. A refrigerating apparatus, comprising:

a refrigerant circuit (5) including a radiator and an evaporator and performing a refrigeration cycle; and

a first compression mechanism (71) and a second compression mechanism (72) each including a compression chamber (85, 95), wherein the first compression mechanism (71) sucks low-pressure refrigerant into the compression chamber (85) and compresses the low-pressure refrigerant, and the second compression mechanism (72) sucks the refrigerant discharged from the first compression mechanism (71) into the compression chamber (95) and compresses the refrigerant, and

the refrigerant circuit (5) includes an enthalpy reducing unit (20) for reducing an enthalpy of refrigerant flowing from the radiator to the evaporator by generating first intermediate-pressure gas refrigerant and second intermediate-pressure gas refrigerant having a pressure lower than that of the first intermediate-pressure gas refrigerant,

a first injection path (35) for supplying the first intermediate-pressure gas refrigerant generat-

ed in the enthalpy reducing unit (20) to the compression chamber (85) of the first compression mechanism (71) in the middle of a compression process, and

a second injection path (45) for supplying the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (95) of the second compression mechanism (72) in the middle of a compression process, or to an inlet side of the second compression mechanism (72).

3. A refrigerating apparatus, comprising:

a refrigerant circuit (5) including a radiator and an evaporator and performing a refrigeration cycle; and

a first compression mechanism (71) and a second compression mechanism (72) each including a compression chamber (85, 95),

wherein the first compression mechanism (71) sucks low-pressure refrigerant into the compression chamber (85) and compresses the low-pressure refrigerant, and the second compression mechanism (72) sucks the refrigerant discharged from the first compression mechanism (71) into the compression chamber (95) and compresses the refrigerant, and the refrigerant circuit (5) includes

an enthalpy reducing unit (20) for reducing an enthalpy of refrigerant flowing from the radiator to the evaporator by generating first intermediate-pressure gas refrigerant and second intermediate-pressure gas refrigerant having a pressure lower than that of the first intermediate-pressure gas refrigerant,

a first injection path (35) for supplying the first intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to an inlet side of the second compression mechanism (72), and

a second injection path (45) for supplying the second intermediate-pressure gas refrigerant generated in the enthalpy reducing unit (20) to the compression chamber (95) of the second compression mechanism (72) in the middle of a compression process.

4. The refrigerating apparatus of any one of claims 1-3, wherein

in the refrigerant circuit (5), a portion of the refrigerant circuit (5) from an outlet of the radiator to an inlet of the evaporator forms a main path (7), and the enthalpy reducing unit (20) includes

a branched path (21) which is connected to the main path (7) and into which a part of refrigerant flowing through the main path (7) flows,

an expansion mechanism (22) for expanding the re-

frigerant flowing into the branched path (21) to generate first intermediate-pressure refrigerant and second intermediate-pressure refrigerant having a pressure lower than that of the first intermediate-pressure refrigerant,

a first heat exchanger (30) which is connected to the main path (7) downstream the radiator to exchange heat between the refrigerant flowing through the main path (7) and the first intermediate-pressure refrigerant, which cools the refrigerant flowing through the main path (7), and which generates the first intermediate-pressure gas refrigerant by evaporating the first intermediate-pressure refrigerant, and a second heat exchanger (40) which is connected to the main path (7) between the first heat exchanger (30) and the evaporator to exchange heat between the refrigerant flowing through the main path (7) and the second intermediate-pressure refrigerant, which cools the refrigerant flowing through the main path (7), and which generates the second intermediate-pressure gas refrigerant by evaporating the second intermediate-pressure refrigerant.

5. The refrigerating apparatus of claim 4, wherein the branched path (21) of the enthalpy reducing unit (20) includes

a first branched pipe (33) which is connected to the main path (7) between the radiator and the first heat exchanger (30), and which supplies refrigerant flowing from the main path (7) to the first heat exchanger (30), and

a second branched pipe (43) which is connected to the main path (7) between the first heat exchanger (30) and the second heat exchanger (40), and which supplies the refrigerant flowing from the main path (7) to the second heat exchanger (40), and the expansion mechanism (22) of the enthalpy reducing unit (20) includes

a first expansion valve (34) which is provided in the first branched pipe (33), and which generates the first intermediate-pressure refrigerant by expanding refrigerant flowing into the first branched pipe (33), and

a second expansion valve (44) which is provided in the second branched pipe (43), and which generates the second intermediate-pressure refrigerant by expanding refrigerant flowing into the second branched pipe (43).

6. The refrigerating apparatus of claim 4, wherein the branched path (21) of the enthalpy reducing unit (20) includes

a first branched pipe (33) which is connected to the main path (7) between the radiator and the first heat exchanger (30), and which supplies refrigerant flowing from the main path (7) to the first heat exchanger (30), and

a second branched pipe (43) which is connected to

the first branched pipe (33), and which supplies refrigerant flowing from the first branched pipe (33) to the second heat exchanger (40), and the expansion mechanism (22) of the enthalpy reducing unit (20) includes

a first expansion valve (34) which is provided in the first branched pipe (33), and which generates the first intermediate-pressure refrigerant by expanding refrigerant flowing into the first branched pipe (33), and

a second expansion valve (44) which is provided in the second branched pipe (43), and which generates the second intermediate-pressure refrigerant by expanding refrigerant flowing into the second branched pipe (43).

second compression mechanism (72).

7. The refrigerating apparatus of any one of claims 1-3, wherein

the enthalpy reducing unit (20) includes

a first expansion valve (37) for expanding high-pressure refrigerant flowing out from the radiator,

a first gas-liquid separator (36) for separating the refrigerant flowing out from the first expansion valve (37) in a gas-liquid two-phase state into gas refrigerant and liquid refrigerant, and supplying the gas refrigerant to the first injection path (35) as the first intermediate-pressure gas refrigerant,

a second expansion valve (47) for expanding the liquid refrigerant flowing out from the first gas-liquid separator (36), and

a second gas-liquid separator (46) for separating the refrigerant flowing out from the second expansion valve (47) in the gas-liquid two-phase state into gas refrigerant and liquid refrigerant, supplying the gas refrigerant to the second injection path (45) as the second intermediate-pressure gas refrigerant, and supplying the liquid refrigerant to the evaporator.

8. The refrigerating apparatus of any one of claims 1-3, wherein

the first compression mechanism (71) and the second compression mechanism (72) are provided in a single compressor (50), and

the compressor (50) includes a single drive shaft (65) engaged with both of the first compression mechanism (71) and the second compression mechanism (72).

9. The refrigerating apparatus of any one of claims 1-3, wherein

the first compression mechanism (71) is provided in a first compressor (50a), and the second compression mechanism (72) is provided in a second compressor (50b), and

the first compressor (50a) includes a drive shaft (65a) engaged with the first compression mechanism (71), and the second compression mechanism (72) includes a drive shaft (65b) engaged with the

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FIG.1 1

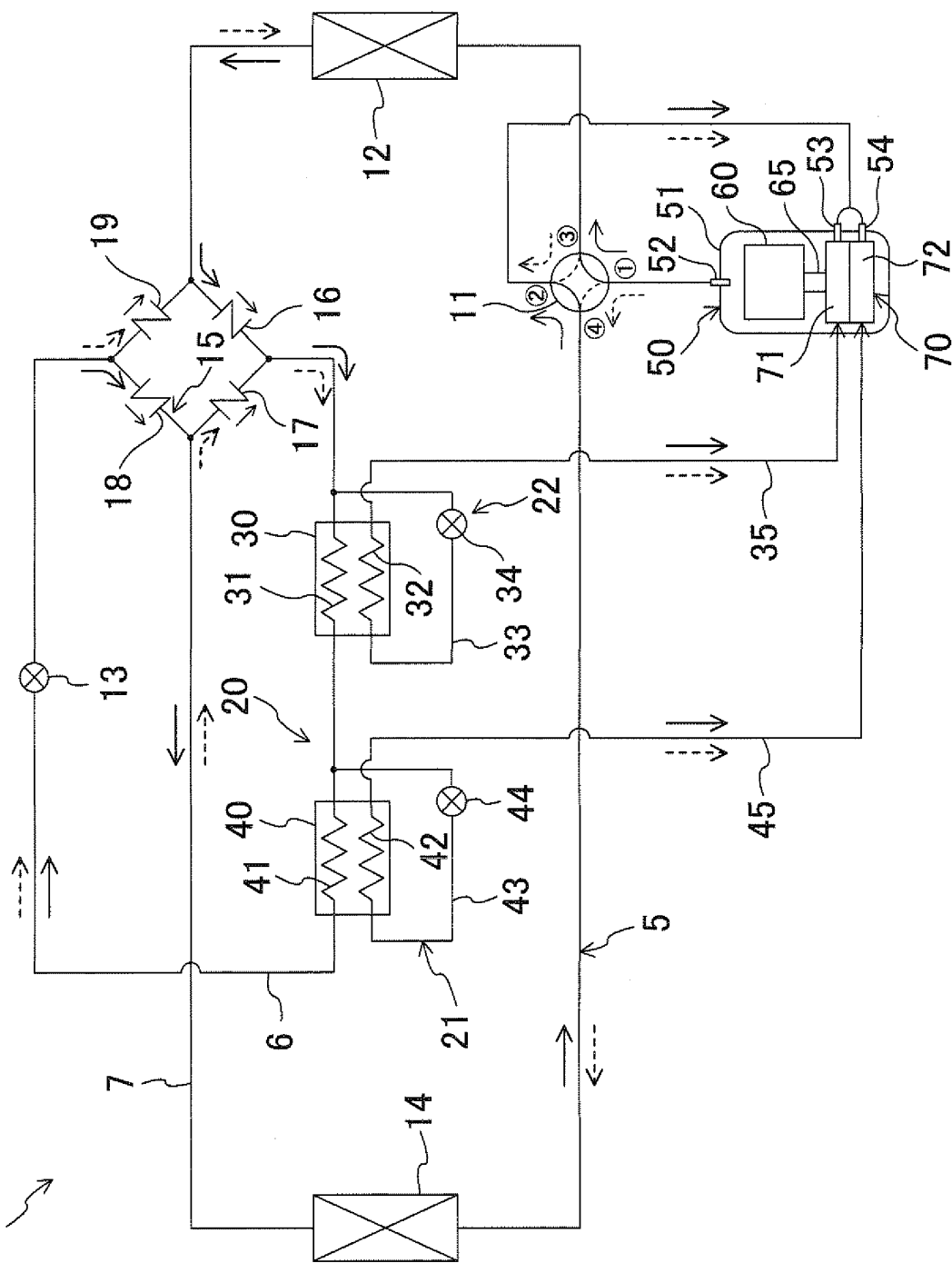


FIG.2

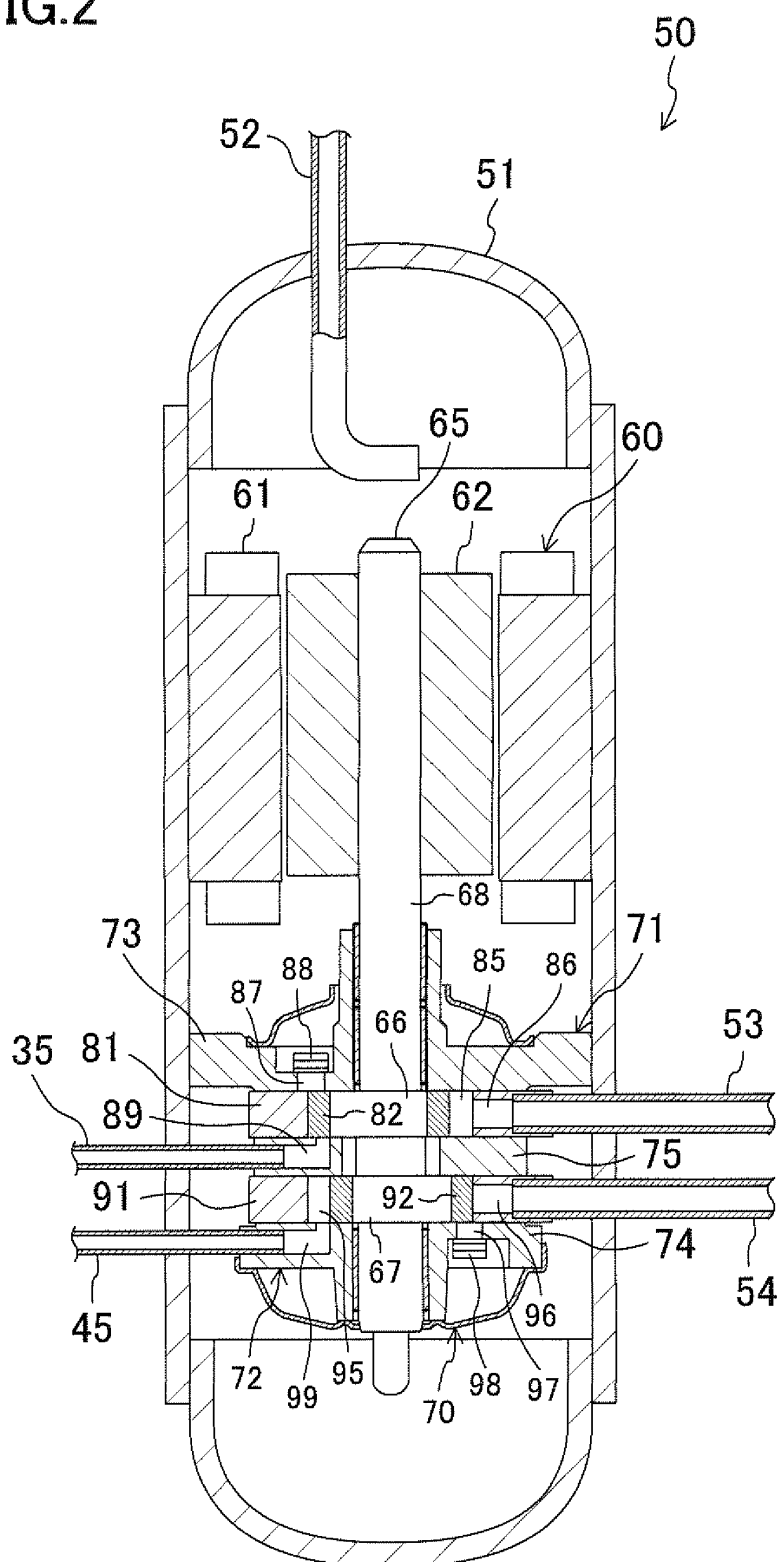
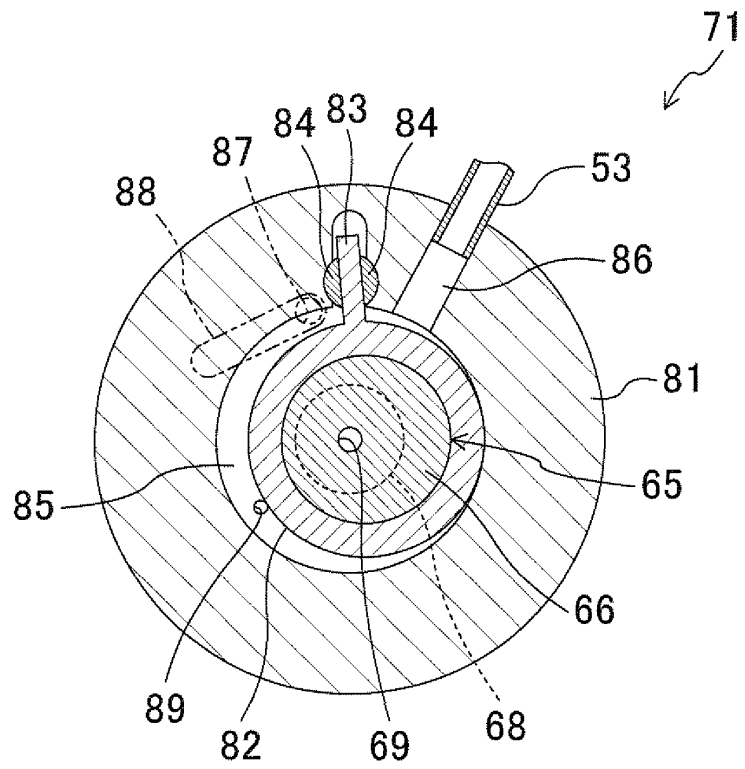


FIG.3

(A)



(B)

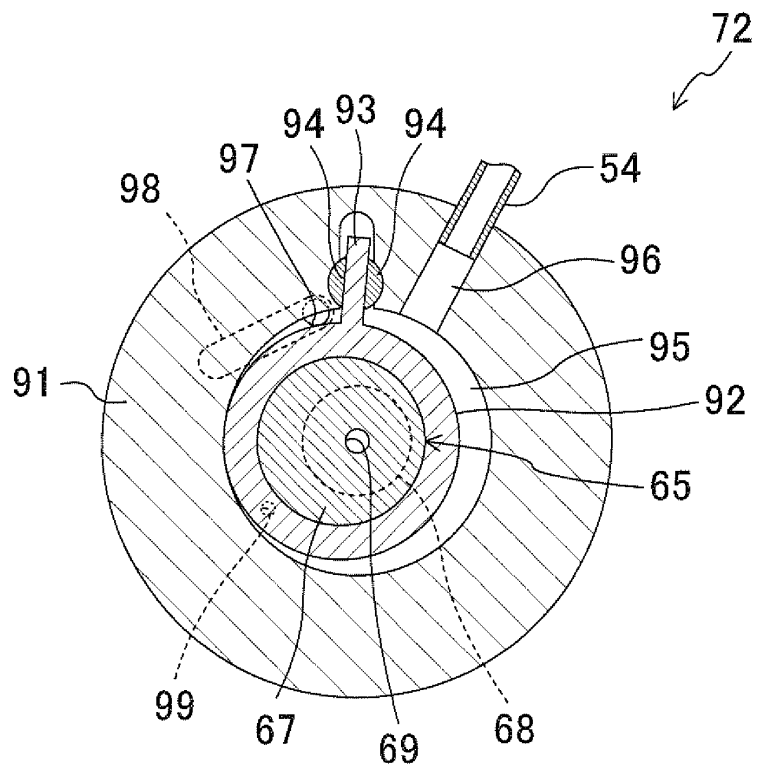


FIG.4

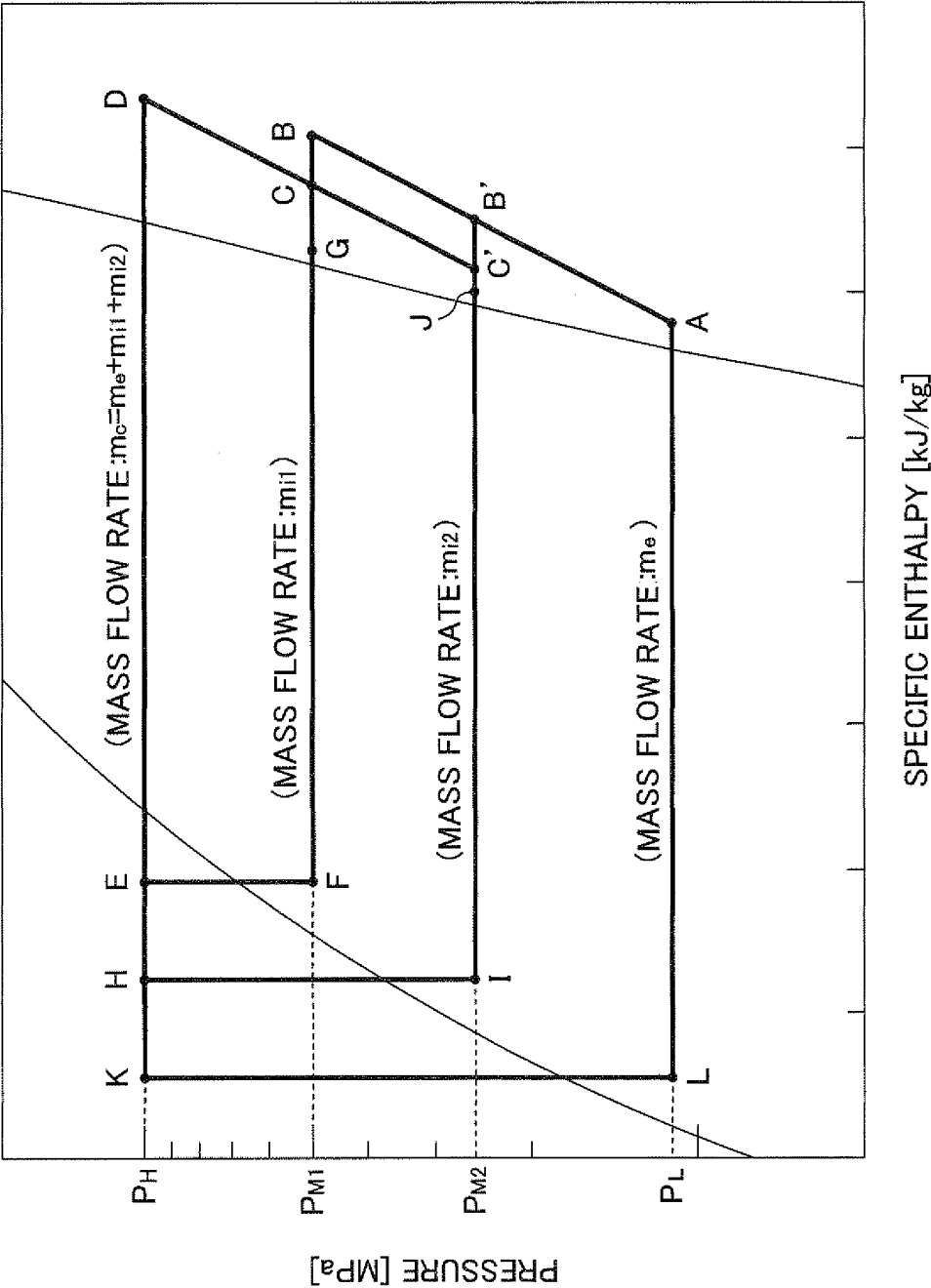


FIG.5

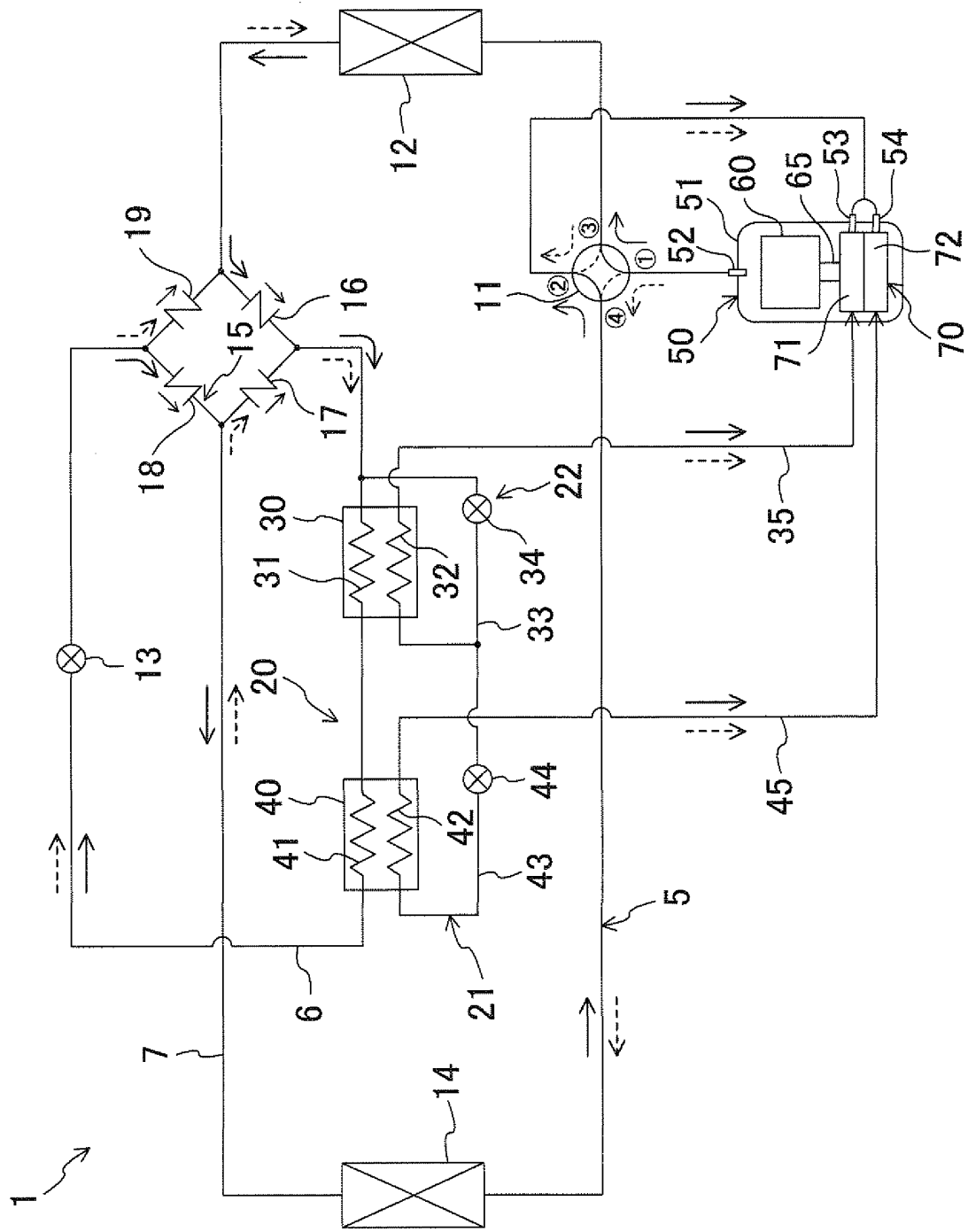


FIG.6

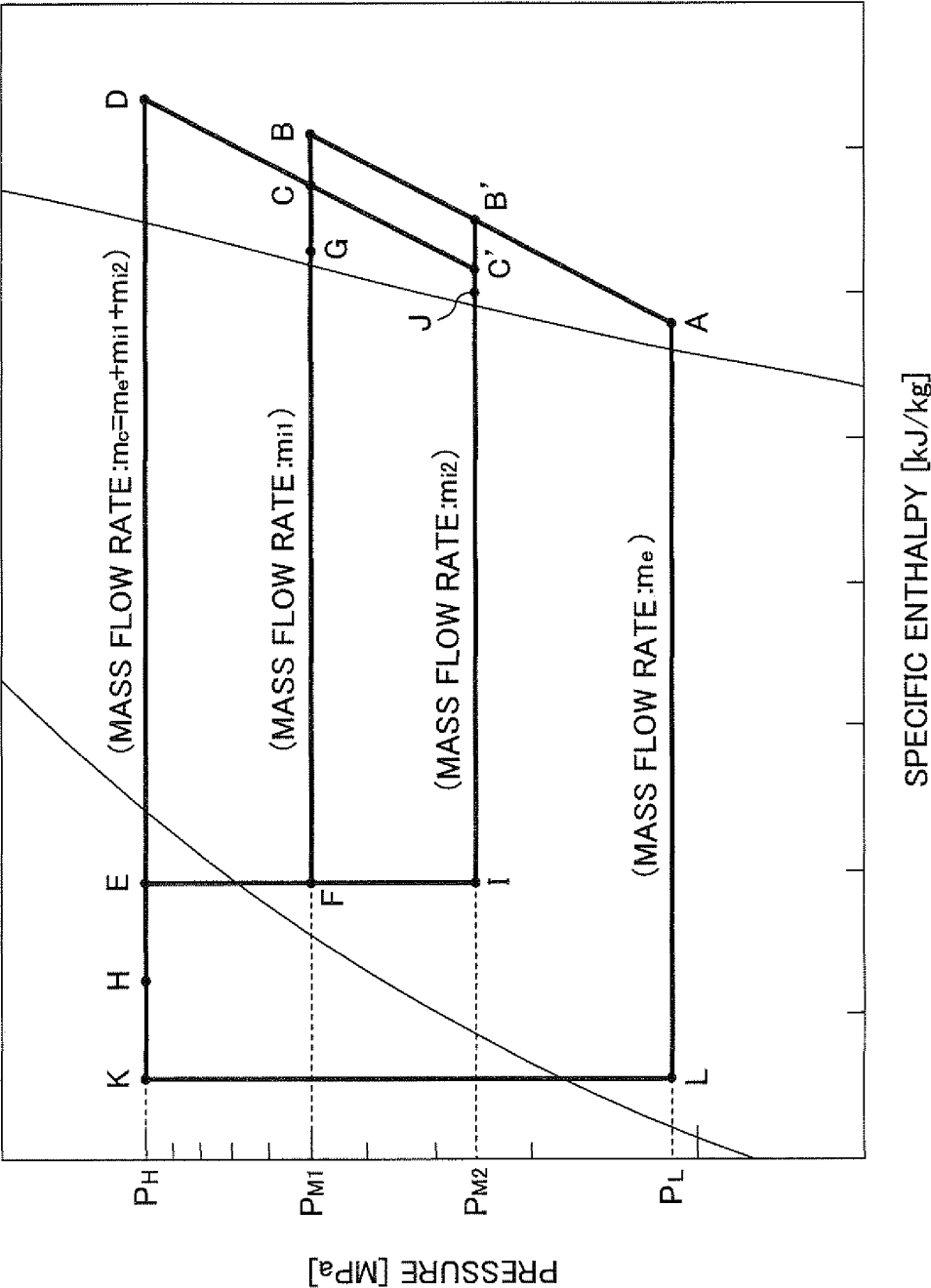


FIG. 7

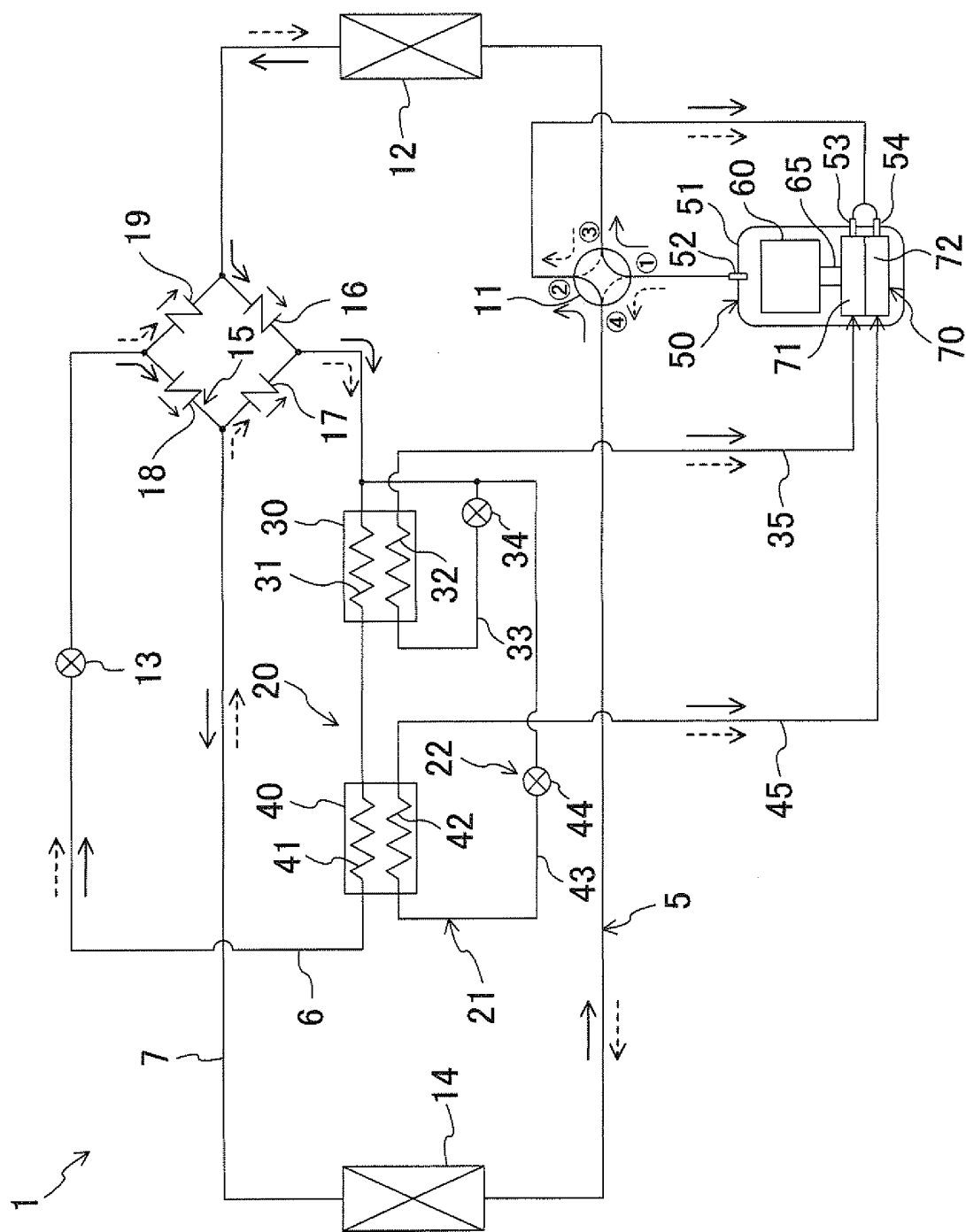


FIG.8

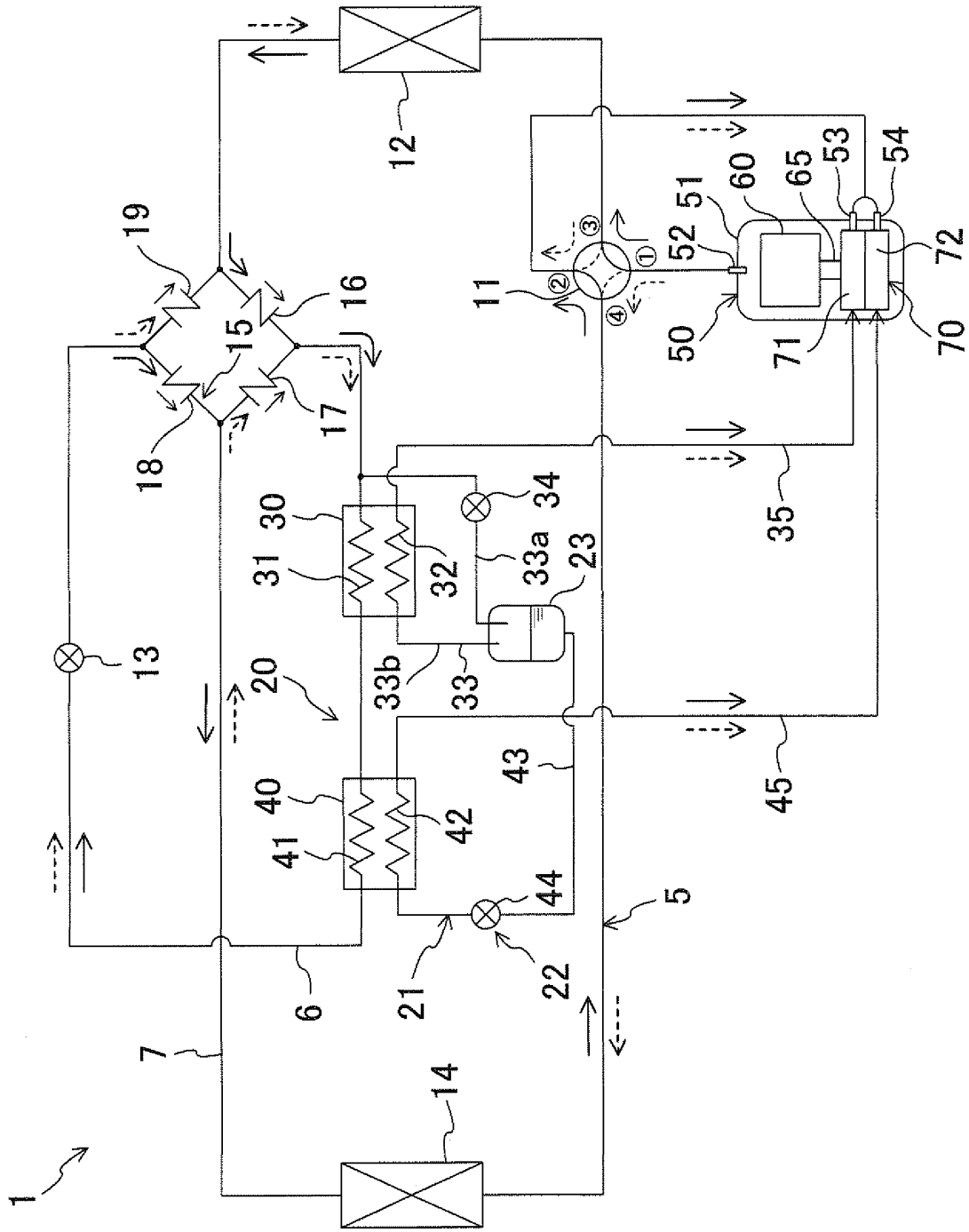
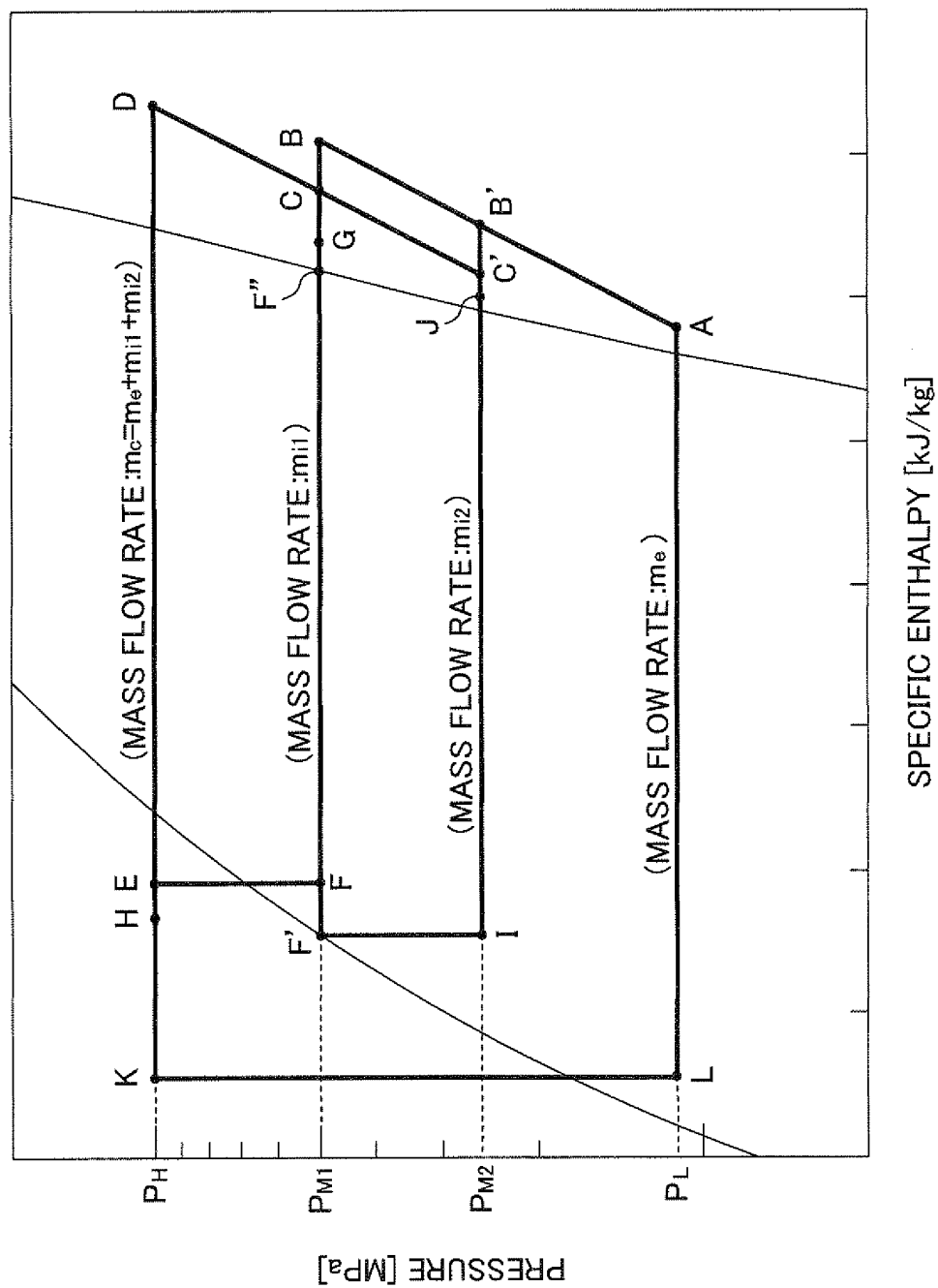


FIG.9



OTILE

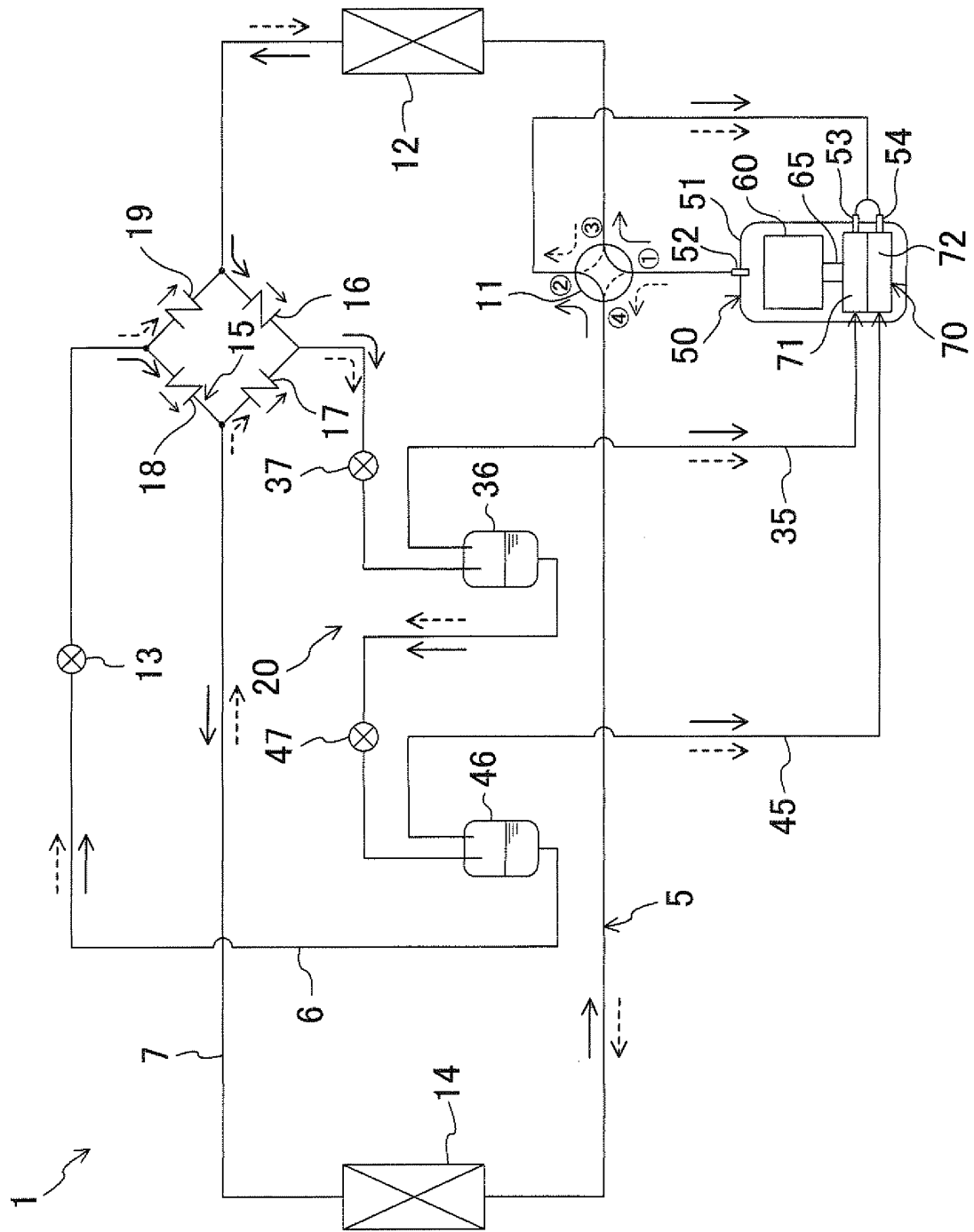
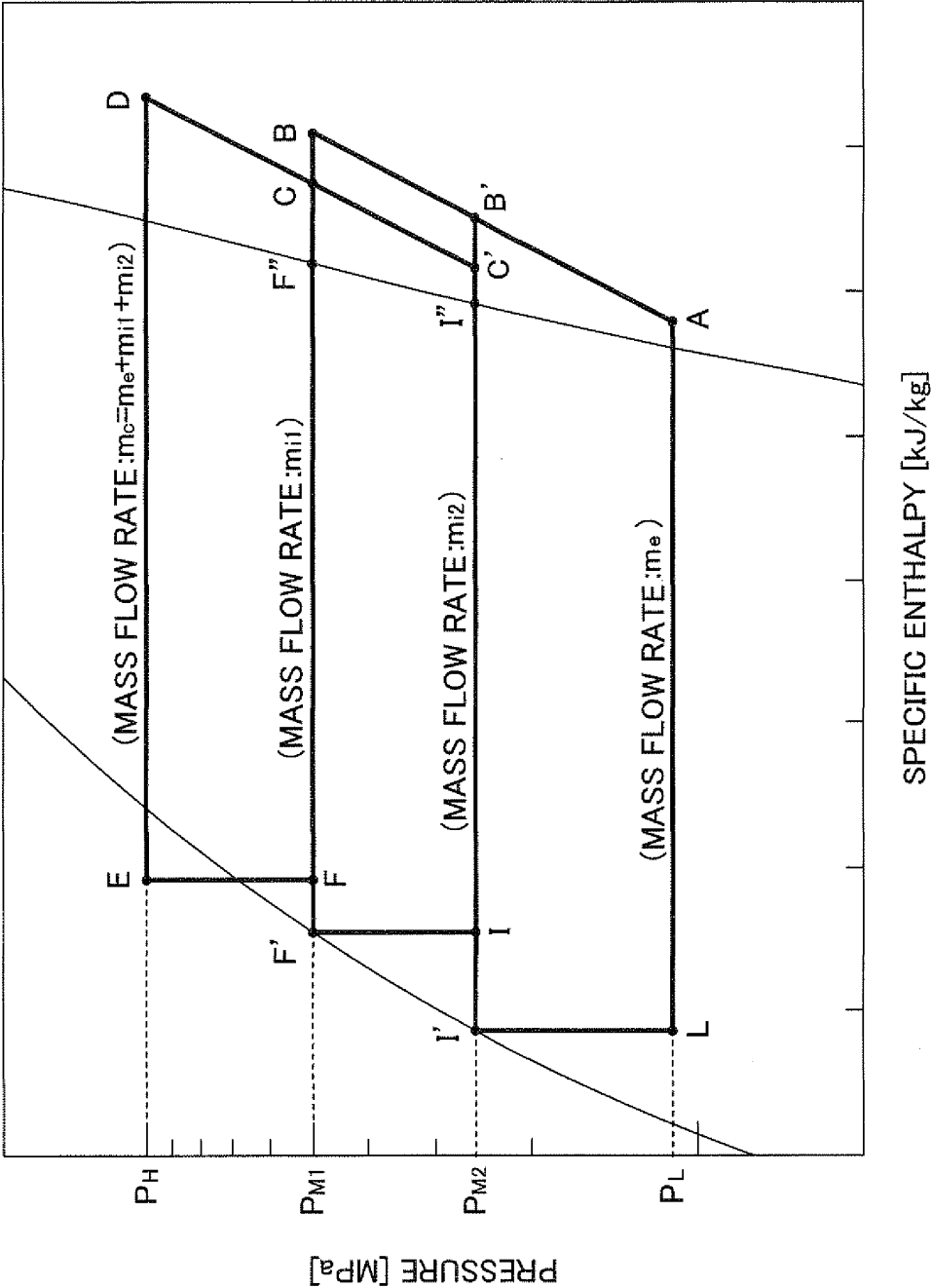


FIG.11



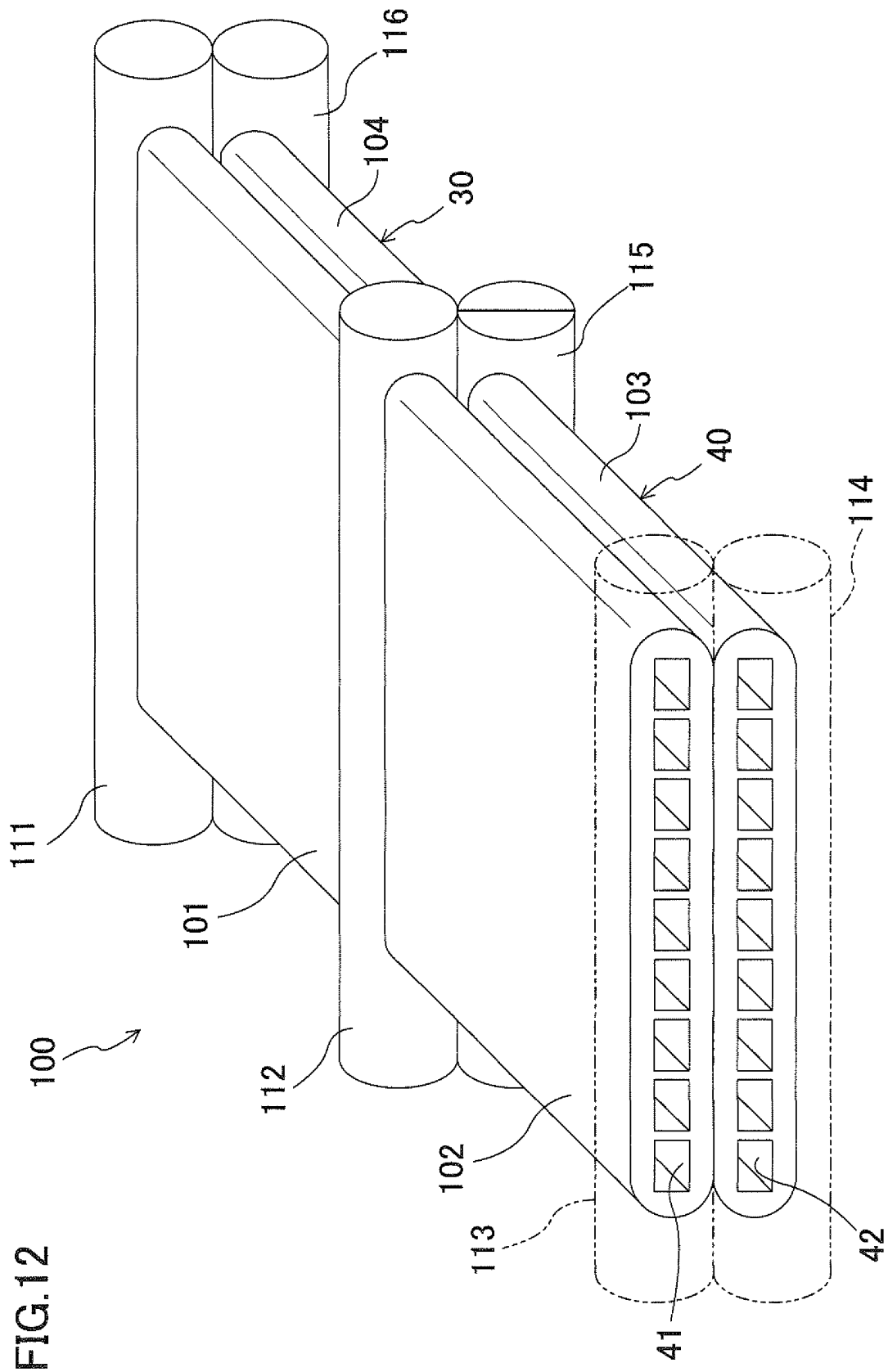


FIG.13

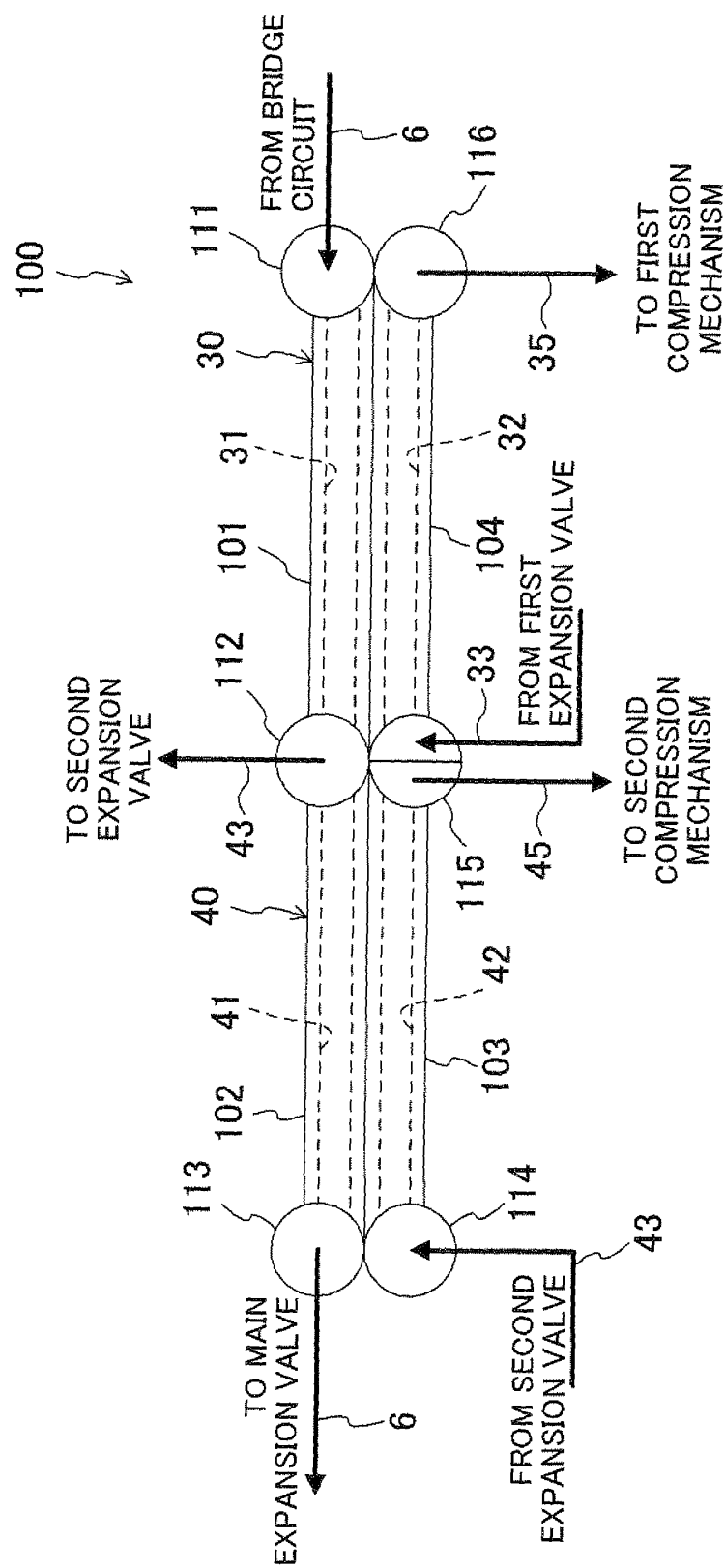


FIG.14

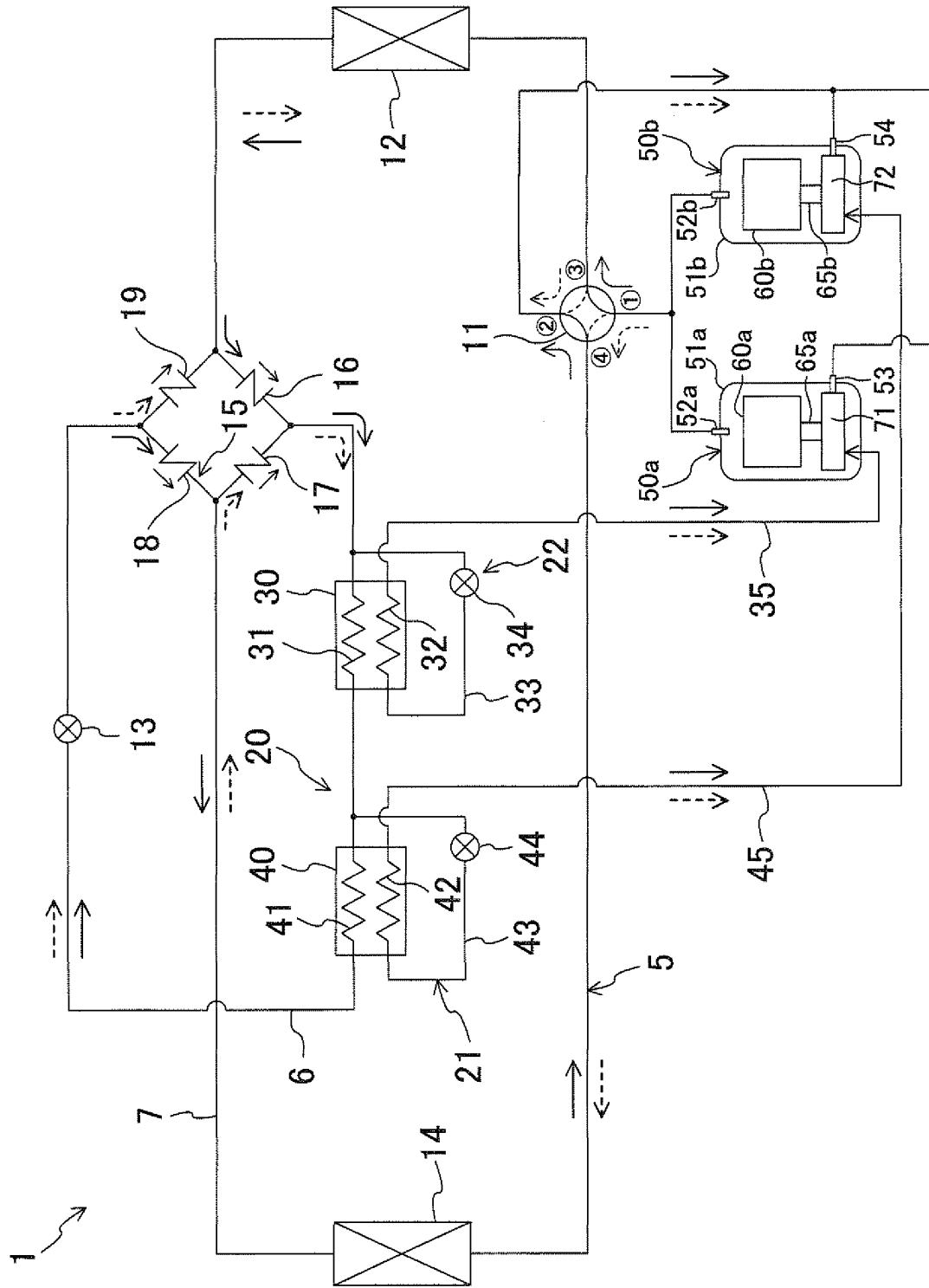


FIG.15

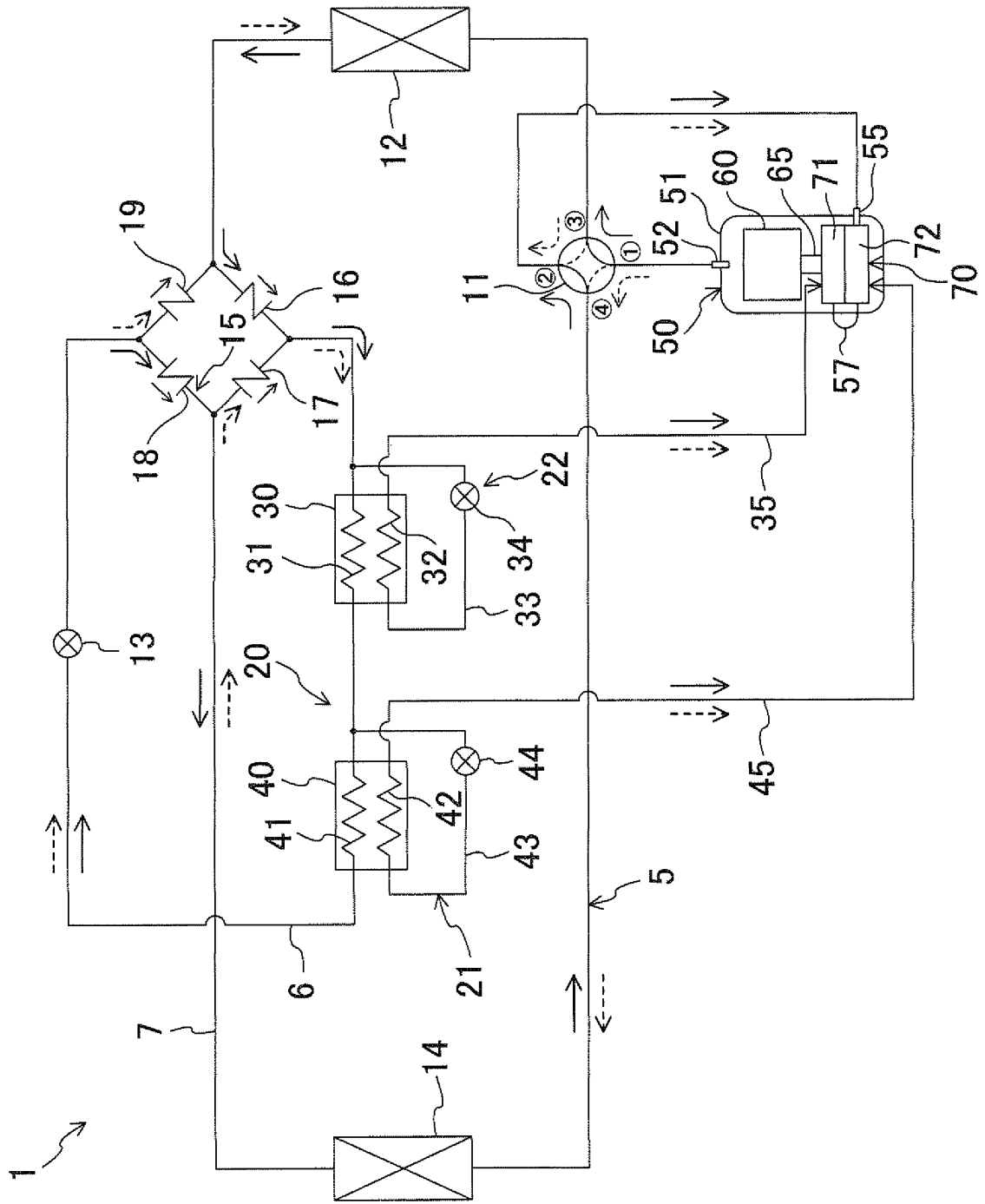


FIG.16

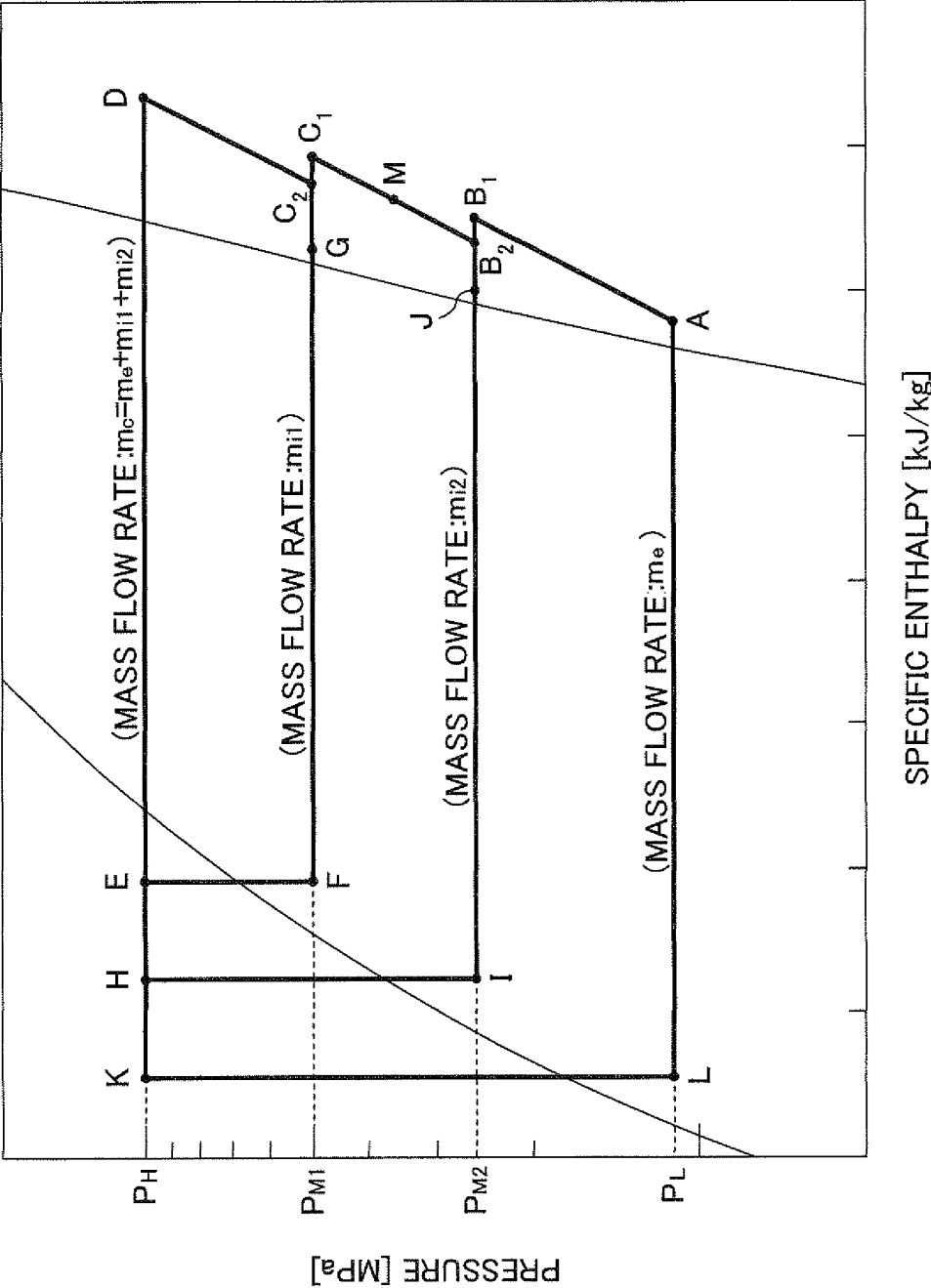


FIG.17

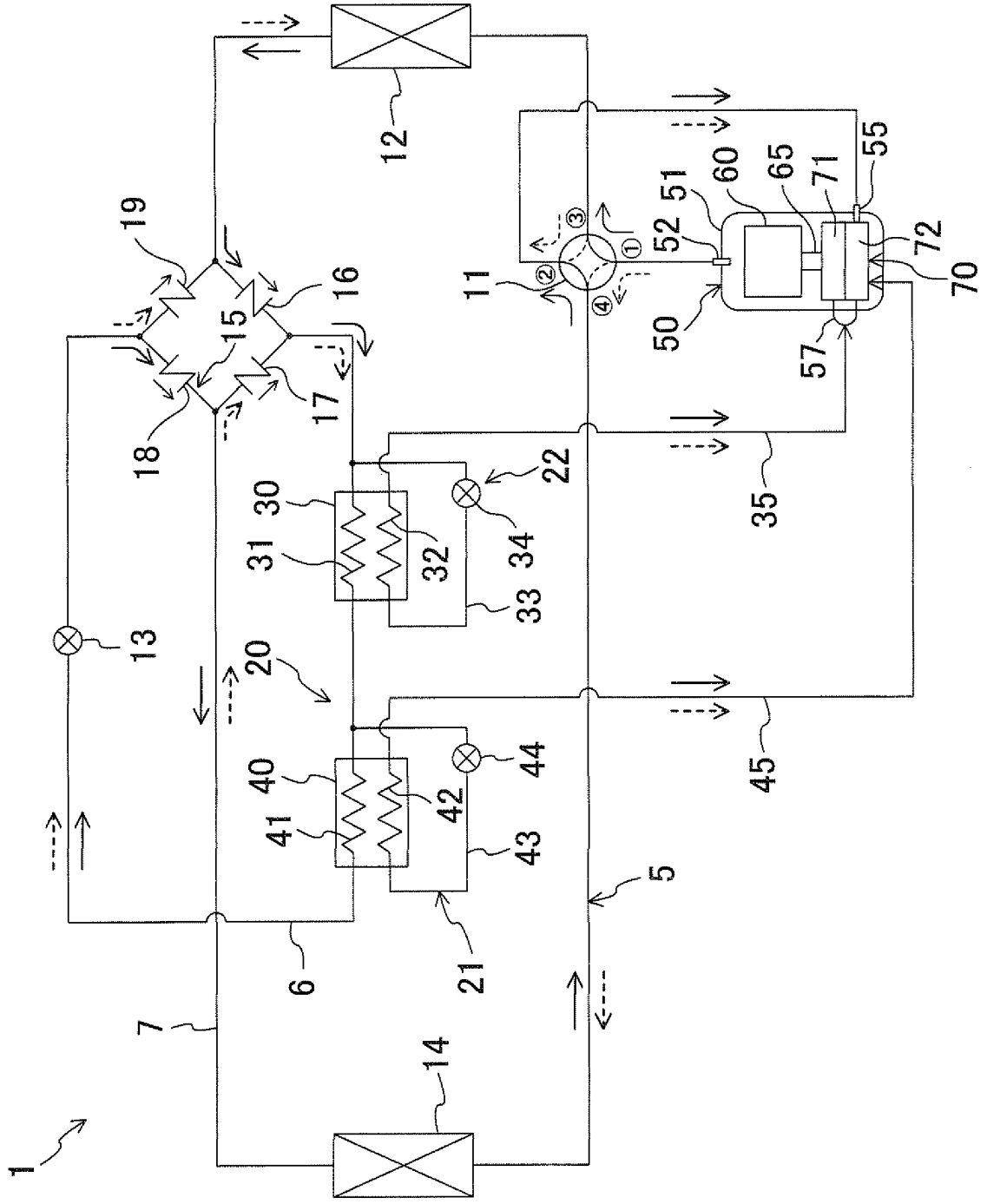
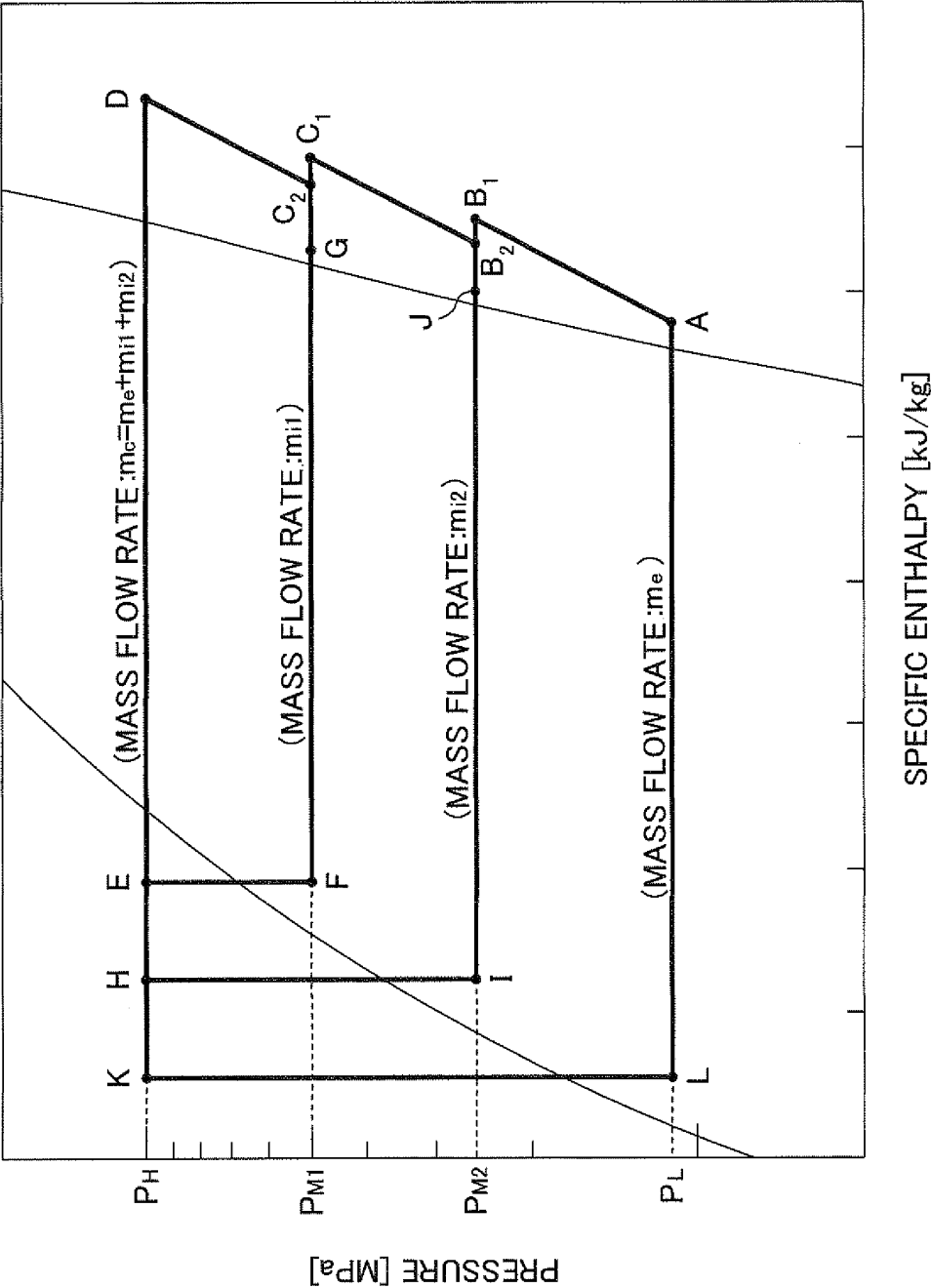


FIG.18



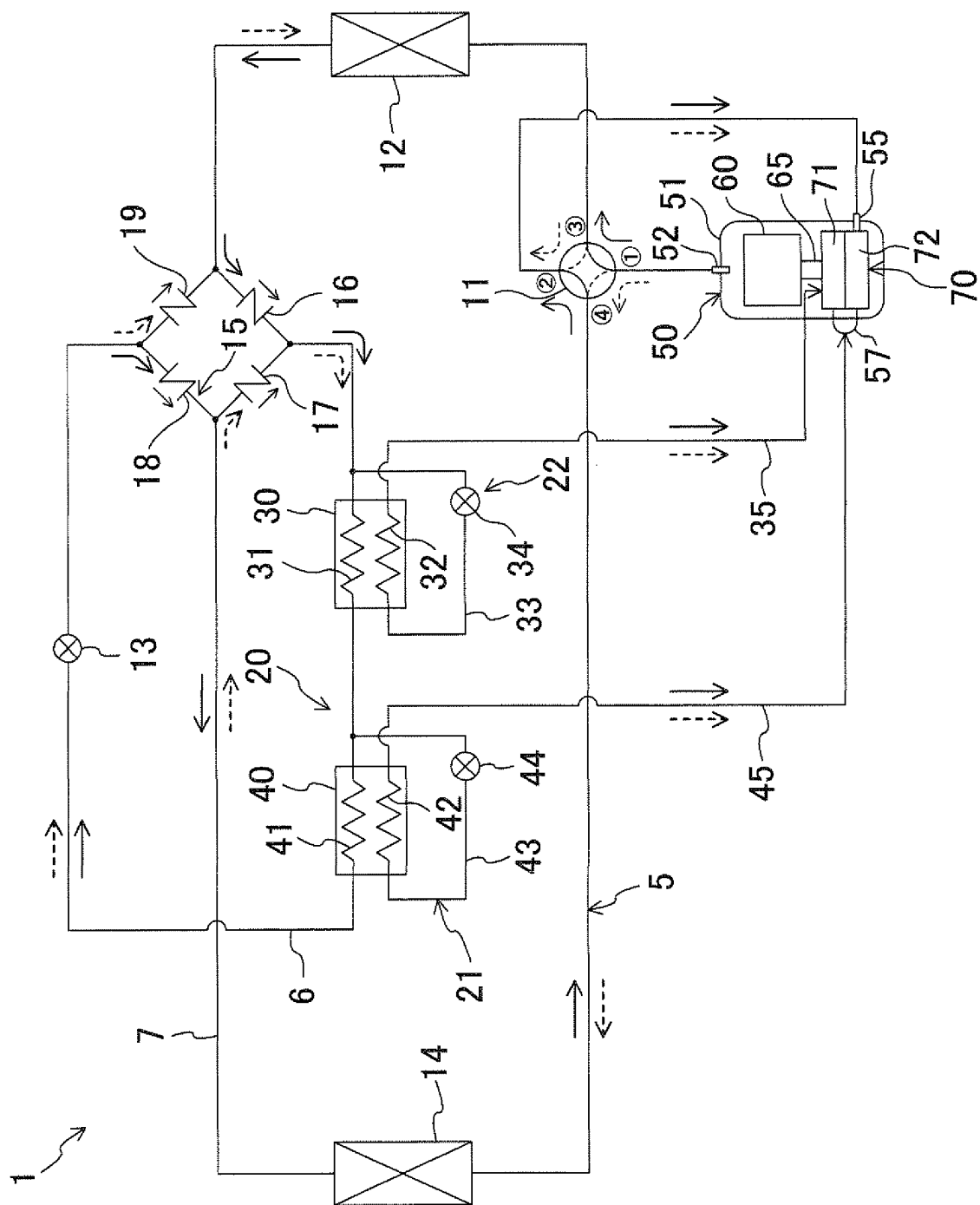
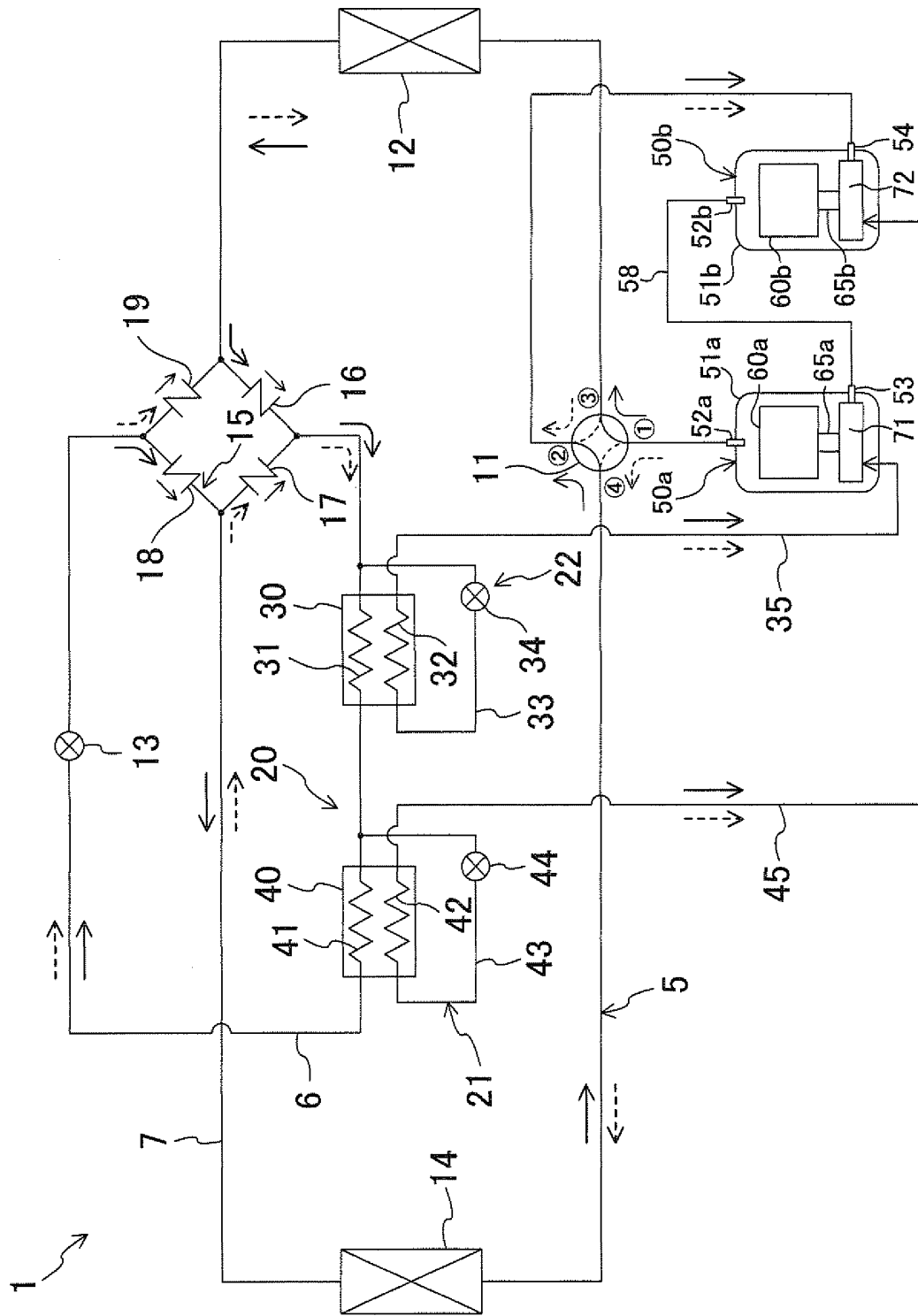


FIG. 19

FIG.20



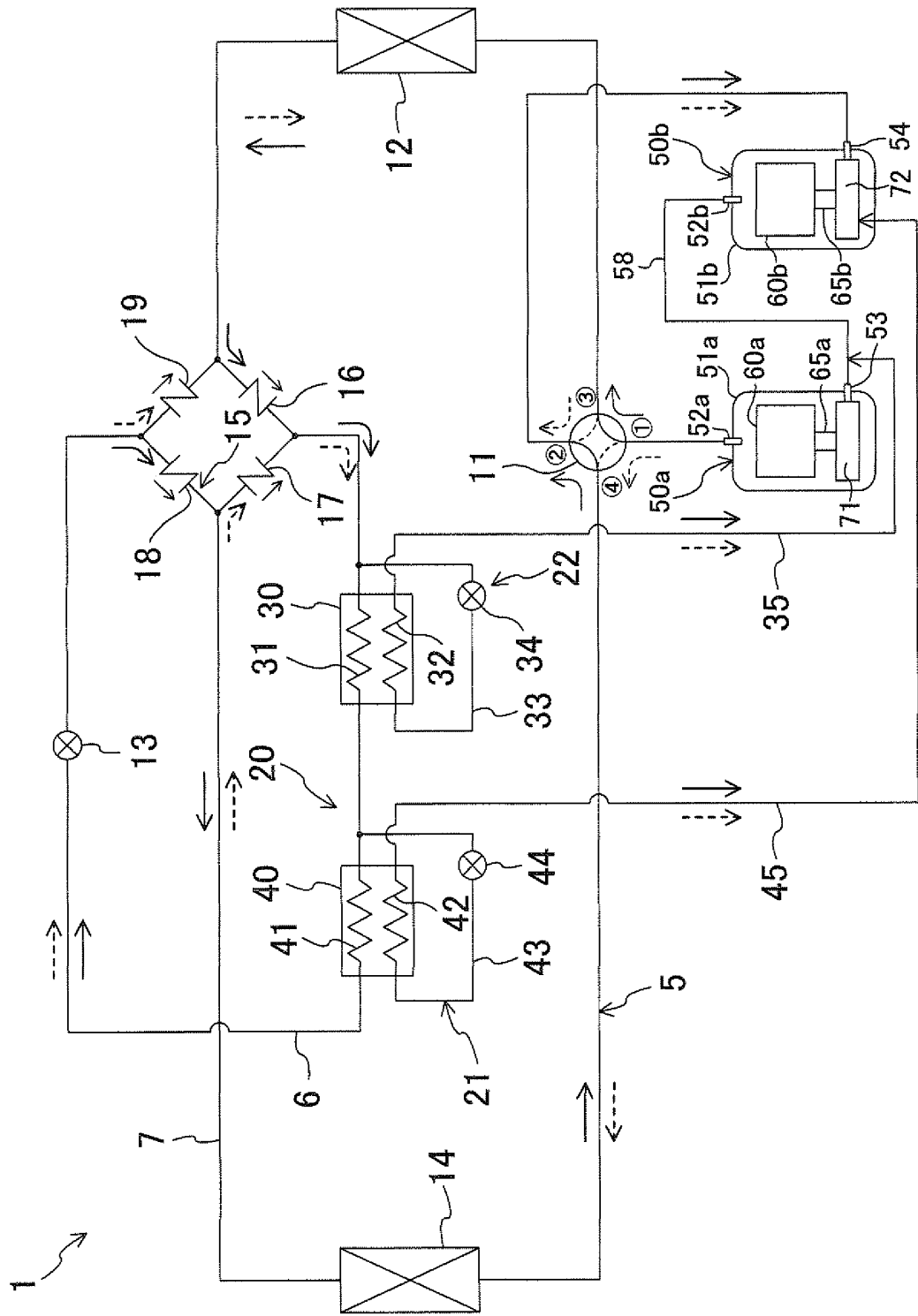
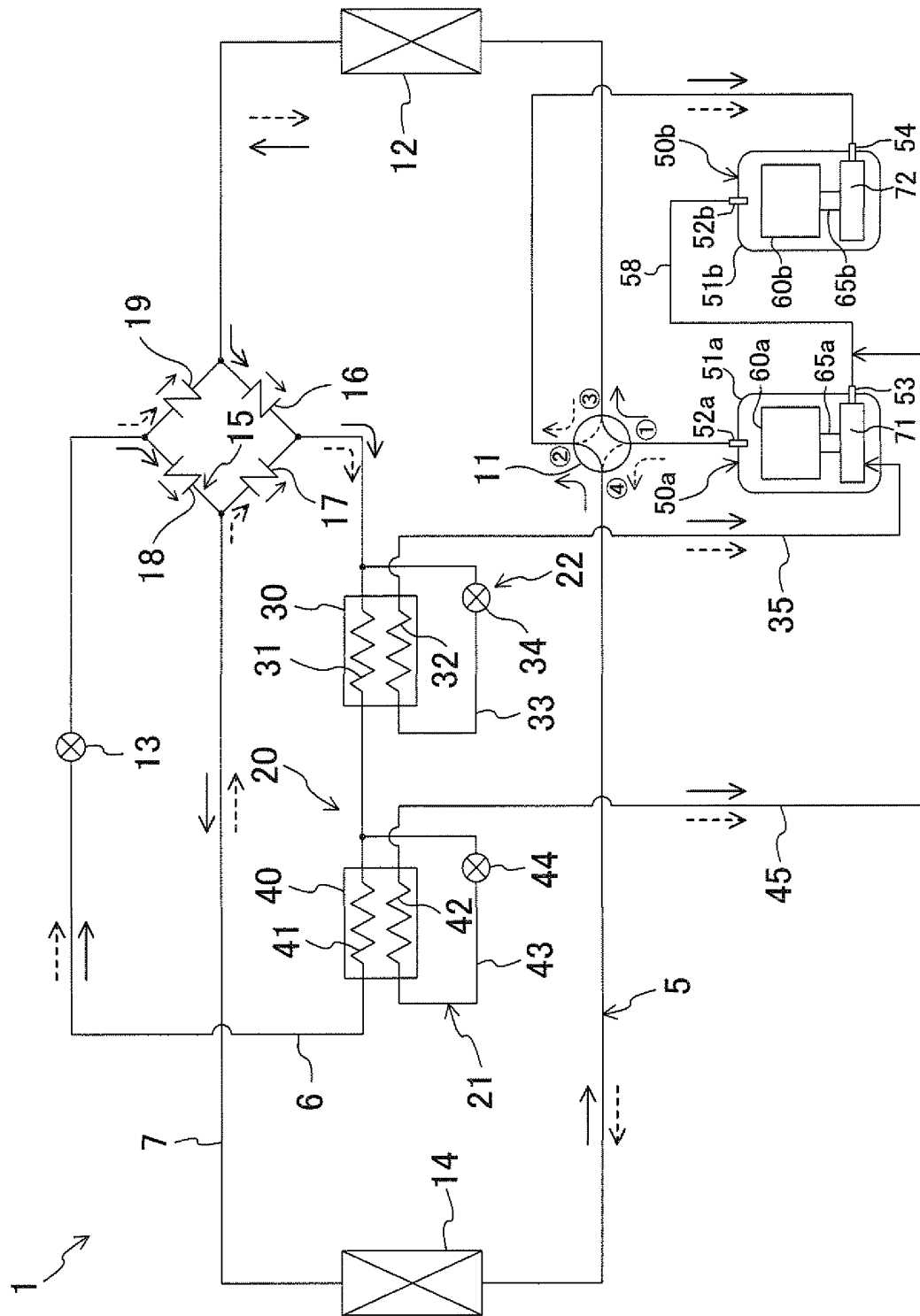


FIG. 21

FIG. 22



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/006561

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/10(2006.01) i, F25B1/00(2006.01) i, F25B13/00(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/10, F25B1/00, F25B13/00

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2010

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 008174/1981 (Laid-open No. 120972/1982) (Mitsubishi Electric Corp.), 27 July 1982 (27.07.1982), specification, page 2, line 7 to page 5, line 20; fig. 1, 2 (Family: none)	1 2-9
X Y	JP 2005-315506 A (Kobe Steel, Ltd.), 10 November 2005 (10.11.2005), paragraphs [0017] to [0023]; fig. 3 to 5 (Family: none)	3-5, 9 2, 6-8

☒ 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

04 February, 2010 (04.02.10)

Date of mailing of the international search report

16 February, 2010 (16.02.10)

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2009/006561

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 62-5055 A (Kobe Steel, Ltd.), 12 January 1987 (12.01.1987), page 3, lower left column, lines 7 to 11; fig. 4 (Family: none)	7 1-6, 8, 9
Y A	JP 2003-130477 A (Hitachi, Ltd.), 08 May 2003 (08.05.2003), paragraph [0019]; fig. 2 (Family: none)	1 2-9
Y A	JP 7-190520 A (Kobe Steel, Ltd.), 28 July 1995 (28.07.1995), paragraphs [0011], [0012]; fig. 1 (Family: none)	2, 6-8 1, 3-5, 9
Y A	JP 2007-232280 A (Daikin Industries, Ltd.), 13 September 2007 (13.09.2007), entire text; all drawings (Family: none)	8 1-7, 9

Form PCT/ISA/210 (continuation of second sheet) (April 2007)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004183913 A [0006]
- JP H11093874 B [0006]
- JP 2002188865 A [0006]