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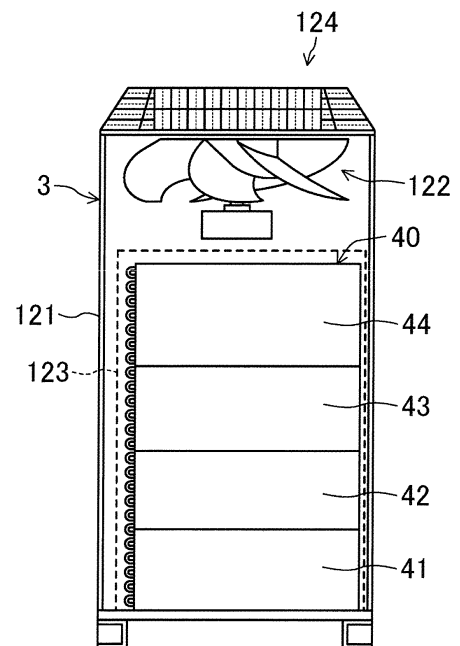
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(54) **OUTDOOR MACHINE OF REFRIGERATION DEVICE**

(57) In an outdoor unit (3), first through third intermediate heat exchangers (41, 42, 43) and an outdoor heat exchanger (44) are disposed to stand along an air inlet (123) of an outdoor casing (121), and the outdoor heat exchanger (44) is located above the first through third intermediate heat exchangers (41, 42, 43).

FIG.3



Description

TECHNICAL FIELD

BACKGROUND ART

[0001] The present invention relates to outdoor units of refrigeration systems, and particularly to a refrigeration system that performs a refrigeration cycle of a multistage compression type.

[0002] An air conditioner that performs a two-stage compression refrigeration cycle by using carbon dioxide as refrigerant as described in Patent Document 1 is known as a refrigeration system that performs a multistage compression refrigeration cycle by using refrigerant that becomes active in a supercritical region. In this air conditioner, refrigerant discharged from a compression element at a previous stage is cooled in an intercooler to be sucked into a compression element at a subsequent stage, so that the temperature of refrigerant discharged from the subsequent-stage compression element is reduced and, thereby, a loss in heat dissipation in an outdoor heat exchanger is reduced.

[0003] In an air conditioner described in Patent Document 1, as illustrated in FIG. 20, an intercooler (a) and a heat-source-side heat exchanger (b) are housed in a heat source unit (c). The intercooler (a) and the heat-source-side heat exchanger (b) are disposed on a side surface of the heat source unit (c). The intercooler (a) is located above the heat-source-side heat exchanger (b). A heat-source-side fan is provided above the intercooler (a).

CITATION LIST

PATENT DOCUMENT

[0004] [Patent Document 1] Japanese Unexamined Patent Publication No. 2009-150641

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0005] In the heat source unit (c) of Patent Document 1 configured to draw in air from the side and blow the air upward, i.e., of a so-called upward blowing type, the air-flow velocity is higher in a higher position than in a lower position as illustrated in FIG. 21, and thus, the intercooler (a) located at a higher position has a high heat exchange efficiency. Thus, the heat source unit (c) can be reduced in size by placing the intercooler (a) at an upper position.

[0006] Since the pressure of refrigerant flowing in the intercooler (a) is lower than that of refrigerant flowing in the heat-source-side heat exchanger (b), the density of refrigerant flowing in the intercooler (a) is lower than that of refrigerant flowing in the heat-source-side heat exchanger (b). Thus, as long as the mass flow rates of refrigerant flowing in the intercooler (a) and the heat-

source-side heat exchanger (b) are approximately the same, the volume flow rate of refrigerant flowing in the intercooler (a) is higher than that of refrigerant flowing in the heat-source-side heat exchanger (b). Even when the number of refrigerant paths is approximately identical in the intercooler (a) and the heat-source-side heat exchanger (b), the flow velocity of refrigerant flowing in the intercooler (a) is higher than that of refrigerant flowing in the heat-source-side heat exchanger (b), and thus, the pressure loss of refrigerant in the intercooler (a) is larger than that in the heat-source-side heat exchanger (b).

[0007] As described above, size reduction of the intercooler (a) to reduce the number of refrigerant paths has a problem of a large pressure loss of refrigerant in the intercooler (a). On the other hand, an increase in size of the intercooler (a) for the purpose of reducing an increase of the pressure loss of refrigerant also has a problem of an increase in size of the heat source unit (c).

[0008] It is therefore an object of the present invention to reduce an increase in size of a heat source unit with a reduced degree of increase in pressure loss of refrigerant in an intercooler.

SOLUTION TO THE PROBLEM

[0009] According to the present invention, in an outdoor unit of a refrigeration system, an outdoor heat exchanger (44, 162) is located above an intermediate heat exchanger (41, 42, 43, 161).

[0010] An outdoor unit of a refrigeration system in a first aspect of the present invention includes: a multistage compressor (20, 150) including a plurality of serially connected compression mechanisms (21-24, 151, 152) in which refrigerant discharged from a low-stage one (21, 22, 23, 151) of the compression mechanisms is sucked and compressed in a high-stage one (22, 23, 24, 152) of the compression mechanisms; an intermediate heat exchanger (41, 42, 43, 161) located between adjacent two of the compression mechanisms (21, 22, 23, 24, 151, 152) and configured to cause refrigerant flowing from the low-stage compression mechanism (21, 22, 23, 151) to the high-stage compression mechanism (22, 23, 24, 152) to exchange heat with outdoor air to be cooled; an outdoor heat exchanger (44, 162) configured to cause refrigerant discharged from the highest-stage compression mechanism (24, 152) to exchange heat with outdoor air; and a casing (121, 163) having a side surface in which an air suction port (123, 164) is provided and an upper surface in which an air outlet (124, 165) is provided, and housing the compression mechanisms (21-24, 151, 152), the intermediate heat exchanger (41, 42, 43, 161), and the outdoor heat exchanger (44, 162). In this outdoor unit, the intermediate heat exchanger (41, 42, 43, 161) and the outdoor heat exchanger (44, 162) are disposed to stand along the suction port (123, 164) of the casing (121, 163), and the outdoor heat exchanger (44, 162) is located above the intermediate heat exchanger (41, 42, 43, 161).

[0011] In the first aspect, in the multistage compressor (20, 150), refrigerant discharged from the low-stage compression mechanism (21, 22, 23, 151) is sucked and compressed in the high-stage compression mechanism (22, 23, 24, 152). The intermediate heat exchanger (41, 42, 43, 161) is located between adjacent two (21, 22, 23, 24, 151, 152) of the compression mechanisms (21-24, 151, 152) and configured to cause refrigerant flowing from the low-stage compression mechanism (21, 22, 23, 151) to the high-stage compression mechanism (22, 23, 24, 152) to exchange heat with outdoor air to be cooled. The outdoor heat exchanger (44, 162) causes refrigerant discharged from the highest-stage compression mechanism (24, 152) to exchange heat with outdoor air.

[0012] The casing (121, 163) has the side surface in which the air suction port (123, 164) is provided and the upper surface in which the air outlet (124, 165) is provided, and houses the compression mechanisms (21-24, 151, 152), the intermediate heat exchanger (41, 42, 43, 161), and the outdoor heat exchanger (44, 162). In the casing (121, 163), the outdoor heat exchanger (44, 162) and the intermediate heat exchanger (41, 42, 43, 161) are disposed to stand along the suction port (123, 164), and the outdoor heat exchanger (44, 162) is located above the intermediate heat exchanger (41, 42, 43, 161).

[0013] The air taken in the casing (121, 163) from the suction port (123, 164) is subjected to heat exchange in the intermediate heat exchanger (41, 42, 43, 161) and the outdoor heat exchanger (44, 162), flows to upper space in the casing (121, 163), and is blown out through the air outlet (124, 165).

[0014] Here, the outdoor unit of this aspect is of a so-called upward blow type in which air is sucked from the suction port (123, 164) in the side surface and is blown upward from the air outlet (124, 165). Thus, the airflow velocity is higher in an upper portion of the suction port (123, 164) than in a lower portion of the suction port (123, 164). The pressure of refrigerant flowing in the intermediate heat exchanger (41, 42, 43, 161) is lower than that of refrigerant flowing in the outdoor heat exchanger (44, 162), and thus, the density of refrigerant in the intermediate heat exchanger (41, 42, 43, 161) is lower than that of refrigerant in the outdoor heat exchanger (44, 162). In view of this, when the mass flow rate of refrigerant flowing in the intermediate heat exchanger (41, 42, 43, 161) is substantially equal to that of refrigerant flowing in the outdoor heat exchanger (44, 162), the volume flow rate of refrigerant in the intermediate heat exchanger (41, 42, 43, 161) is higher than that of refrigerant in the outdoor heat exchanger (44, 162). Even when the number of refrigerant paths in the intermediate heat exchanger (41, 42, 43, 161) is equal to that in the outdoor heat exchanger (44, 162), the flow velocity of refrigerant flowing in the intermediate heat exchanger (41, 42, 43, 161) is higher than that of refrigerant flowing in the outdoor heat exchanger (44, 162), and thus, a pressure loss of refrigerant in the intermediate heat exchanger (41, 42, 43, 162) is larger than that of refrigerant in the outdoor heat exchanger

(44, 162).

[0015] The outdoor heat exchanger (44, 162) located in an upper portion of the casing (121, 163) where the airflow velocity is high, has a high heat exchange efficiency, and can be reduced in size. On the other hand, the intermediate heat exchanger (41, 42, 43, 161) located in a lower portion of the casing (121, 163) where the airflow velocity is low, has a low heat exchange efficiency. Thus, to increase the amount of heat exchange, the intermediate heat exchanger (41, 42, 43, 161) needs to be larger than that in a case where this exchanger is located in an upper portion.

[0016] For this reason, the size of the outdoor unit does not increase even when the size of the outdoor heat exchanger (44, 162) and the intermediate heat exchanger (41, 42, 43, 161) increases.

[0017] An increase in size of the intermediate heat exchanger (41, 42, 43, 161) increases the number of refrigerant paths in the intermediate heat exchanger (41, 42, 43, 161). Thus, in the intermediate heat exchanger (41, 42, 43, 161), the flow velocity of refrigerant in each refrigerant path decreases, resulting in a decrease in pressure loss of refrigerant passing through the refrigerant path. The flow velocity of refrigerant flowing in the intermediate heat exchanger (41, 42, 43, 161) is originally high, and thus, a decrease in flow velocity due to an increase in the number of refrigerant paths relatively greatly reduces the pressure loss.

[0018] On the other hand, size reduction of the outdoor heat exchanger (44, 162) reduces the number of refrigerant paths in the outdoor heat exchanger (44, 162). The reduction of the number of refrigerant paths increases the flow velocity of refrigerant in each refrigerant path to increase the pressure loss of refrigerant passing through the refrigerant path.

[0019] However, since the flow velocity of refrigerant flowing in the outdoor heat exchanger (44, 162) is originally low, a certain degree of increase in flow velocity due to the reduction of the number of refrigerant paths relatively slightly increases the pressure loss arising from the increase in flow velocity.

[0020] Thus, by disposing the outdoor heat exchanger (44, 162) above the intermediate heat exchanger (41, 42, 43, 161), the pressure loss of refrigerant in the intermediate heat exchanger (41, 42, 43, 161) can be reduced with a reduced degree of increase in size of the outdoor unit.

[0021] In a second aspect, in the outdoor unit of the first aspect, the multistage compressor (20) includes three or more compression mechanisms (21-24), the intermediate heat exchanger includes a plurality of intermediate heat exchangers (41, 42, 43), and the highest-stage intermediate heat exchanger (43) is located above the other intermediate heat exchangers (41, 42) and below the outdoor heat exchanger (44).

[0022] In the second aspect, the multistage compressor (20) includes the three or more compression mechanisms (21-24), and refrigerant discharged from the low-

stage compression mechanism (21, 22, 23) is sucked and compressed in the high-stage compression mechanism (22, 23, 24). Thus, the intermediate heat exchanger includes the plurality of intermediate heat exchangers (41, 42, 43), where the highest-stage intermediate heat exchanger (43) is located above the other intermediate heat exchangers (41, 42) and is located below the outdoor heat exchanger (44).

[0023] The pressure of refrigerant flowing in the highest-stage intermediate heat exchanger (43) is higher than those of refrigerant flowing in the other intermediate heat exchangers (41, 42), and thus, the densities of refrigerant in the other intermediate heat exchangers (41, 42) are lower than that of refrigerant in the highest-stage intermediate heat exchanger (43). In view of this, when the mass flow rates of refrigerant flowing in the other intermediate heat exchangers (41, 42) are substantially equal to that of refrigerant flowing in the highest-stage intermediate heat exchanger (43), the volume flow rates of refrigerant in the other intermediate heat exchangers (41, 42) are higher than that of refrigerant in the highest-stage intermediate heat exchanger (43). Even when the number of refrigerant paths in each of the other intermediate heat exchangers (41, 42) is equal to that in the highest-stage intermediate heat exchanger (43), the flow velocities of refrigerant flowing in the other intermediate heat exchangers (41, 42) are higher than that of refrigerant flowing in the highest-stage intermediate heat exchanger (43), and thus, pressure losses of refrigerant in the other intermediate heat exchangers (41, 42) are larger than that in the highest-stage intermediate heat exchanger (43).

[0024] The high-stage intermediate heat exchanger (43) located in an upper portion of the casing (121) where the airflow velocity is high, has a high heat exchange efficiency, and can be reduced in size. On the other hand, the other intermediate heat exchangers (41, 42) located in a lower portion of the casing (121) where the airflow velocity is low, have low heat exchange efficiencies. Thus, to increase the amount of heat exchange, the other intermediate heat exchangers (41, 42) need to be larger than those in a case where these exchangers are located in an upper portion.

[0025] For this reason, the size of the outdoor unit does not increase even when the size of the high-stage intermediate heat exchanger (43) and the other intermediate heat exchangers (41, 42) increases.

[0026] An increase in size of the other intermediate heat exchangers (41, 42) increases the number of refrigerant paths in the other intermediate heat exchangers (41, 42). Thus, in the other intermediate heat exchangers (41, 42), the flow velocity of refrigerant in each refrigerant path decreases, resulting in a decrease in pressure loss of refrigerant passing through the refrigerant path. The flow velocity of refrigerant flowing in the other intermediate heat exchangers (41, 42) is originally high, and thus, a decrease in flow velocity due to an increase in the number of refrigerant paths relatively greatly reduces the

pressure loss.

[0027] On the other hand, size reduction of the high-stage intermediate heat exchanger (43) reduces the number of refrigerant paths in the high-stage intermediate heat exchanger (43). The reduction of the number of refrigerant paths increases the flow velocity of refrigerant in each refrigerant path to increase the pressure loss of refrigerant passing through the refrigerant path.

[0028] However, since the flow velocity of refrigerant flowing in the high-stage intermediate heat exchanger (43) is originally low, a certain degree of increase in flow velocity due to the reduction of the number of refrigerant paths relatively slightly increases the pressure loss arising from the increase in flow velocity.

[0029] Thus, by disposing the high-stage intermediate heat exchanger (43) above the other intermediate heat exchangers (41, 42), the pressure loss of refrigerant in the other intermediate heat exchangers (41, 42) can be reduced with a reduced degree of increase in size of the outdoor unit.

[0030] In a third aspect, in the outdoor unit of the second aspect, the intermediate heat exchangers (41, 42, 43) are stacked from the bottom in the order of increasing pressure of inflow refrigerant.

[0031] In the third aspect, the intermediate heat exchangers (41, 42, 43) are stacked from the bottom in the order of increasing pressure of inflow refrigerant.

[0032] The refrigerant density in the intermediate heat exchanger (42) where inflow refrigerant has a high pressure is higher than that in the intermediate heat exchanger (41) where inflow refrigerant has a low pressure. Thus, when the mass flow rate of refrigerant flowing in the low-pressure intermediate heat exchanger (41) is substantially equal to that of refrigerant flowing in the high-pressure intermediate heat exchanger (42), the volume flow rate of refrigerant in the low-pressure intermediate heat exchanger (42) is higher than that of refrigerant in the high-pressure intermediate heat exchanger (42). Even when the number of refrigerant paths in the low-pressure intermediate heat exchanger (41) is equal to that in the high-pressure intermediate heat exchanger (42), the flow velocity of refrigerant flowing in the low-pressure intermediate heat exchanger (41) is higher than that of refrigerant flowing in the high-pressure intermediate heat exchanger (42), and thus, a pressure loss of refrigerant in the low-pressure intermediate heat exchanger (41) is larger than that of refrigerant in the high-pressure intermediate heat exchanger (42).

[0033] The high-pressure intermediate heat exchanger (42) located in an upper portion of the casing (121) where the airflow velocity is high, has a high heat exchange efficiency, and can be reduced in size. On the other hand, the low-pressure intermediate heat exchanger (41) located in a lower portion of the casing (121) where the airflow velocity is low, has a low heat exchange efficiency. Thus, to increase the amount of heat exchange, the low-pressure intermediate heat exchanger (41) needs to be larger than that in a case where this exchang-

er is located in an upper portion.

[0034] For this reason, the size of the outdoor unit does not increase even when the size of the high-pressure intermediate heat exchanger (42) and the low-pressure intermediate heat exchanger (41) increases.

[0035] An increase in size of the low-pressure intermediate heat exchanger (41) increases the number of refrigerant paths in the low-pressure intermediate heat exchanger (41). Thus, in the low-pressure intermediate heat exchanger (41), the flow velocity of refrigerant in each refrigerant path decreases, resulting in a decrease in pressure loss of refrigerant passing through the refrigerant path. The flow velocity of refrigerant flowing in the low-pressure intermediate heat exchanger (41) is originally high, and thus, a decrease in flow velocity due to an increase in the number of refrigerant paths relatively greatly reduces the pressure loss.

[0036] On the other hand, size reduction of the high-pressure intermediate heat exchanger (42) reduces the number of refrigerant paths in the high-pressure intermediate heat exchanger (42). The reduction of the number of refrigerant paths increases the flow velocity of refrigerant in each refrigerant path to increase the pressure loss of refrigerant passing through the refrigerant path.

[0037] However, since the flow velocity of refrigerant flowing in the high-pressure intermediate heat exchanger (42) is originally low, a certain degree of increase in flow velocity due to the reduction of the number of refrigerant paths relatively slightly increases the pressure loss arising from the increase in flow velocity.

[0038] Thus, by disposing the high-pressure intermediate heat exchanger (42) above the low-pressure intermediate heat exchanger (41), the pressure loss of refrigerant in the low-pressure intermediate heat exchanger (41) can be reduced with a reduced degree of increase in size of the outdoor unit.

[0039] In a fourth aspect, in the outdoor unit of one of the first through third aspects, the intermediate heat exchanger (41, 42, 43, 161) includes a plurality of flat tubes (231) which are arranged in an up and down direction with their side surfaces facing one another and each of which includes a plurality of fluid passage (232) extending in a tube length direction, and also includes a plurality of fins (235, 235) dividing space between adjacent ones of the flat tubes (231) into a plurality of air passages in which air flows.

[0040] In the fourth aspect, the plurality of flat tubes (231) and the plurality of fins (235, 235) are provided. The fins (235, 235) are disposed between the flat tubes (231) arranged in the up and down direction. In the intermediate heat exchanger (41, 42, 43, 161), air passes between the flat tubes (231) arranged in the up and down direction, and exchanges heat with fluid flowing in the fluid passages (232) in the flat tubes (231).

[0041] The intermediate heat exchanger (41, 42, 43, 161) has a small stack loss (resistance of ventilation), and thus, has a high velocity of air flowing therein. In addition, the flat tubes (231) increase the heat transfer

area of refrigerant, and thus, the heat exchange efficiency of refrigerant increases. Accordingly, the coefficient of performance (COP) of the refrigeration system can be enhanced. Since the flat tubes (231) have pipe diameters smaller than those of conventional heat exchanger tubes, the flow velocity in the tubes increases. Thus, refrigerant passing through the fluid passage (232) has a large pressure loss.

[0042] However, in the intermediate heat exchanger (41, 42, 43, 161) located in the lower portion of the casing (121, 163) where the airflow velocity is low has a low heat exchange efficiency. Thus, to increase the amount of heat exchange, the intermediate heat exchanger (41, 42, 43, 161) is larger than that in a case where the exchanger is located in an upper portion. The larger intermediate heat exchanger (41, 42, 43, 161) includes a larger number of the refrigerant paths (232), and thus, the flow velocity of refrigerant in the refrigerant paths (232) of the intermediate heat exchanger (41, 42, 43, 161) decreases, thereby reducing the pressure loss of refrigerant occurring when refrigerant passes through the refrigerant paths (232).

[0043] Consequently, reduction in diameter of the pipe diameter of the flat tubes (231) relatively reduces the degree of increase in pressure loss of refrigerant.

[0044] In a fifth aspect, in the outdoor unit of the fourth aspect, the outdoor heat exchangers (44, 162) includes a plurality of flat tubes (231) which are arranged in the up and down direction with their side surfaces facing one another, and each of which includes a plurality of fluid passage (232) extending in a tube length direction, and also includes a plurality of fins (235, 235) dividing space between adjacent ones of the flat tubes (231) into a plurality of air passages in which air flows.

[0045] In the fifth aspect, the plurality of flat tubes (231) and the plurality of fins (235, 235) are provided. The fins (235, 235) are disposed between the flat tubes (231) arranged in the up and down direction. In the outdoor heat exchanger (44, 162), air passes between the flat tubes (231) arranged in the up and down direction, and exchanges heat with fluid flowing in the fluid passages (232) in the flat tubes (231).

[0046] The outdoor heat exchanger (44, 162) has a small stack loss, and thus, has a high velocity of air flowing therein. In addition, the flat tubes (231) increase the heat transfer area of refrigerant, and thus, the heat exchange efficiency of refrigerant increases. Accordingly, the coefficient of performance (COP) of the refrigeration system is enhanced. Since the flat tubes (231) have pipe diameters smaller than those of conventional heat exchanger tubes, the flow velocity in the tubes increases. Thus, refrigerant passing through the fluid passages (232) has a large pressure loss.

[0047] However, since the flow velocity of refrigerant flowing in the outdoor heat exchangers (44, 162) is originally low, a certain degree of increase in flow velocity due to a decrease in the diameters of pipes relatively slightly increases the pressure loss arising from the in-

crease in flow velocity.

ADVANTAGES OF THE INVENTION

[0048] In the first aspect, since the outdoor heat exchanger (44, 162) is located in the upper portion of the casing (121, 163) where the airflow velocity is high, the heat exchange efficiency of the outdoor heat exchanger (44, 162) can be increased. In addition, since the outdoor heat exchanger (44, 162) having a low flow velocity of refrigerant is located in the upper portion of the casing (121, 163) where the airflow velocity is high, the size of the outdoor heat exchanger (44, 162) can be reduced without an increase in pressure loss of refrigerant.

[0049] On the other hand, the intermediate heat exchanger (41, 42, 43, 161) is located in the lower portion of the casing (121, 163) where the airflow velocity is low to increase the number of refrigerant paths, thereby ensuring prevention of an increase in pressure loss of refrigerant in the intermediate heat exchanger (41, 42, 43, and 161).

[0050] In the above-described configuration, the outdoor heat exchanger (44, 162) where a pressure loss of refrigerant does not easily increase is located in the upper portion for size reduction, thereby reducing a pressure loss of refrigerant in the intermediate heat exchanger (41, 42, 43, 161) with reduced size increase in the outdoor unit.

[0051] In the second aspect, since the highest-stage intermediate heat exchanger (43) is located in the upper portion of the casing (121) where the airflow velocity is high, the heat exchange efficiency of the highest-stage intermediate heat exchanger (43) can be increased. In addition, since the highest-stage intermediate heat exchanger (43) having a low flow velocity of refrigerant is located in the upper portion of the casing (121) where the airflow velocity is high, the size of the highest-stage intermediate heat exchanger (43) can be reduced without an increase in pressure loss of refrigerant.

[0052] On the other hand, the other heat exchangers (41, 42) having large flow velocities of refrigerant are located in the lower portion of the casing (121) where the airflow velocity is low to increase the number of paths for refrigerant, thereby ensuring prevention of an increase in pressure loss of refrigerant in the other intermediate heat exchangers (41, 42).

[0053] In the above-described configuration, the highest-stage intermediate heat exchanger (43) where a pressure loss of refrigerant does not easily increase is located in the upper portion for size reduction, thereby reducing a pressure loss of refrigerant in the other intermediate heat exchangers (41, 42) with reduced size increase in the outdoor unit.

[0054] In the third aspect, since the high-pressure intermediate heat exchanger (42) is located in the upper portion of the casing (121) where the airflow velocity is high, the heat exchange efficiency of the high-pressure intermediate heat exchanger (42) can be increased. In

addition, since the high-pressure intermediate heat exchanger (42) having a low flow velocity of refrigerant is located in the upper portion of the casing (121) where the airflow velocity is high, the size of the high-pressure intermediate heat exchanger (42) can be reduced without an increase in pressure loss of refrigerant.

[0055] On the other hand, the low-pressure intermediate heat exchanger (41) having a large flow velocity of refrigerant is located in the lower portion of the casing (121) where the airflow velocity is low to increase the number of paths for refrigerant, thereby ensuring prevention of an increase in pressure loss of refrigerant in the low-pressure intermediate heat exchanger (41).

[0056] In the above-described configuration, the high-pressure intermediate heat exchanger (42) where a pressure loss of refrigerant does not easily increase is located in the upper portion for size reduction, thereby reducing a pressure loss of refrigerant in the low-pressure intermediate heat exchanger (41) with reduced size increase in the outdoor unit.

[0057] In the fourth aspect, the plurality of flat tubes (231), in which the plurality of fluid passages (232) are provided, and the plurality of fins (235, 235) are provided, thereby reducing a stack loss. Thus, the flow velocity of air flowing in the air passages increases. In addition, the flat tubes (231) increase the heat transfer area of refrigerant, and thus, heat exchange efficiency of refrigerant can be increased. Accordingly, the coefficient of performance (COP) of the refrigeration system can be enhanced.

[0058] In the fifth aspect, the plurality of flat tubes (231), in which the plurality of fluid passages (232) are provided, and the plurality of fins (235, 235) are provided, thereby reducing a stack loss. Thus, the flow velocity of air flowing in the air passages increases. In addition, the flat tubes (231) increase the heat transfer area of refrigerant, and thus, heat exchange efficiency of refrigerant can be increased. Accordingly, the coefficient of performance (COP) of the refrigeration system can be enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0059]

[FIG. 1] FIG. 1 is a piping system diagram illustrating cooling operation of a refrigerant circuit according to a first embodiment.

[FIG. 2] FIG. 2 is a mollier chart of the refrigerant circuit of the first embodiment.

[FIG. 3] FIG. 3 illustrates an outdoor unit according to the first embodiment.

[FIG. 4] FIG. 4 is a top view schematically illustrating the outdoor unit of the first embodiment.

[FIG. 5] FIG. 5 is a cross-sectional view taken along line V-V in FIG. 4.

[FIG. 6] FIG. 6 illustrates an airflow velocity distribution in an outdoor casing according to the first embodiment.

[FIG. 7] FIG. 7 is a piping system diagram illustrating

heating operation of the refrigerant circuit of the first embodiment.

[FIG. 8] FIG. 8 is a piping system diagram illustrating cooling operation of a refrigerant circuit according to a second embodiment.

[FIG. 9] FIG. 9 is a mollier chart of the refrigerant circuit of the second embodiment.

[FIG. 10] FIG. 10 is a piping system diagram illustrating cooling operation of a refrigerant circuit according to a third embodiment.

[FIG. 11] FIG. 11 is a mollier chart of the refrigerant circuit of the third embodiment.

[FIG. 12] FIG. 12 illustrates an outdoor unit according to the third embodiment.

[FIG. 13] FIG. 13 is a piping system diagram illustrating heating operation of the refrigerant circuit of the third embodiment.

[FIG. 14] FIG. 14 schematically illustrates an outdoor unit according to a variation of the third embodiment.

[FIG. 15] FIG. 15 is an enlarged view of flat tubes and fins of a heat exchanger according to the variation of the third embodiment.

[FIG. 16] FIG. 16 schematically illustrates an outdoor unit according to another embodiment.

[FIG. 17] FIG. 17 is an enlarged view of flat tubes and fins of a heat exchanger according to the another embodiment.

[FIG. 18] FIGS. 18A and 18B schematically illustrate a configuration of an outdoor unit according to a reference example, where FIG. 18A illustrates an example layout of an outdoor heat exchange unit, and FIG. 18B illustrates an airflow velocity distribution of the outdoor heat exchange unit.

[FIG. 19] FIG. 19 is a cross-sectional view illustrating an outdoor heat exchange unit according to the reference example.

[FIG. 20] FIG. 20 illustrates an outdoor unit according to a conventional example.

[FIG. 21] FIGS. 21A and 21B schematically illustrate a configuration of the outdoor unit of the conventional example, where FIG. 21A illustrates an example layout of an outdoor heat exchange unit, and FIG. 21B illustrates an airflow velocity distribution of the outdoor heat exchange unit.

DESCRIPTION OF EMBODIMENTS

[0060] Embodiments of the present invention will be described in detail with reference to the drawings.

<First Embodiment>

-Refrigerant Circuit of Air Conditioner-

[0061] As illustrated in FIG. 1, an air conditioner (1) according to the first embodiment will be described. The air conditioner (1) includes a refrigerant circuit (10) in which a flow of refrigerant is allowed to be changed re-

versibly, and is switchable between cooling operation and heating operation. The air conditioner (1) includes an outdoor unit (3) located outdoors and an indoor unit (2) located indoors. The refrigerant circuit (10) of the air conditioner (1) is obtained by connecting an outdoor circuit (11) of the outdoor unit (3) and an indoor circuit (12) of the indoor unit (2) to each other through a gas-side communication pipe (13) and a liquid-side communication pipe (14). The refrigerant circuit (10) is filled with carbon dioxide (hereinafter referred to as refrigerant), and configured to perform a multistage compression supercritical refrigeration cycle by circulating refrigerant in the refrigerant circuit (10).

<Outdoor Circuit>

[0062] As illustrated in FIG. 1, the outdoor circuit (11) is connected to a four-stage compressor (20), an outdoor heat exchange unit (40), first through fourth four-way valves (93, 94, 95, 96), first through third subcooling heat exchangers (100, 101, 102), first through fifth expansion valves (80-84), an expander (87), and a gas-liquid separator (88). The outdoor heat exchange unit (40) includes first through third intermediate heat exchangers (41, 42, 43) and an outdoor heat exchanger (44).

[0063] The outdoor heat exchanger (44) in this embodiment corresponds to an outdoor heat exchanger of the present invention, and the first through third intermediate heat exchangers (41, 42, 43) are intermediate heat exchangers of the present invention. The first and second intermediate heat exchangers (41, 42) are other intermediate heat exchangers of the present invention, and the third intermediate heat exchanger (43) is a highest-stage intermediate heat exchanger of the present invention.

[0064] The outdoor circuit (11) is also connected to four oil separators (89, 90, 91, 92), a distributor (18), a capillary tube (15), a bridge circuit (17), and check valves (CV1 - CV13).

[0065] In the first embodiment, the refrigerant circuit (10) is switched between cooling operation and heating operation by switching the first through fourth four-way valves (93, 94, 95, 96).

[0066] The four-stage compressor (20) includes first through fourth compressors (21, 22, 23, 24) and corresponds to a multistage compressor of the present invention. The first through fourth compressors (21, 22, 23, 24) are connected to first through fourth discharge pipes (25, 26, 27, 28) at discharge sides thereof, while being connected to first through fourth suction pipes (29, 30, 31, 32) at suction sides thereof. Each of the compressors (21, 22, 23, 24) compresses a gas refrigerant sucked through an associated one of the suction pipes (29, 30, 31, 32) to a predetermined pressure, and discharges this refrigerant from an associated one of the discharge pipes (25, 26, 27, 28).

[0067] The first four-way valve (93) has its first port connected to the first discharge pipe (25) of the first compressor (21), its second port connected to an end of a

junction pipe (67), its third port connected to an end of the first intermediate heat exchanger (41), and its fourth port connected to the second suction pipe (30) of the second compressor (22). The first four-way valve (93) is switched between a first state (a state indicated by a continuous line in FIG. 1) in which the first port communicates with the third port and the second port communicates with the fourth port and a second state (a state indicated by a broken line in FIG. 1) in which the first port communicates with the fourth port and the second port communicates with the third port.

[0068] The second four-way valve (94) has its first port connected to the second discharge pipe (26) of the second compressor (22), its second port connected to a midpoint of the junction pipe (67), its third port connected to an end of the second intermediate heat exchanger (42), and its fourth port connected to the third suction pipe (31) of the third compressor (23). The second four-way valve (94) is switched between a first state (a state indicated by a continuous line in FIG. 1) in which the first port communicates with the third port and the second port communicates with the fourth port and a second state (a state indicated by a broken line in FIG. 1) in which the first port communicates with the fourth port and the second port communicates with the third port.

[0069] The third four-way valve (95) has its first port connected to the third discharge pipe (27) of the third compressor (23), its second port connected to a midpoint of the junction pipe (67), and its third port connected to an end of the third intermediate heat exchanger (43), and its fourth port connected to the fourth suction pipe (32) of the fourth compressor (24). The third four-way valve (95) is switched between a first state (a state indicated by a continuous line in FIG. 1) in which the first port communicates with the third port and the second port communicates with the fourth port and a second state (a state indicated by a broken line in FIG. 1) in which the first port communicates with the fourth port and the second port communicates with the third port.

[0070] The fourth four-way valve (96) has its first port connected to the fourth discharge pipe (28) of the fourth compressor (24), its second port connected to an end of the connection pipe (66), its third port connected to an end of the outdoor heat exchanger (44), and its fourth port connected to the gas-side communication pipe (13). The fourth four-way valve (96) is switched between a first state (a state indicated by a continuous line in FIG. 1) in which the first port communicates with the third port and the second port communicates with the fourth port and a second state (a state indicated by a broken line in FIG. 1) in which the first port communicates with the fourth port and the second port communicates with the third port.

[0071] The check valves (CV1, CV2, CV3) are connected to midpoints of the second through fourth suction pipes (30, 31, 32). Each of the check valves (CV1, CV2, CV3) allows refrigerant to flow from the first through third four-way valves (93, 94, 95) to the four-stage compressor

(20), and prevents refrigerant from flowing in a reverse direction.

[0072] Oil separators (89, 90, 91, 92) are connected to midpoints of the first through fourth discharge pipes (25, 26, 27, 28), respectively. The oil separators (89, 90, 91, 92) are used to separate lubricating oil contained in refrigerant flowing in the discharge pipes (25, 26, 27, 28) from refrigerant. The oil separators (89, 90, 91, 92) are connected to oil outflow pipes (16, 16, 16, 16) through which lubricating oil separated in the oil separators (89, 90, 91, 92) flows to the outside of the oil separators (89, 90, 91, 92).

[0073] Specifically, the oil outflow pipe (16) of the first oil separator (89) for the first discharge pipe (25) is connected to the second suction pipe (30). The oil outflow pipe (16) of the second oil separator (90) for the second discharge pipe (26) is connected to the third suction pipe (31). The oil outflow pipe (16) of the third oil separator (91) for the third discharge pipe (27) is connected to the fourth suction pipe (32). The oil outflow pipe (16) of the fourth oil separator (92) for the fourth discharge pipe (28) is connected to the first suction pipe (29). The capillary tube (15) is connected to the midpoint of each of the oil outflow pipes (16, 16, 16, 16).

[0074] The first through third intermediate heat exchangers (41, 42, 43) and the outdoor heat exchanger (44) are configured as fin-and-tube heat exchangers. An outdoor fan (122) is disposed near each of the heat exchangers (41, 42, 43, 44) so that heat exchange is performed between outdoor air from the outdoor fan (122) and refrigerant flowing in the heat exchanger tubes (52) of each of the heat exchangers (41, 42, 43, 44). The configurations of the heat exchangers (41, 42, 43, 44) will be described in detail.

[0075] An end of the first intermediate heat exchanger (41) is connected to the third port of the first four-way valve (93), an end of the second intermediate heat exchanger (42) is connected to the third port of the second four-way valve (94), an end of the third intermediate heat exchanger (43) is connected to the third port of the third four-way valve (95), and an end of the outdoor heat exchanger (44) is connected to the third port of the fourth four-way valve (96). On the other hand, the other ends of the first through third intermediate heat exchangers (41, 42, 43) are connected to the first through third refrigerant pipes (70, 71, 72), respectively, and the other end of the outdoor heat exchanger (44) is connected to an end of the fourth refrigerant pipe (73).

[0076] The other end of the fourth refrigerant pipe (73) branches off into two parts, one of which is connected to the bridge circuit (17) and the other of which is connected to a fourth outflow port (P4) of the distributor (18). The check valve (CV7) and the capillary tube (15) are located between the branch point of the fourth refrigerant pipe (73) and the fourth outflow port (P4) of the distributor. The check valve (CV7) allows refrigerant to flow from the distributor (18) to the branch point of the fourth refrigerant pipe (73), and prevents refrigerant from flowing in a re-

verse direction.

[0077] The other end of the third refrigerant pipe (72) branches off into two parts, one of which is connected to a midpoint (between the check valve (CV3) and the fourth compressor (24)) of the fourth suction pipe (32), and the other of which is connected to a third outflow port (P3) of the distributor (18). The check valve (CV6) and the capillary tube (15) are located between the branch point of the third refrigerant pipe (72) and the third outflow port (P3) of the distributor (18). The check valve (CV6) allows refrigerant to flow from the distributor (18) to the branch point of the third refrigerant pipe (72), and prevents refrigerant from flowing in a reverse direction. The check valve (CV10) is located between the branch point of the third refrigerant pipe (72) and the connection point of the fourth suction pipe (32). The check valve (CV10) allows refrigerant to flow from the branch point of the third refrigerant pipe (72) to the connection point of the fourth suction pipe (32), and prevents refrigerant from flowing in a reverse direction.

[0078] The other end of the second refrigerant pipe (71) branches off into two parts, one of which is connected to a midpoint (between the check valve (CV2) and the third compressor (23)) of the third suction pipe (31), and the other of which is connected to a second outflow port (P2) of the distributor (18). The check valve (CV5) and the capillary tube (15) are located between the branch point of the second refrigerant pipe (71) and the second outflow port (P2) of the distributor (18). The check valve (CV5) allows refrigerant to flow from the distributor (18) to the branch point of the second refrigerant pipe (71), and prevents refrigerant from flowing in a reverse direction. The check valve (CV9) is located between the branch point of the second refrigerant pipe (71) and the connection point of the third suction pipe (31). The check valve (CV9) allows refrigerant to flow from the branch point of the second refrigerant pipe (71) to the connection point of the third suction pipe (31), and prevents refrigerant from flowing in a reverse direction.

[0079] The other end of the first refrigerant pipe (70) branches off into two parts, one of which is connected to a midpoint (between the check valve (CV1) and the second compressor (22)) of the second suction pipe (30), and the other of which is connected to a first outflow port (P1) of the distributor (18). The check valve (CV4) and the capillary tube (15) are located between the branch point of the first refrigerant pipe (70) and the first outflow port (P1) of the distributor (18). The check valve (CV4) allows refrigerant to flow from the distributor (18) to the branch point of the first refrigerant pipe (70), and prevents refrigerant from flowing in a reverse direction. The check valve (CV8) is located between the branch point of the first refrigerant pipe (70) and the connection point of the second suction pipe (30). The check valve (CV8) allows refrigerant to flow from the branch point of the first refrigerant pipe (70) to the connection point of the second suction pipe (30), and prevents refrigerant from flowing in a reverse direction.

[0080] The bridge circuit (17) is a circuit in which the check valves (CV11, CV12, CV13) and a fifth expansion valve (84) are bridged. In the bridge circuit (17), a connection end located between an inflow end of the check valve (CV13) and the other end of the fifth expansion valve (84) is connected to the first outflow pipe (61), and a connection end located between an outflow end of the check valve (CV13) and an inflow end of the check valve (CV12) is connected to the liquid-side communication pipe (14). A refrigerant pipe connecting the liquid-side communication pipe (14) to the first indoor heat exchanger (110) includes a first indoor expansion valve (85) having a variable opening degree. A refrigerant pipe connecting the liquid-side communication pipe (14) to the second indoor heat exchanger

[0081] (111) includes a second indoor expansion valve (86) having a variable opening degree. A connection end located between an outflow end of the check valve (CV12) and an outflow end of the check valve (CV11) is connected to the inflow pipe (60). An end of the fifth expansion valve (84) is connected to the distributor (18), and the inflow end of the check valve (CV11) is connected to the fourth refrigerant pipe (73).

[0082] On the inflow pipe (60), the first subcooling heat exchanger (100), the second subcooling heat exchanger (101), expander (87), the gas-liquid separator (88), and the third subcooling heat exchanger (102) are disposed in this order.

[0083] The first subcooling heat exchanger (100) includes a high-pressure channel (100a) and a low-pressure channel (100b). In the first subcooling heat exchanger (100), heat exchange is performed between refrigerant flowing in the high-pressure channel (100a) and refrigerant flowing in the low-pressure channel (100b) to subcool refrigerant flowing in the high-pressure channel (100a).

[0084] An inflow end of the high-pressure channel (100a) is connected to the inflow pipe (60), and an inflow end of the low-pressure channel (100b) is connected to a first branch pipe (62) serving as a passage for subcooling. The first branch pipe (62) includes a second expansion valve (81) for subcooling. The second expansion valve (81) is an electronic expansion valve having an adjustable opening degree. An outflow end of the low-pressure channel (100b) is connected to an end of the injection pipe (106).

[0085] An end of the injection pipe (106) is connected to the low-pressure channel (100b) of the first subcooling heat exchanger (100) and the other end of the injection pipe (106) is connected to the second refrigerant pipe (71). Specifically, the other end of the injection pipe (106) is connected to an outflow end of the check valve (CV9) in the second refrigerant pipe (71).

[0086] The second subcooling heat exchanger (101) includes a high-pressure channel (101a) and a low-pressure channel (101b). In the second subcooling heat exchanger (101), heat exchange is performed between refrigerant flowing high-pressure channel (101a) and re-

refrigerant flowing in the low-pressure channel (101b) to subcool refrigerant flowing in the high-pressure channel (101a).

[0087] An inflow end of the high-pressure channel (101a) is connected to the inflow pipe (60). An inflow end of the low-pressure channel (101b) is connected to the other end of the connection pipe (66), and an outflow end of the low-pressure channel (101b) is connected to the first suction pipe (29).

[0088] An end of the connection pipe (66) is connected to the second port of the fourth four-way valve (96), and the other end of the connection pipe (66) is connected to an inflow end of the low-pressure channel (101b) of the second subcooling heat exchanger (101). The other end of the junction pipe (67) is connected to a midpoint of the connection pipe (66).

[0089] An end of the junction pipe (67) is connected to the second port of the first four-way valve (93), and the other end of the junction pipe (67) is connected to a midpoint of the connection pipe (66). A pipe communicating with the second port of the second four-way valve (94) and the second port of the third four-way valve (95) is connected to a midpoint of the junction pipe (67).

[0090] The expander (87) includes an expander casing having a vertically elongated cylindrical shape, and is located between the second subcooling heat exchanger (101) and the gas-liquid separator (88) on the inflow pipe (60). In the expander casing, an expansion mechanism for generating power by expanding refrigerant is provided. The expander (87) constitutes a so-called rotary positive-displacement fluid machine. The expander (87) expands inflow refrigerant and sends the expanded refrigerant back to the inflow pipe (60).

[0091] The inflow pipe (60) includes a bypass pipe (64) that bypasses the expander (87). An end of the bypass pipe (64) is connected to an inflow end of the expander (87), and the other end of the bypass pipe (64) is connected to an outflow end of the expander (87) to bypass the expander (87). The bypass pipe (64) includes a first expansion valve (80). The first expansion valve (80) is an electronic expansion valve having an adjustable opening degree.

[0092] The gas-liquid separator (88) is an hermetic container having a vertically elongated cylindrical shape. The gas-liquid separator (88) is connected to the inflow pipe (60), the first outflow pipe (61), and the second outflow pipe (65). The inflow pipe (60) is open in an upper portion of the inner space of the gas-liquid separator (88). The first outflow pipe (61) is open in a lower portion of the inner space of the gas-liquid separator (88). The second outflow pipe (65) is open in an upper portion of the inner space of the gas-liquid separator (88). In the gas-liquid separator (88), refrigerant from the inflow pipe (60) is separated into a saturated liquid and a saturated gas, where the saturated liquid flows out of the first outflow pipe (61) and the saturated gas flows out of the second outflow pipe (65).

[0093] An end of the second outflow pipe (65) is con-

nected to the gas-liquid separator (88), and the other end of the second outflow pipe (65) is connected to a midpoint of the return pipe (68). The second outflow pipe (65) includes a fourth expansion valve (83). The fourth expansion valve (83) is an electronic expansion valve having an adjustable opening degree.

[0094] The third subcooling heat exchanger (102) is connected to a midpoint of the first outflow pipe (61). The third subcooling heat exchanger (102) includes a high-pressure channel (102a) and a low-pressure channel (102b). In the third subcooling heat exchanger (102), heat exchange is performed between refrigerant flowing in the high-pressure channel (102a) and refrigerant flowing in the low-pressure channel (102b) to subcool refrigerant flowing in the high-pressure channel (102a).

[0095] An inflow end of the high-pressure channel (102a) is connected to an outflow end of the gas-liquid separator (88), and an outflow end of the high-pressure channel (102a) is connected to the bridge circuit (17). An inflow end of the low-pressure channel (102b) is connected to a second branch pipe (63) serving as a passage for subcooling, and an outflow end of the low-pressure channel (102b) is connected to the other end of the return pipe (68).

[0096] An end of the second branch pipe (63) is connected to a point of the first outflow pipe (61) between the gas-liquid separator (88) and the third subcooling heat exchanger (102), and the other end of the second branch pipe (63) is connected to an inflow end of the low-pressure channel (102b) of the third subcooling heat exchanger (102). The second branch pipe (63) includes a third expansion valve (82). The third expansion valve (82) is an electronic expansion valve having an adjustable opening degree.

[0097] One end of the return pipe (68) is connected to the other end of the connection pipe (66), and the other end of the return pipe (68) is connected to an outflow end of the low-pressure channel (102b) of the third subcooling heat exchanger (102). The second outflow pipe (65) is connected to a point of the return pipe (68) between the one end and the other end.

<Indoor Circuit>

[0098] In the indoor circuit (12), a pair of the first indoor expansion valve (85) and the first indoor heat exchanger (110) and a pair of the second indoor expansion valve (86) and the second indoor heat exchanger (111) are disposed in this order from a liquid side to a gas side, and are connected in parallel. Each of the indoor expansion valves (85, 86) is an electronic expansion valve having an adjustable opening degree. Each of the indoor heat exchangers (110, 111) is a cross-fin type fin-and-tube heat exchanger. Although not shown, indoor fans for sending indoor air to the indoor heat exchangers (110, 111) are provided near the indoor heat exchangers (110, 111). In each of the indoor heat exchangers (110, 111), heat exchange is performed between refrigerant and the

indoor air.

<Configuration of Outdoor Unit>

[0099] As illustrated in FIGS. 3-5, the outdoor unit (3) includes an outdoor casing (121) that is a casing of the present invention. The outdoor casing (121) is in the shape of a vertically elongated rectangular box, and has an air inlet (123) in a lower portion of the front surface and an air outlet (124) in an upper surface thereof. The air inlet (123) is a suction port of the present invention. In the outdoor casing (121), the outdoor heat exchanger (44), the first intermediate heat exchanger (41), the second intermediate heat exchanger (42), and the third intermediate heat exchanger (43) constituting the outdoor heat exchange unit (40), and the outdoor fan (122) are placed. Each of the heat exchangers (41, 42, 43, 44) has an approximately U shape in plan view, and stands along the air inlet (123).

[0100] The outdoor fan (122) is a fan for sending air taken in the outdoor casing (121) to the heat exchangers (41, 42, 43, 44), and is a so-called sirocco fan. The outdoor fan (122) is located above the heat exchangers (41, 42, 43, 44) in the outdoor casing (121). The outdoor fan (122) causes air sucked through the air inlet (123) to pass through the heat exchangers (41, 42, 43, 44) and then to flow to the outside through the air outlet (124).

[0101] As illustrated in FIG. 5, in the outdoor casing (121), the first intermediate heat exchanger (41), the second intermediate heat exchanger (42), the third intermediate heat exchanger (43), and the outdoor heat exchanger (44) are stacked in this order from the bottom to the top. The first intermediate heat exchanger (41) and the second intermediate heat exchanger (42) may be replaced with each other in the up and down direction.

[0102] The first intermediate heat exchanger (41) is a so-called cross-fin type fin-and-tube heat exchanger. The first intermediate heat exchanger (41) includes a plurality of heat exchanger tube groups (50) each including a plurality of heat exchanger tubes (52) and a plurality of U-shaped tubes, and also includes heat transmission fins (51).

[0103] As the heat exchanger tube groups (50), seven heat exchanger tube groups (50) are aligned in the up and down direction. In each of the heat exchanger tube groups (50), a plurality of (six in FIG. 5) heat exchanger tubes (52) are arranged such that three rows of heat exchanger tubes (52) each along an airflow direction are arranged side by side and each of the three rows includes two heat exchanger tubes (52) aligned in the up and down direction. In addition, a first bank of tubes (53) is disposed at the left in FIG. 5 (i.e., the windward side), a second bank of tubes (54) is disposed at the middle in FIG. 5, and a third bank of tubes (55) is disposed at the right in FIG. 5 (i.e., the leeward side). That is, in each of the heat exchanger tube groups (50), the heat exchanger tubes (52) are disposed in two stages in each row.

[0104] In each of the heat exchanger tube groups (50),

among the heat exchanger tubes (52), ends of the heat exchanger tubes (52) at one side except an end (a first end) of the upper-stage heat exchanger tubes (52) of the first bank of tubes (53) and an end (a second end) of the lower-stage heat exchanger tubes (52) of the third bank of tubes (55) are connected together with the U-shaped tubes, thereby forming one refrigerant path whose one end is the first end and the other end is the second end. The first end of the first bank of tubes (53) of each of the heat exchanger tube groups (50) is connected to the first refrigerant pipe (70) of the refrigerant circuit (10) via headers. The second end of the third bank of tubes (55) of each of the heat exchanger tube groups (50) communicates with the third port of the first four-way valve (93).

[0105] As illustrated in FIG. 5, each of the heat transmission fins (51) is in the shape of an approximately rectangular thin plate. The heat transmission fins (51) are arranged at predetermined intervals along the direction in which the heat exchanger tube groups (50) extend. Each of the heat transmission fins (51) has three rows of through holes through which the heat exchanger tubes (52) penetrate. In this manner, the heat transmission fins (51) are disposed around the heat exchanger tubes (52), and thereby, the heat transfer area increases so that heat transmission is promoted.

[0106] The second intermediate heat exchanger (42) is a so-called cross-fin type fin-and-tube heat exchanger. The second intermediate heat exchanger (42) includes a plurality of heat exchanger tube groups (50) each including a plurality of heat exchanger tubes (52) and a plurality of U-shaped tubes, and also includes heat transmission fins (51).

[0107] As the heat exchanger tube groups (50), seven heat exchanger tube groups (50) are aligned in the up and down direction. In each of the heat exchanger tube groups (50), a plurality of (six in FIG. 5) heat exchanger tubes (52) are arranged such that three rows of heat exchanger tubes (52) each along an airflow direction are arranged side by side and each of the three rows includes two heat exchanger tubes (52) aligned in the up and down direction. In addition, a first bank of tubes (53) is disposed at the left in FIG. 5 (i.e., the windward side), a second bank of tubes (54) is disposed at the middle in FIG. 5, and a third bank of tubes (55) is disposed at the right in FIG. 5 (i.e., the leeward side). That is, in each of the heat exchanger tube groups (50), the heat exchanger tubes (52) are disposed in two stages in each row.

[0108] In each of the heat exchanger tube groups (50), among the heat exchanger tubes (52), ends of the heat exchanger tubes (52) at one side except an end (a first end) of the upper-stage heat exchanger tubes (52) of the first bank of tubes (53) and an end (a second end) of the lower-stage heat exchanger tubes (52) of the third bank of tubes (55) are connected together with the U-shaped tubes, thereby forming one refrigerant path whose one end is the first end and the other end is the second end. The first end of the first bank of tubes (53) of each of the heat exchanger tube groups (50) is connected to the sec-

ond refrigerant pipe (71) of the refrigerant circuit (10) via headers. The second end of the third bank of tubes (55) of each of the heat exchanger tube groups (50) communicates with the third port of the second four-way valve (94).

[0109] As illustrated in FIG. 5, each of the heat transmission fins (51) is in the shape of an approximately rectangular thin plate. The heat transmission fins (51) are arranged at predetermined intervals along the direction in which the heat exchanger tube groups (50) extend. Each of the heat transmission fins (51) has three rows of through holes through which the heat exchanger tubes (52) penetrate. In this manner, the heat transmission fins (51) are disposed around the heat exchanger tubes (52), and thereby, the heat transfer area increases so that heat transmission is promoted.

[0110] The third intermediate heat exchanger (43) is a so-called cross-fin type fin-and-tube heat exchanger. The third intermediate heat exchanger (43) includes a plurality of heat exchanger tube groups (50) each including a plurality of heat exchanger tubes (52) and a plurality of U-shaped tubes, and also includes heat transmission fins (51).

[0111] As the heat exchanger tube groups (50), six heat exchanger tube groups (50) are aligned in the up and down direction. In each of the heat exchanger tube groups (50), a plurality of (six in FIG. 5) heat exchanger tubes (52) are arranged such that three rows of heat exchanger tubes (52) each along an airflow direction are arranged side by side and each of the three rows includes two heat exchanger tubes (52) aligned in the up and down direction. In addition, a first bank of tubes (53) is disposed at the left in FIG. 5 (i.e., the windward side), a second bank of tubes (54) is disposed at the middle in FIG. 5, and a third bank of tubes (55) is disposed at the right in FIG. 5 (i.e., the leeward side). That is, in each of the heat exchanger tube groups (50), the heat exchanger tubes (52) are disposed in two stages in each row.

[0112] In each of the heat exchanger tube groups (50), among the heat exchanger tubes (52), ends of the heat exchanger tubes (52) at one side except an end (a first end) of the upper-stage heat exchanger tubes (52) of the first bank of tubes (53) and an end (a second end) of the lower-stage heat exchanger tubes (52) of the third bank of tubes (55) are connected together with the U-shaped tubes, thereby forming one refrigerant path whose one end is the first end and the other end is the second end. The first end of the first bank of tubes (53) of each of the heat exchanger tube groups (50) is connected to the third refrigerant pipe (72) of the refrigerant circuit (10) via headers. The second end of the third bank of tubes (55) of each of the heat exchanger tube groups (50) communicates with the third port of the third four-way valve (95).

[0113] As illustrated in FIG. 5, each of the heat transmission fins (51) is in the shape of an approximately rectangular thin plate. The heat transmission fins (51) are arranged at predetermined intervals along the direction in which the heat exchanger tube groups (50) extend.

Each of the heat transmission fins (51) has three rows of through holes through which the heat exchanger tubes (52) penetrate. In this manner, the heat transmission fins (51) are disposed around the heat exchanger tubes (52), and thereby, the heat transfer area increases so that heat transmission is promoted.

[0114] The outdoor heat exchanger (44) is a so-called cross-fin type fin-and-tube heat exchanger. The outdoor heat exchanger (44) includes a plurality of heat exchanger tube groups (50) each including a plurality of heat exchanger tubes (52) and a plurality of U-shaped tubes, and also includes heat transmission fins (51).

[0115] As the heat exchanger tube groups (50), eight heat exchanger tube groups (50) are aligned in the up and down direction. In each of the heat exchanger tube groups (50), a plurality of (six in FIG. 5) heat exchanger tubes (52) are arranged such that three rows of heat exchanger tubes (52) each along an airflow direction are arranged side by side and each of the three rows includes two heat exchanger tubes (52) aligned in the up and down direction. In addition, a first bank of tubes (53) is disposed at the left in FIG. 5 (i.e., the windward side), a second bank of tubes (54) is disposed at the middle in FIG. 5, and a third bank of tubes (55) is disposed at the right in FIG. 5 (i.e., the leeward side). That is, in each of the heat exchanger tube groups (50), the heat exchanger tubes (52) are disposed in two stages in each row.

[0116] In each of the heat exchanger tube groups (50), among the heat exchanger tubes (52), ends of the heat exchanger tubes (52) at one side except an end (a first end) of the upper-stage heat exchanger tubes (52) of the first bank of tubes (53) and an end (a second end) of the lower-stage heat exchanger tubes (52) of the third bank of tubes (55) are connected together with the U-shaped tubes, thereby forming one refrigerant path whose one end is the first end and the other end is the second end. The first end of the first bank of tubes (53) of each of the heat exchanger tube groups (50) is connected to the fourth refrigerant pipe (74) of the refrigerant circuit (10) via headers. The second end of the third bank of tubes (55) of each of the heat exchanger tube groups (50) communicates with the third port of the fourth four-way valve (96).

[0117] As illustrated in FIG. 5, each of the heat transmission fins (51) is in the shape of an approximately rectangular thin plate. The heat transmission fins (51) are arranged at predetermined intervals along the direction in which the heat exchanger tube groups (50) extend. Each of the heat transmission fins (51) has three rows of through holes through which the heat exchanger tubes (52) penetrate. In this manner, the heat transmission fins (51) are disposed around the heat exchanger tubes (52), and thereby, the heat transfer area increases so that heat transmission is promoted.

-Operation-

[0118] Operation of the air conditioner (1) will now be

described. In the air conditioner (1), switching is performed among the first through fourth four-way valves (93, 94, 95, 96) to switch operation of the refrigerant circuit (10) between cooling operation and heating operation. Reference numerals 1-26 in FIGS. 1 and 2 represent pressure states of refrigerant.

-Cooling Operation-

[0119] Cooling operation of the air conditioner (1) will be described with reference to FIGS. 1 and 2. In FIG. 1, a refrigerant flow in this cooling operation is represented by arrows of continuous line. In the cooling operation, the outdoor heat exchanger (44) operates as a heat dissipator, and the indoor heat exchangers (110, 111) operate as evaporators, thereby performing a four-stage compression supercritical refrigeration cycle. The first through third intermediate heat exchangers (41, 42, 43) operate as coolers that cool high-pressure refrigerant discharged from the compressors (21, 22, 23).

[0120] In the cooling operation, all the four-way valves (93, 94, 95, 96) are set in the first states, and the four-stage compressor (20) is driven. When the four-stage compressor (20) is driven, refrigerant is compressed in the compressors (21, 22, 23, 24). Refrigerant compressed in the first compressor (21) is discharged to the first discharge pipe (25) (see "2" in FIGS. 1 and 2). In this state, the first oil separator (89) of the first discharge pipe (25) separates lubricating oil from gas refrigerant flowing in the first discharge pipe (25). The separated lubricating oil is sent from the oil outflow pipe (16) to the second suction pipe (30). Refrigerant flowing in the first discharge pipe (25) passes through the first four-way valve (93) and flows into the first intermediate heat exchanger (41). In the first intermediate heat exchanger (41), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the first intermediate heat exchanger (41) flows into the first refrigerant pipe (70). Refrigerant flowing in the first refrigerant pipe (70) passes through the check valve (CV8), flows into the second suction pipe (30), and is sucked into the second compressor (22) (see "3" in FIGS. 1 and 2).

[0121] Refrigerant compressed in the second compressor (22) is discharged to the second discharge pipe (26) (see "4" in FIGS. 1 and 2). In this state, the second oil separator (90) of the second discharge pipe (26) separates lubricating oil from gas refrigerant flowing in the second discharge pipe (26). The separated lubricating oil is sent from the oil outflow pipe (16) to the second suction pipe (30). Refrigerant flowing in the second discharge pipe (26) passes through the second four-way valve (94) and flows into the second intermediate heat exchanger (42). In the second intermediate heat exchanger (42), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the second intermediate heat exchanger (42) flows into the second refrigerant pipe (71) (see "5" in FIGS. 1 and 2). Refrigerant flowing in the second refrigerant pipe (71) passes through

the check valve (CV9), merges with refrigerant flowing in the injection pipe (106), flows into the third suction pipe (31), and is sucked into the third compressor (23) (see "6" in FIGS. 1 and 2).

[0122] Refrigerant compressed in the third compressor (23) is discharged to the third discharge pipe (27) (see "7" in FIGS. 1 and 2). In this state, the third oil separator (91) of the third discharge pipe (27) separates lubricating oil from gas refrigerant flowing in the third discharge pipe (27). The separated lubricating oil is sent from the oil outflow pipe (16) to the fourth suction pipe (32). Refrigerant flowing in the third discharge pipe (27) passes through the third four-way valve (95) and flows into the third intermediate heat exchanger (43). In the third intermediate heat exchanger (43), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the third intermediate heat exchanger (43) flows into the third refrigerant pipe (72). Refrigerant flowing in the third refrigerant pipe (72) passes through the check valve (CV10), flows into the fourth suction pipe (32), and is sucked into the fourth compressor (24) (see "8" in FIGS. 1 and 2).

[0123] Refrigerant compressed in the fourth compressor (24) is discharged to the fourth discharge pipe (28) (see "9" in FIGS. 1 and 2). The compression and cooling operations described above are alternately performed in order to make compression strokes of the four-stage compressor (20) approach those of isothermal compression to reduce compression power necessary for the four-stage compressor (20). At this time, the fourth oil separator (92) of the fourth discharge pipe (28) separates lubricating oil from gas refrigerant flowing in the fourth discharge pipe (28). The separated lubricating oil is sent from the oil outflow pipe (16) to the first suction pipe (29). Refrigerant flowing in the fourth discharge pipe (28) passes through the fourth four-way valve (96) and flows into the outdoor heat exchanger (44). In the outdoor heat exchanger (44), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the outdoor heat exchanger (44) flows into the fourth refrigerant pipe (73). Refrigerant flowing in the fourth refrigerant pipe (73) passes through the check valve (CV11) and flows into the inflow pipe (60).

[0124] Part of refrigerant flowing in the inflow pipe (60) flows into the first branch pipe (62). The pressure of refrigerant flowing in the first branch pipe (62) (see "10" in FIGS. 1 and 2) is reduced in the second expansion valve (81). Refrigerant whose pressure has been reduced in the second expansion valve (81) (see "11" in FIGS. 1 and 2) flows into the low-pressure channel (100b) of the first subcooling heat exchanger (100). On the other hand, the other part of refrigerant flowing in the inflow pipe (60) flows into the high-pressure channel (100a) of the first subcooling heat exchanger (100) (see "10" in FIGS. 1 and 2). In the first subcooling heat exchanger (100), heat exchange is performed between refrigerant flowing in the high-pressure channel (100a) and refrigerant flowing in the low-pressure channel (100b) to subcool refrigerant

flowing in the high-pressure channel (100a).

[0125] Refrigerant that has flown out of the high-pressure channel (100a) of the first subcooling heat exchanger (100) flows in the inflow pipe (60) again (see "13" in FIGS. 1 and 2), and flows into the high-pressure channel (101a) of the second subcooling heat exchanger (101). On the other hand, refrigerant that has flown out of the low-pressure channel (100b) of the first subcooling heat exchanger (100) (see "12" in FIGS. 1 and 2) flows into the injection pipe (106). Refrigerant flowing in the injection pipe (106) flows into the second refrigerant pipe (71) and merges with refrigerant flowing in the second refrigerant pipe (71) (see "6" in FIGS. 1 and 2). That is, refrigerant that has flown into the injection pipe (106) is injected toward a suction side of the third compressor (23).

[0126] In the second subcooling heat exchanger (101), heat exchange is performed between refrigerant flowing in the high-pressure channel (101a) and refrigerant flowing in the low-pressure channel (101b) to subcool refrigerant flowing in the high-pressure channel (101a).

[0127] Refrigerant that has flown out of the high-pressure channel (101a) of the second subcooling heat exchanger (101) flows in the inflow pipe (60) again (see "14" in FIGS. 1 and 2), and part of this refrigerant flows into the expander (87). The expander (87) expands the inflow refrigerant (see "14" to "16" in FIGS. 1 and 2), and sends the expanded refrigerant back to the inflow pipe (60). On the other hand, the other part of refrigerant that has flown out of the high-pressure channel (101a) of the second subcooling heat exchanger (101) branches off into the bypass pipe (64). Refrigerant flowing in the bypass pipe (64) is subjected to pressure reduction in the first expansion valve (80) (see "15" in FIGS. 1 and 2) and returns back to the inflow pipe (60). Refrigerant that has flown out of the expander (87) and refrigerant that has flown out of the bypass pipe (64) merge together in the inflow pipe (60) (see "17" in FIGS. 1 and 2) and flow into the gas-liquid separator (88). The gas-liquid separator (88) separates the inflow refrigerant into gas refrigerant (see "22" in FIGS. 1 and 2) and liquid refrigerant (see "18" in FIGS. 1 and 2).

[0128] The liquid refrigerant (see "18" in FIGS. 1 and 2) that has flown out of the gas-liquid separator (88) flows in the first outflow pipe (61), and part of this refrigerant flows into the second branch pipe (63). The pressure of refrigerant flowing in the second branch pipe (63) is reduced in the third expansion valve (82). Refrigerant whose pressure has been reduced in the third expansion valve (82) (see "19" in FIGS. 1 and 2) flows into the low-pressure channel (102b) of the third subcooling heat exchanger (102). On the other hand, the other part of refrigerant flowing in the outflow pipe (61) flows into the high-pressure channel (102a) of the third subcooling heat exchanger (102).

[0129] In the third subcooling heat exchanger (102), heat exchange is performed between refrigerant flowing in the high-pressure channel (102a) and refrigerant flowing in the low-pressure channel (102b) to subcool liquid

refrigerant flowing in the high-pressure channel (102a).

[0130] The liquid refrigerant that has flown out of the high-pressure channel (102a) of the third subcooling heat exchanger (102) (see "20" in FIGS. 1 and 2) flows in the first outflow pipe (61) again, passes through the check valve (CV13) of the bridge circuit (17), and flows into the liquid-side communication pipe (14). On the other hand, refrigerant that has flown out of the low-pressure channel (102b) of the third subcooling heat exchanger (102) flows in the return pipe (68). Refrigerant flowing in the return pipe (68) (see "24" in FIGS. 1 and 2) merges with gas refrigerant that has flown out of the second outflow pipe (65) (see "23" in FIGS. 1 and 2) at a midpoint thereof, and continues to flow. Refrigerant that has flown out of the return pipe (68) merges with refrigerant that has flown out of the connection pipe (66). The merged refrigerant (see "26" in FIGS. 1 and 2) flows into the low-pressure channel (101b) of the second subcooling heat exchanger (101).

[0131] Part of liquid refrigerant flowing in the liquid-side communication pipe (14) branches off, and is subjected to pressure reduction in the first indoor expansion valve (85). The pressure-reduced refrigerant (see "21a" in FIGS. 1 and 2) flows into the first indoor heat exchanger (110). In the first indoor heat exchanger (110), liquid refrigerant absorbs heat from indoor air and evaporates. The evaporated gas refrigerant (see "25a" in FIGS. 1 and 2) flows into the gas-side communication pipe (13).

[0132] The pressure of the other part of the liquid refrigerant flowing in the liquid-side communication pipe (14) is reduced in the second indoor expansion valve (86). The pressure-reduced refrigerant (see "21b" in FIGS. 1 and 2) flows into the second indoor heat exchanger (111). In the second indoor heat exchanger (111), liquid refrigerant absorbs heat from indoor air and evaporates. The evaporated gas refrigerant (see "25b" in FIGS. 1 and 2) flows into the gas-side communication pipe (13).

[0133] In the gas-side communication pipe (13), refrigerant that has flown out of the first indoor heat exchanger (110) and refrigerant that has flown out of the second indoor heat exchanger (111) merge together. Refrigerant flowing in the gas-side communication pipe (13) passes through the fourth four-way valve (96) and flows into the connection pipe (66). Part of refrigerant flowing in the connection pipe (66) branches off from the junction pipe (67) into parts flowing into the first through third four-way valves (92, 93, 94).

[0134] Refrigerant that has passed through the second port of the first four-way valve (93) flows into the second suction pipe (30). Refrigerant flowing in the second suction pipe (30) passes through the check valve (CV1) and merges with refrigerant flowing in the first refrigerant pipe (70) to be sucked into the second compressor (22). Refrigerant that has passed through the second port of the second four-way valve (94) flows into the third suction pipe (31). Refrigerant flowing in the third suction pipe (31) passes through the check valve (CV2) and merges with

refrigerant flowing in the second refrigerant pipe (71) to be sucked into the third compressor (23). Refrigerant that has passed through the second port of the third four-way valve (95) flows into the fourth suction pipe (32). Refrigerant flowing in the fourth suction pipe (32) passes through the check valve (CV3) and merges with refrigerant flowing in the third refrigerant pipe (72) to be sucked into the fourth compressor (24).

[0135] The other part of refrigerant flowing in the connection pipe (66) merges with refrigerant flowing in the return pipe (68). The merged refrigerant (see "26" in FIGS. 1 and 2) passes through the low-pressure channel (101b) of the second subcooling heat exchanger (101) and flows into the first suction pipe (29). Refrigerant flowing in the first suction pipe (29) (see "1" in FIGS. 1 and 2) is compressed in the first compressor (21) of the four-stage compressor (20) again.

-Heating Operation-

[0136] Heating operation of the air conditioner (1) will now be described with reference to FIG. 7. In FIG. 7, a refrigerant flow in this heating operation is represented by arrows of broken line. In the heating operation, the indoor heat exchangers (110, 111) operate as heat dissipators, and the first through third intermediate heat exchangers (41, 42, 43) and the outdoor heat exchanger (44) operate as evaporators, thereby performing a four-stage compression supercritical refrigeration cycle.

[0137] In the heating operation, all the four-way valves (93, 94, 95, 96) are set in the second states, and the four-stage compressor (20) is driven. When the four-stage compressor (20) is driven, refrigerant is compressed in the compressors (21, 22, 23, 24). Refrigerant compressed in the first compressor (21) is discharged to the first discharge pipe (25). Refrigerant flowing in the first discharge pipe (25) passes through the first four-way valve (93) and is sucked into the second compressor (22). Refrigerant further compressed in the second compressor (22) passes through the second four-way valve (94) and is sucked into the third compressor (23). Refrigerant further compressed in the third compressor (23) passes through the third four-way valve (95) and is sucked into the fourth compressor (24). Refrigerant is further compressed in the fourth compressor (24). In this manner, unlike the cooling operation, four-stage compression is performed without cooling in the heating operation. In this heating operation, the temperature of refrigerant discharged from the four-stage compressor (20) does not decrease, unlike the case of performing four-stage compression with cooling. As a result, the heating operation shows a larger heating capacity than that in the case of four-stage compression with cooling.

[0138] Refrigerant discharged from the fourth compressor (24) passes through the fourth four-way valve (96) and is sent to the first and second indoor heat exchangers (110, 111). In the first and second indoor heat exchangers (110, 111), refrigerant dissipates heat to the

indoor air to be cooled. Refrigerant cooled in the indoor heat exchangers (110, 111) is subjected to pressure reduction in the first and second indoor expansion valves (85, 86) and then sent to the bridge circuit (17). This refrigerant passes through the check valve (CV12) and flows into the inflow pipe (60).

[0139] Part of refrigerant flowing in the inflow pipe (60) flows into the first branch pipe (62). The pressure of refrigerant flowing in the first branch pipe (62) is reduced in the second expansion valve (81). Refrigerant whose pressure has been reduced in the second expansion valve (81) flows into the low-pressure channel (100b) of the first subcooling heat exchanger (100). On the other hand, the other part of refrigerant flowing in the inflow pipe (60) flows into the high-pressure channel (100a) of the first subcooling heat exchanger (100). In the first subcooling heat exchanger (100), heat exchange is performed between refrigerant flowing in the high-pressure channel (100a) and refrigerant flowing in the low-pressure channel (100b) to subcool refrigerant flowing in the high-pressure channel (100a).

[0140] Refrigerant that has flown out of the high-pressure channel (100a) of the first subcooling heat exchanger (100) flows in the first outflow pipe (61) again, and flows into the high-pressure channel (101a) of the second subcooling heat exchanger (101). On the other hand, refrigerant that has flown out of the low-pressure channel (100b) of the first subcooling heat exchanger (100) flows into the injection pipe (106). Refrigerant flowing in the injection pipe (106) flows into the second refrigerant pipe (71) and merges with refrigerant in the second refrigerant pipe (71). That is, refrigerant that has flown into the injection pipe (106) is injected toward a suction side of the third compressor (23).

[0141] In the second subcooling heat exchanger (101), heat exchange is performed between refrigerant flowing in the high-pressure channel (101a) and refrigerant flowing in the low-pressure channel (101b) to subcool refrigerant flowing in the high-pressure channel (101a).

[0142] Refrigerant that has flown out of the high-pressure channel (101a) of the second subcooling heat exchanger (101) flows in the first outflow pipe (61) again, and part of this refrigerant flows into the expander (87). The expander (87) expands the inflow refrigerant, and sends the expanded refrigerant back to the inflow pipe (60). On the other hand, the other part of refrigerant that has flown out of the high-pressure channel (101a) of the second subcooling heat exchanger (101) branches off into the bypass pipe (64). Refrigerant flowing in the bypass pipe (64) is subjected to pressure reduction in the first expansion valve (80) and returns back to the inflow pipe (60). Refrigerant that has flown out of the expander (87) and refrigerant that has flown out of the bypass pipe (64) merge together in the inflow pipe (60) and flow into the gas-liquid separator (88). The gas-liquid separator (88) separates the inflow refrigerant into gas refrigerant and liquid refrigerant.

[0143] The liquid refrigerant that has flown out of the

gas-liquid separator (88) flows in the first outflow pipe (61), and part of this refrigerant flows into the second branch pipe (63). The pressure of refrigerant flowing in the second branch pipe (63) is reduced in the third expansion valve (82). Refrigerant whose pressure has been reduced in the third expansion valve (82) flows into the low-pressure channel (102b) of the third subcooling heat exchanger (102). On the other hand, the other part of refrigerant flowing in the inflow pipe (60) flows into the high-pressure channel (102a) of the third subcooling heat exchanger (102).

[0144] In the third subcooling heat exchanger (102), heat exchange is performed between refrigerant flowing in the high-pressure channel (102a) and refrigerant flowing in the low-pressure channel (102b) to subcool liquid refrigerant flowing in the high-pressure channel (102a)

[0145] The liquid refrigerant that has flown out of the high-pressure channel (102a) of the third subcooling heat exchanger (102) flows in the first outflow pipe (61) again, is subjected to pressure reduction in the fifth expansion valve (84) of the bridge circuit (17), and then is sent to the distributor (18). Refrigerant distributed in the distributor (18) passes through the capillary tube (15) and the check valves (CV4, CV5, CV6, CV7) to flow into the first through third intermediate heat exchangers (41, 42, 43) and the outdoor heat exchanger (44). In the first through third intermediate heat exchangers (41, 42, 43) and the outdoor heat exchanger (44), liquid refrigerant absorbs heat from the outdoor air and evaporates. Refrigerant that has flown out of the first intermediate heat exchanger (41) passes through the first four-way valve (93) and flows into the junction pipe (67). Refrigerant that has flown out of the second intermediate heat exchanger (42) passes through the second four-way valve (94) and flows into the junction pipe (67). Refrigerant that has flown out of the third intermediate heat exchanger (43) passes through the third four-way valve (95) and flows into the junction pipe (67). Refrigerant that has flown out of the first through third intermediate heat exchangers (41, 42, 43) passes through the junction pipe (67) and flows into the connection pipe (66).

[0146] Refrigerant that has flown out of the outdoor heat exchanger (44) passes through the fourth four-way valve (96), flows into the connection pipe (66), and merges with refrigerant that has flown out of the first through third intermediate heat exchangers (41, 42, 43). The merged refrigerant flows in the connection pipe (66) and merges with refrigerant flowing in the return pipe (68). The merged refrigerant flows into the first suction pipe (29). Refrigerant flowing in the first suction pipe (29) is compressed in the first compressor (21) of the four-stage compressor (20) again.

-Outdoor Unit-

[0147] The outdoor unit will now be described. As illustrated in FIG. 3, air taken into the outdoor casing (121) from the air inlet (123) is subjected to heat exchange in

the first through third intermediate heat exchangers (41, 42, 43) and the outdoor heat exchanger (44), flows to upper space in the outdoor casing (121), and is blown out through the air outlet (124).

[0148] As illustrated in FIG. 6, the outdoor unit (3) is of a so-called upward blow type in which air is sucked through the air inlet (123) in the side surface and is blown upward from the air outlet (124). Thus, the airflow velocity is higher in an upper portion of the air inlet (123) than in a lower portion of the air inlet (123). As illustrated in FIG. 2, the pressure of refrigerant flowing in the first through third intermediate heat exchangers (41, 42, 43) is lower than that of refrigerant flowing in the outdoor heat exchanger (44), and thus, the densities of refrigerant flowing in the first through third intermediate heat exchangers (41, 42, 43) are lower than that of refrigerant flowing in the outdoor heat exchanger (44). In view of this, when the mass flow rates of refrigerant flowing in the first through third intermediate heat exchangers (41, 42, 43) are substantially equal to that of refrigerant flowing in the outdoor heat exchanger (44), the volume flow rates of refrigerant in the first through third intermediate heat exchangers (41, 42, 43) are higher than that of refrigerant in the outdoor heat exchanger (44). Even when the number of refrigerant paths in each of the first through third intermediate heat exchangers (41, 42, 43) is equal to that in the outdoor heat exchanger (44), the flow velocities of refrigerant flowing in the first through third intermediate heat exchangers (41, 42, 43) are higher than that of refrigerant flowing in the outdoor heat exchanger (44), and thus, pressure losses of refrigerant in the first through third intermediate heat exchangers (41, 42, 43) are larger than that in the outdoor heat exchanger (44).

[0149] The outdoor heat exchanger (44) located in an upper portion of the outdoor casing (121) where the airflow velocity is high, has a high heat exchange efficiency, and can be reduced in size. On the other hand, the first through third intermediate heat exchangers (41, 42, 43) located in a lower portion of the outdoor casing (121) where the airflow velocity is low, have low heat exchange efficiencies. Thus, to increase the amount of heat exchange, the first through third intermediate heat exchangers (41, 42, 43) need to be larger than those in a case where these exchangers are located in an upper portion.

[0150] For this reason, the size of the outdoor heat exchange unit (40) does not increase even when the size of the outdoor heat exchanger (44) and the first through third intermediate heat exchangers (41, 42, 43) increases.

[0151] An increase in size of the first through third intermediate heat exchangers (41, 42, 43) increases the number of refrigerant paths in each of the first through third intermediate heat exchangers (41, 42, 43). Thus, in the first through third intermediate heat exchangers (41, 42, 43), the flow velocity of refrigerant in each refrigerant path decreases, resulting in a decrease in pressure loss of refrigerant passing through the refrigerant path. The flow velocities of refrigerant flowing in the first through

third intermediate heat exchangers (41, 42, 43) are originally high, and thus, a decrease in flow velocity due to an increase in the number of refrigerant paths relatively greatly reduces the pressure loss.

[0152] On the other hand, size reduction of the outdoor heat exchanger (44) reduces the number of refrigerant paths in the outdoor heat exchanger (44). The reduction of the number of refrigerant paths increases the flow velocity of refrigerant in each refrigerant path to increase the pressure loss of refrigerant passing through the refrigerant path.

[0153] However, since the flow velocity of refrigerant flowing in the outdoor heat exchanger (44) is originally low, a certain degree of increase in flow velocity due to the reduction of the number of refrigerant paths relatively slightly increases the pressure loss arising from the increase in flow velocity.

[0154] Thus, by disposing the outdoor heat exchanger (44) above the first through third intermediate heat exchangers (41, 42, 43), the pressure losses of refrigerant in the first through third intermediate heat exchangers (41, 42, 43) can be reduced with a reduced degree of increase in size of the outdoor heat exchange unit (40).

[0155] Since the pressure of refrigerant flowing in the third intermediate heat exchanger (43) is higher than that of refrigerant flowing in the first and second intermediate heat exchangers (41, 42) as illustrated in FIG. 2, the densities of refrigerant flowing in the first and second intermediate heat exchangers (41, 42) are lower than that of refrigerant flowing in the third intermediate heat exchanger (43). Thus, when the mass flow rates of refrigerant flowing in the first and second intermediate heat exchangers (41, 42) are substantially equal to that of refrigerant flowing in the third intermediate heat exchanger (43), the volume flow rates of refrigerant in the first and second intermediate heat exchangers (41, 42) are higher than that of refrigerant in the third intermediate heat exchanger (43). Even when the numbers of refrigerant paths in the first and second intermediate heat exchangers (41, 42) are substantially equal to that in the third intermediate heat exchanger (43), the pressure losses of refrigerant in the first and second intermediate heat exchangers (41, 42) are larger than that of refrigerant in the third intermediate heat exchanger (43) because the refrigerant flow velocities in the first and second intermediate heat exchangers (41, 42) are higher than that in the third intermediate heat exchanger (43).

[0156] Since the third intermediate heat exchanger (43) located in an upper portion of the outdoor casing (121) where the airflow velocity is high has a high heat exchange efficiency, the size of the third intermediate heat exchanger (43) can be reduced. On the other hand, the first and second intermediate heat exchangers (41, 42) located in a lower portion of the outdoor casing (121) where the airflow velocity is low, have low heat exchange efficiencies. Thus, to increase the amount of heat exchange, the first and second intermediate heat exchangers (41, 42, 43) need to be larger than those in a case

where these exchangers are located in an upper portion.

[0157] For this reason, the size of the outdoor heat exchange unit (40) does not increase even when the size of the third intermediate heat exchanger (43) and the first and second intermediate heat exchangers (41, 42) increases.

[0158] An increase in size of the first and second intermediate heat exchangers (41, 42) increases the numbers of refrigerant paths in the first and second intermediate heat exchangers (41, 42). Thus, in the first and second intermediate heat exchangers (41, 42), the flow velocity of refrigerant in each refrigerant path decreases, resulting in a decrease in pressure loss of refrigerant passing through the refrigerant path. The flow velocities of refrigerant flowing in the first and second intermediate heat exchangers (41, 42) are originally high, and thus, a decrease in flow velocity due to an increase in the number of refrigerant paths relatively greatly reduces the pressure loss.

[0159] On the other hand, size reduction of the third intermediate heat exchanger (43) reduces the number of refrigerant paths in the third intermediate heat exchanger (43). The reduction of the number of refrigerant paths increases the flow velocity of refrigerant in each refrigerant path to increase the pressure loss of refrigerant passing through the refrigerant paths.

[0160] However, since the flow velocity of refrigerant flowing in the third intermediate heat exchanger (43) is originally low, a certain degree of increase in flow velocity due to the reduction of the number of refrigerant paths relatively slightly increases the pressure loss arising from the increase in flow velocity.

[0161] Thus, by disposing the third intermediate heat exchanger (43) above the first and second intermediate heat exchangers (41, 42), the pressure losses of refrigerant in the first and second intermediate heat exchangers (41, 42) can be reduced with a reduced degree of increase in size of the outdoor heat exchange unit (40).

[0162] As illustrated in FIG. 2, the refrigerant density in the second intermediate heat exchanger (42) where inflow refrigerant has a high pressure is higher than that in the first intermediate heat exchanger (41) where inflow refrigerant has a low pressure. Thus, when the mass flow rate of refrigerant flowing in the first intermediate heat exchanger (41) is substantially equal to that of refrigerant flowing in the second intermediate heat exchanger (42), the volume flow rate of refrigerant in the first intermediate heat exchanger (41) is higher than that of refrigerant in the second intermediate heat exchanger (42). Even when the number of refrigerant paths in the first intermediate heat exchanger (41) is substantially equal to that in the second intermediate heat exchanger (42), the pressure loss of refrigerant in the first intermediate heat exchanger (41) is larger than that of refrigerant in the second intermediate heat exchanger (42) because the refrigerant flow velocity in the first intermediate heat exchanger (41) is higher than that in the second intermediate heat exchanger (42). The first intermediate heat exchanger (41)

is located in a lower portion of the outdoor casing (121) where the airflow velocity is low does not have a high heat exchange efficiency, and thus, does not decrease in size. Since the number of refrigerant paths in the first intermediate heat exchanger (41) does not decrease, the pressure loss of refrigerant does not increase. For the foregoing reasons, an increase in pressure loss of refrigerant in the first intermediate heat exchanger (41) can be reduced.

-Advantages of First Embodiment-

[0163] In the first embodiment, since the outdoor heat exchanger (44) is located in an upper portion of the outdoor casing (121) where the airflow velocity is high, the heat exchange efficiency of the outdoor heat exchanger (44) can be increased. In addition, since the outdoor heat exchanger (44) having a low flow velocity of refrigerant is located in an upper portion of the outdoor casing (121) where the airflow velocity is high, the size of the outdoor heat exchanger (44) can be reduced without an increase in pressure loss of refrigerant.

[0164] On the other hand, the first through third intermediate heat exchangers (41, 42, 43) are located in a lower portion of the outdoor casing (121) where the airflow velocity is low to increase the number of refrigerant paths, thereby ensuring prevention of an increase in pressure loss of refrigerant in the first through third intermediate heat exchangers (41, 42, 43).

[0165] In the above-described configuration, the outdoor heat exchangers (44, 162) where a pressure loss of refrigerant does not easily increase is located in upper portions for size reduction, thereby reducing pressure losses of refrigerant in the first through third intermediate heat exchangers (41, 42, 43) with reduced size increase in the outdoor heat exchange unit (40).

[0166] In addition, since the third intermediate heat exchanger (43) is located in an upper portion of the outdoor casing (121) where the airflow velocity is high, the heat exchange efficiency of the third intermediate heat exchanger (43) can be increased. Further, since the third intermediate heat exchanger (43) having a low flow velocity of refrigerant is located in an upper portion of the outdoor casing (121) where the airflow velocity is high, the size of the third intermediate heat exchanger (43) can be reduced without an increase in pressure loss of refrigerant.

[0167] On the other hand, the first and second intermediate heat exchangers (41, 42) having high flow velocities of refrigerant are located in a lower portion of the outdoor casing (121) where the airflow velocity is low to increase the number of refrigerant paths, thereby ensuring prevention of an increase in pressure loss of refrigerant in the first and second intermediate heat exchangers (41, 42).

[0168] In the above-described configuration, the third intermediate heat exchanger (43) where a pressure loss of refrigerant does not easily increase is located in the

upper portion for size reduction, thereby reducing a pressure loss of refrigerant in the other intermediate heat exchangers (41, 42) with reduced size increase in the outdoor heat exchange unit (40).

[0169] In addition, the first intermediate heat exchanger (41) having a high flow velocity of refrigerant is located in a lower portion of the outdoor casing (121) where the airflow velocity is low to increase the number of refrigerant paths, thereby ensuring prevention of an increase in pressure loss of refrigerant in the first intermediate heat exchanger (41). This configuration can reduce an increase in the pressure loss of refrigerant in the first intermediate heat exchanger (41).

15 <Second Embodiment>

[0170] A second embodiment according to the present invention will now be described. As illustrated in FIG. 8, the air conditioner (1) according to this second embodiment has a configuration of a refrigerant circuit different from that of the air conditioner (1) of the first embodiment. In the second embodiment, only part of the configuration different from that of the first embodiment is described, and like reference characters are used to designate identical or equivalent elements.

[0171] Specifically, the refrigerant circuit (10) of the second embodiment includes three subcooling heat exchangers: a first-a subcooling heat exchanger (103), a first-b subcooling heat exchanger (104), and a first-c subcooling heat exchanger (105).

-Circuit Configuration-

[0172] The first-a subcooling heat exchanger (103) includes a high-pressure channel (103a) and a low-pressure channel (103b). In the first-a subcooling heat exchanger (103), heat exchange is performed between the high-pressure channel (103a) and the low-pressure channel (103b) to subcool refrigerant flowing in the high-pressure channel (103a).

[0173] An inflow end of the high-pressure channel (103a) is connected to an inflow pipe (60), and an inflow end of the low-pressure channel (103b) is connected to a first-a branch pipe (62a) serving as a passage for subcooling. The first-a branch pipe (62a) includes a second-a expansion valve (81 a) for subcooling. The second-a expansion valve (81 a) is an electronic expansion valve having an adjustable opening degree. An outflow end of the low-pressure channel (103b) is connected to an end of a first injection pipe (107).

[0174] An end of the first injection pipe (107) is connected to the low-pressure channel (103b) of the first-a subcooling heat exchanger (103), and the other end of the first injection pipe (107) is connected to a third refrigerant pipe (72). The other end of the first injection pipe (107) is connected to an outflow end of a check valve (CV10) in the third refrigerant pipe (72). The first-a subcooling heat exchanger (103) and the second-a expansion

sion valve (81a) constitute a so-called economizer circuit.

[0175] The first-b subcooling heat exchanger (104) includes a high-pressure channel (104a) and a low-pressure channel (104b). In the first-b subcooling heat exchanger (104), heat exchange is performed between refrigerant flowing in the high-pressure channel (104a) and refrigerant flowing in the low-pressure channel (104b) to subcool refrigerant flowing in the high-pressure channel (104a).

[0176] An inflow end of the high-pressure channel (104a) is connected to the inflow pipe (60), and an inflow end of the low-pressure channel (104b) is connected to a first-b branch pipe (62b) serving as a passage for subcooling. The first-b branch pipe (62b) includes a second-b expansion valve (81b) for subcooling. The second-b expansion valve (81b) is an electronic expansion valve having an adjustable opening degree. An outflow end of the low-pressure channel (104b) is connected to an end of a second injection pipe (108).

[0177] An end of the second injection pipe (108) is connected to the low-pressure channel (104b) of the first-b subcooling heat exchanger (104), and the other end of the second injection pipe (108) is connected to the second refrigerant pipe (71). The other end of the second injection pipe (108) is connected to an outflow end of a check valve (CV9) in the second refrigerant pipe (71). The first-b subcooling heat exchanger (104) and the second-b expansion valve (81b) constitute a so-called economizer circuit.

[0178] The first-c subcooling heat exchanger (105) includes a high-pressure channel (105a) and a low-pressure channel (105b). In the first-c subcooling heat exchanger (105), heat exchange is performed between refrigerant flowing in the high-pressure channel (105a) and refrigerant flowing in the low-pressure channel (105b) to subcool refrigerant flowing in the high-pressure channel (105a).

[0179] An inflow end of the high-pressure channel (105a) is connected to the inflow pipe (60), and an inflow end of the low-pressure channel (105b) is connected to a first-c branch pipe (62c) serving as a passage for subcooling. The first-c branch pipe (62c) includes a second-c expansion valve (81c) for subcooling. The second-c expansion valve (81c) is an electronic expansion valve having an adjustable opening degree. An outflow end of the low-pressure channel (105b) is connected to an end of a third injection pipe (109).

[0180] An end of the third injection pipe (109) is connected to the low-pressure channel (105a) of the first-c subcooling heat exchanger (105), and the other end of the third injection pipe (109) is connected to the first refrigerant pipe (70). The other end of the third injection pipe (109) is connected to an outflow end of a check valve (CV8) in the first refrigerant pipe (70). The first-c subcooling heat exchanger (105) and the second-c expansion valve (81c) constitute a so-called economizer circuit.

-Circuit Operation-

[0181] Operations of the subcooling heat exchangers (103, 104, 105) and the expansion valves (81a, 81b, 81c) will now be described with reference to FIGS. 8 and 9. Description of part of operations also described in the first embodiment will not be repeated.

[0182] Refrigerant compressed in a fourth compressor (24) of a four-stage compressor (20) is discharged to a fourth discharge pipe (28). Compression and cooling operations are alternately performed in the four-stage compressor (20) and first through third intermediate heat exchangers (41, 42, 43) in order to make compression strokes of the four-stage compressor (20) approach those of isothermal compression to reduce compression power necessary for the four-stage compressor (20).

[0183] Refrigerant flowing in the fourth discharge pipe (28) passes through a fourth four-way valve (96) and flows into an outdoor heat exchanger (44). In the outdoor heat exchanger (44), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the outdoor heat exchanger (44) flows into a fourth refrigerant pipe (73). Refrigerant flowing in the fourth refrigerant pipe (73) passes through a check valve (CV11) and flows into the inflow pipe (60).

[0184] Part of refrigerant flowing in the inflow pipe (60) flows into the first-a branch pipe (62a). The pressure of refrigerant flowing in the first-a branch pipe (62a) (see "27" in FIGS. 8 and 9) is reduced in the second-a expansion valve (81a). Refrigerant whose pressure has been reduced in the second-a expansion valve (81a) (see "28" in FIGS. 8 and 9) flows into the low-pressure channel (103b) of the first-a subcooling heat exchanger (103). On the other hand, the other part of refrigerant flowing in the inflow pipe (60) flows into the high-pressure channel (103a) of the first-a subcooling heat exchanger (103) (see "27" in FIGS. 8 and 9). In the first-a subcooling heat exchanger (103), heat exchange is performed between refrigerant flowing in the high-pressure channel (103a) and refrigerant flowing in the low-pressure channel (103b) to subcool refrigerant flowing in the high-pressure channel (103a).

[0185] Refrigerant that has flown out of the high-pressure channel (103a) of the first-a subcooling heat exchanger (103) flows in the inflow pipe (60) again (see "31" in FIGS. 8 and 9), and flows into the high-pressure channel (104a) of the first-b subcooling heat exchanger (104). On the other hand, refrigerant that has flown out of the low-pressure channel (103b) of the first-a subcooling heat exchanger (103) (see "29" in FIGS. 8 and 9) flows into the first injection pipe (107). Refrigerant flowing in the first injection pipe (107) flows into the third refrigerant pipe (72) and merges with refrigerant (see "30" in FIGS. 8 and 9) in the third refrigerant pipe (72) to be merged refrigerant (see "8" in FIGS. 8 and 9). That is, refrigerant that has flown into the first injection pipe (107) is injected toward a suction side of a fourth compressor (24).

[0186] Then, part of refrigerant that has flown out of the first-a subcooling heat exchanger (103) and is flowing in the inflow pipe (60) flows into the first-b branch pipe (62b). The pressure of refrigerant flowing in the first-b branch pipe (62b) (see "31" in FIGS. 8 and 9) is reduced in the second-b expansion valve (81b). Refrigerant whose pressure has been reduced in the second-b expansion valve (81b) (see "32" in FIGS. 8 and 9) flows into the low-pressure channel (104b) of the first-b subcooling heat exchanger (104). On the other hand, the other part of refrigerant flowing in the inflow pipe (60) flows into the high-pressure channel (104a) of the first-b subcooling heat exchanger (104) (see "31" in FIGS. 8 and 9). In the first-b subcooling heat exchanger (104), heat exchange is performed between refrigerant flowing in the high-pressure channel (104a) and refrigerant flowing in the low-pressure channel (104b) to subcool refrigerant flowing in the high-pressure channel (104a).

[0187] Refrigerant that has flown out of the high-pressure channel (104a) of the first-b subcooling heat exchanger (104) flows in the inflow pipe (60) again (see "34" in FIGS. 8 and 9) and flows into the high-pressure channel (105a) of the first-c subcooling heat exchanger (105). On the other hand, refrigerant that has flown out of the low-pressure channel (104b) of the first-b subcooling heat exchanger (104) (see "33" in FIGS. 8 and 9) flows into the second injection pipe (108). Refrigerant flowing in the second injection pipe (108) flows into the second refrigerant pipe (71), and merges with refrigerant (see "5" in FIGS. 8 and 9) in the second refrigerant pipe (71) to be merged refrigerant (see "6" in FIGS. 8 and 9). That is, refrigerant that has flown into the second injection pipe (108) is injected toward a suction side of a third compressor (23).

[0188] Part of refrigerant that has flown out of the first-b subcooling heat exchanger (104) and is flowing in the inflow pipe (60) flows into the first-c branch pipe (62c). The pressure of refrigerant flowing in the first-c branch pipe (62c) (see "34" in FIGS. 8 and 9) is reduced in the second-c expansion valve (81c). Refrigerant whose pressure has been reduced in the second-c expansion valve (81c) (see "35" in FIGS. 8 and 9) flows into the low-pressure channel (105b) of the first-c subcooling heat exchanger (105). On the other hand, the other part of refrigerant flowing in the inflow pipe (60) flows into the high-pressure channel (105a) of the first-c subcooling heat exchanger (105) (see "34" in FIGS. 8 and 9). In the first-c subcooling heat exchanger (105), heat exchange is performed between refrigerant flowing in the high-pressure channel (105a) and refrigerant flowing in the low-pressure channel (105b) to subcool refrigerant flowing in the high-pressure channel (105a).

[0189] Refrigerant that has flown out of the high-pressure channel (105a) of the first-c subcooling heat exchanger (105) flows in the inflow pipe (60) again (see "38" in FIGS. 8 and 9), and flows into the high-pressure channel (101a) of the second subcooling heat exchanger (101). On the other hand, refrigerant that has flown out

of the low-pressure channel (105b) of the first-c subcooling heat exchanger (105) (see "36" in FIGS. 8 and 9) flows into the first injection pipe (107). Refrigerant flowing in the first injection pipe (107) flows into the first refrigerant pipe (70) and merges with refrigerant (see "37" in FIGS. 8 and 9) flowing in the first refrigerant pipe (70) to be merged refrigerant (see "3" in FIGS. 8 and 9). That is, refrigerant that has flown into the third injection pipe (109) is injected toward a suction side of a second compressor (22). The other configurations, operations, and advantages are similar to those of the first embodiment.

<Third Embodiment>

[0190] A third embodiment according to the present invention will now be described. As illustrated in FIG. 10, an air conditioner (140) according to the third embodiment has a configuration of a refrigerant circuit different from that of the air conditioner (1) of the first embodiment. In the third embodiment, only part of the configuration different from that of the first embodiment is described.

[0191] Specifically, the air conditioner (140) of the third embodiment will now be described. The air conditioner (140) includes a refrigerant circuit (143) in which a flow of refrigerant is allowed to be changed reversibly, and is switchable between cooling operation and heating operation. The air conditioner (140) includes an outdoor unit (142) located outdoors and an indoor unit (141) located indoors. The refrigerant circuit (143) of the air conditioner (140) is obtained by connecting an outdoor circuit (144) of the outdoor unit (142) and an indoor circuit (145) of the indoor unit (141) to each other through a gas-side communication pipe (146) and a liquid-side communication pipe (147). The refrigerant circuit (143) is filled with carbon dioxide (hereinafter referred to as refrigerant), and configured to perform a multistage compression supercritical refrigeration cycle by circulating refrigerant in the refrigerant circuit (143).

<Outdoor Circuit>

[0192] As illustrated in FIG. 10, the outdoor circuit (144) is connected to a two-stage compressor (150), an outdoor heat exchange unit (160), first and second four-way valves (175, 176), first and second subcooling heat exchangers (191, 192), first through fifth expansion valves (201-205), an expander (193), and a gas-liquid separator (194). The outdoor heat exchange unit (160) includes an intermediate heat exchanger (161) and an outdoor heat exchanger (162).

[0193] The outdoor circuit (144) is also connected to two oil separators (174, 174), a distributor (173), a capillary tube (170), a bridge circuit (172), and check valves (CV1-CV7).

[0194] In the third embodiment, the refrigerant circuit (143) is switched between cooling operation and heating operation by switching the first and second four-way valves (175, 176).

[0195] The two-stage compressor (150) includes first and second compressors (151, 152) and is a multistage compressor of the present invention. The first and second compressors (151, 152) are connected to first and second discharge pipes (153, 154) at discharge sides thereof, while being connected to first and second suction pipes (155, 156) at suction sides thereof. Each of the compressors (151, 152) compresses low-pressure gas refrigerant sucked through an associated one of the suction pipes (155, 156) to be high-pressure gas refrigerant, which is then discharged from the discharge pipe (153, 154).

[0196] The first four-way valve (175) has its first port connected to the first discharge pipe (153) of the first compressor (151), its second port connected to an end of the junction pipe (187), its third port connected to an end of the intermediate heat exchanger (161), and its fourth port connected to the second suction pipe (156) of the second compressor (152). The first four-way valve (175) is switched between a first state (a state indicated by a continuous line in FIG. 10) in which the first port communicates with the third port and the second port communicates with the fourth port and a second state (a state indicated by a broken line in FIG. 10) in which the first port communicates with the fourth port and the second port communicates with the third port.

[0197] The second four-way valve (176) has its first port connected to the second discharge pipe (154) of the second compressor (152), its second port connected to an end of the connection pipe (186), its third port connected to an end of outdoor heat exchanger (162), and its fourth port connected to the gas-side communication pipe (146). The first four-way valve (175) is switched between a first state (a state indicated by a continuous line in FIG. 10) in which the first port communicates with the third port and the second port communicates with the fourth port and a second state (a state indicated by a broken line in FIG. 10) in which the first port communicates with the fourth port and the second port communicates with the third port.

[0198] The check valve (CV1) is connected to a midpoint of the second suction pipe (156). The check valve (CV1) allows refrigerant to flow from the first four-way valve (175) to the two-stage compressor (150), and prevents refrigerant from flowing in a reverse direction.

[0199] The oil separators (174, 174) are connected to midpoints of the first and second discharge pipes (153, 154), respectively. The oil separators (174, 174) separate lubricating oil contained in high-pressure gas refrigerant flowing in the discharge pipes (153, 154) from the high-pressure gas refrigerant. The oil separators (174, 174) are connected to oil outflow pipe (171, 171) through which lubricating oil separated in the oil separators (174, 174) flows to the outside of the oil separators (174, 174).

[0200] Specifically, the oil outflow pipe (171) of the oil separator (174) for the first discharge pipe (153) is connected to the second suction pipe (156). The oil outflow pipe (171) of the oil separator (174) for the second dis-

charge pipe (154) is connected to the first suction pipe (155). The capillary tubes (170, 170) are connected to midpoints of the oil outflow pipes (171, 171), respectively.

[0201] The intermediate heat exchanger (161) and the outdoor heat exchanger (162) are configured as fin-and-tube heat exchangers. The intermediate heat exchanger (161) in this embodiment corresponds to an intermediate heat exchanger of the present invention, and the outdoor heat exchanger (162) in this embodiment corresponds to an outdoor heat exchanger of the present invention. An outdoor fan (122) is disposed near each of the heat exchangers (161, 162) so that heat exchange is performed between outdoor air from the outdoor fan (122) and refrigerant flowing in heat exchanger tubes of the heat exchangers (161, 162).

[0202] An end of the intermediate heat exchanger (161) is connected to the third port of the first four-way valve (175), and an end of the outdoor heat exchanger (162) is connected to the third port of the second four-way valve (176). On the other hand, the other end of the intermediate heat exchanger (161) is connected to the first refrigerant pipe (181), and the other end of the outdoor heat exchanger (162) is connected to the second refrigerant pipe (182).

[0203] The other end of the second refrigerant pipe (182) branches off into two parts, one of which is connected to the bridge circuit (172) and the other of which is connected to a second outflow port (P2) of the distributor (173). The check valve (CV3) and the capillary tube (170) are located between the branch point of the second refrigerant pipe (182) and the second outflow port (P2) of the distributor (173). The check valve (CV3) allows refrigerant to flow from the distributor (173) to the branch point of the second refrigerant pipe (182), and prevents refrigerant from flowing in a reverse direction.

[0204] The other end of the first refrigerant pipe (181) branches off into two parts, one of which is connected to a midpoint (between the check valve (CV1) and the second compressor (152)) of the second suction pipe (156) and the other of which is connected to a first outflow port (P1) of the distributor (173). The check valve (CV2) and the capillary tube (170) are located between the branch point of the first refrigerant pipe (181) and the first outflow port (P1) of the distributor (173). The check valve (CV2) allows refrigerant to flow from the distributor (173) to the branch point of the first refrigerant pipe (181), and prevents refrigerant from flowing in a reverse direction. The check valve (CV4) is located between the branch point of the first refrigerant pipe (181) and the connection point of the second suction pipe (156). The check valve (CV4) allows refrigerant to flow from the branch point of the first refrigerant pipe (181) to the connection point of the second suction pipe (156), and prevents refrigerant from flowing in a reverse direction.

[0205] The bridge circuit (172) is a circuit in which the check valves (CV5, CV6, CV7) and a fifth expansion valve (205) are bridged. In the bridge circuit (172), a connection end between an inflow end of the check valve

(CV7) and the other end of the fifth expansion valve (205) is connected to the first outflow pipe (180), and a connection end located between outflow end of the check valve (CV7) and an inflow end of the check valve (CV6) is connected to the liquid-side communication pipe (147). A refrigerant pipe connecting the liquid-side communication pipe (147) and the first indoor heat exchanger (211) includes a first indoor expansion valve (206) having a variable opening degree. A refrigerant pipe connecting the liquid-side communication pipe (147) and the second indoor heat exchanger (212) includes a second indoor expansion valve (207) having a variable opening degree. A connection end located between an outflow end of the check valve (CV6) and an outflow end of the check valve (CV5) is connected to the inflow pipe (179). An end of the fifth expansion valve (205) is connected to the distributor (173), and an inflow end of the check valve (CV5) is connected to the second refrigerant pipe (182).

[0206] On the inflow pipe (179), the first subcooling heat exchanger (191), the expander (193), the gas-liquid separator (194), and the second subcooling heat exchanger (192) are disposed in this order.

[0207] The first subcooling heat exchanger (191) includes a high-pressure channel (191a) and a low-pressure channel (191b). In the first subcooling heat exchanger (191), heat exchange is performed between refrigerant flowing in the high-pressure channel (191a) and refrigerant flowing in the low-pressure channel (191b) to subcool refrigerant flowing in the high-pressure channel (191a).

[0208] An inflow end of the high-pressure channel (191a) is connected to the inflow pipe (179), and an inflow end of the low-pressure channel (191b) is connected to the first branch pipe (177) serving as a passage for subcooling. The first branch pipe (177) includes a second expansion valve (202) for subcooling. The second expansion valve (202) is an electronic expansion valve having an adjustable opening degree. An outflow end of the low-pressure channel (191b) is connected to an end of the injection pipe (188).

[0209] An end of the injection pipe (188) is connected to the low-pressure channel (191b) of the first subcooling heat exchanger (191), and the other end of the injection pipe (188) is connected to the first refrigerant pipe (181). The other end of the injection pipe (188) is connected to an outflow end of the check valve (CV4) in the first refrigerant pipe (181).

[0210] The expander (193) includes an expander casing having a vertically elongated cylindrical shape, and is located between the first subcooling heat exchanger (191) and the gas-liquid separator (194) on the inflow pipe (179). In the expander casing, an expansion mechanism for generating power by expanding refrigerant is provided. The expander (193) constitutes a so-called rotary positive-displacement fluid machine. The expander (193) expands the inflow refrigerant and sends the expanded refrigerant back to the inflow pipe (179).

[0211] The inflow pipe (179) includes a bypass pipe

(183) that bypasses the expander (193). An end of the bypass pipe (183) is connected to an inflow end of the expander (193), and the other end of the bypass pipe (183) is connected to an outflow end of the expander (193) to bypass the expander (193). The bypass pipe (183) includes a first expansion valve (201). The first expansion valve (201) is an electronic expansion valve having an adjustable opening degree.

[0212] The gas-liquid separator (194) is an hermetic container having a vertically elongated cylindrical shape. The gas-liquid separator (194) is connected to the inflow pipe (179), the first outflow pipe (180), and the second outflow pipe (184). The inflow pipe (179) is open in an upper portion of the inner space of the gas-liquid separator (194). The first outflow pipe (180) is open in a lower portion of the inner space of the gas-liquid separator (194). The second outflow pipe (184) is open in an upper portion of the inner space of the gas-liquid separator (194). In the gas-liquid separator (194), refrigerant from the inflow pipe (179) is separated into a saturated liquid and a saturated gas, where the saturated liquid flows out of the first outflow pipe (180) and the saturated gas flows out of the second outflow pipe (184).

[0213] An end of the second outflow pipe (184) is connected to the gas-liquid separator (194), and the other end of the second outflow pipe (184) is connected to a midpoint of the second branch pipe (178). The second outflow pipe (184) includes a fourth expansion valve (204). The fourth expansion valve (204) is an electronic expansion valve having an adjustable opening degree.

[0214] The second subcooling heat exchanger (192) is connected to a midpoint of the first outflow pipe (180). The second subcooling heat exchanger (192) includes a high-pressure channel (192a) and a low-pressure channel (192b). In the second subcooling heat exchanger (192), heat exchange is performed between refrigerant flowing in the high-pressure channel (192a) and refrigerant flowing in the low-pressure channel (192b) to subcool refrigerant flowing in the high-pressure channel (192a).

[0215] An inflow end of the high-pressure channel (192a) is connected to an outflow end of the gas-liquid separator (194), and an outflow end of the high-pressure channel (192a) is connected to the bridge circuit (172). An inflow end of the low-pressure channel (192b) is connected to the second branch pipe (178) serving as a passage for subcooling, and an outflow end of the low-pressure channel (192b) is connected to the other end of the return pipe (185).

[0216] One end of the second branch pipe (178) is connected to a midpoint of the first outflow pipe (180) between the gas-liquid separator (194) and the second subcooling heat exchanger (192), and the other end of the second branch pipe (178) is connected to an inflow end of the low-pressure channel (192b) of the second subcooling heat exchanger (192), where the second outflow pipe (184) is connected between the one end and the other end. The second branch pipe (178) includes a third

expansion valve (203). The third expansion valve (203) is an electronic expansion valve having an adjustable opening degree.

[0217] An end of the return pipe (185) is connected to the other end of the connection pipe (186), and the other end of the return pipe (185) is connected to an outflow end of the low-pressure channel (192b) of the second subcooling heat exchanger (192).

[0218] An end of the connection pipe (186) is connected to the second port of the second four-way valve (176), and the other end of the connection pipe (186) is connected to an end of the return pipe (185) and the other end of the first suction pipe (155), where the other end of the junction pipe (187) is connected to a midpoint of the connection pipe (186) between the second port and the connection point connecting the end of the return pipe (185) and the other end of the first suction pipe (155).

[0219] An end of the junction pipe (187) is connected to the second port of the first four-way valve (175), and the other end of the junction pipe (187) is connected to a midpoint of the connection pipe (186).

<Indoor Circuit>

[0220] In the indoor circuit (145), a pair of the first indoor expansion valve (206) and the first indoor heat exchanger (211) and a pair of the second indoor expansion valve (207) and the second indoor heat exchanger (212) are disposed in this order from a liquid side to a gas side, and are connected in parallel. Each of the indoor expansion valves (206, 207) is an electronic expansion valve having an adjustable opening degree. Each of the indoor heat exchangers (211, 212) is a cross-fin type fin-and-tube heat exchanger. Although not shown, indoor fans for sending indoor air to the indoor heat exchangers (211, 212) are provided near the indoor heat exchangers (211, 212). In each of the indoor heat exchangers (211, 212), heat exchange is performed between refrigerant and the indoor air.

<Configuration of Outdoor Unit>

[0221] As illustrated in FIG. 12, the outdoor unit (142) includes an outdoor casing (163). The outdoor casing (163) is in the shape of a vertically elongated rectangular box, and has an air inlet (164) in a lower portion of the front surface and an air outlet (165) in an upper surface thereof. In the outdoor casing (163), the outdoor heat exchange unit (160) and the outdoor fan (166) are placed.

[0222] The outdoor fan (166) is a fan for sending air taken in the outdoor casing (163) to the heat exchangers (161, 162), and is a so-called sirocco fan. The outdoor fan (166) is located above the heat exchangers (161, 162) in the outdoor casing (163). The outdoor fan (166) causes air sucked through the air inlet (164) to pass through the heat exchangers (161, 162) and then to flow to the outside through the air outlet (165).

[0223] As illustrated in FIG. 12, in the outdoor casing

(163), the outdoor heat exchange unit (160) is oriented such that the intermediate heat exchanger (161) and the outdoor heat exchanger (162) are stacked this order from the bottom. That is, the outdoor heat exchanger (162) is located above the intermediate heat exchanger (161).

[0224] Each of the heat exchangers (161, 162) is a so-called cross-fin type fin-and-tube heat exchanger. Each of the heat exchangers (161, 162) includes a plurality of heat exchanger tube groups each including a plurality of heat exchanger tubes and a plurality of U-shaped tubes, and also includes a heat transmission fin.

[0225] The heat exchanger tube groups are aligned in the up and down direction. In each of the heat exchanger tube groups, a plurality of heat exchanger tubes are arranged such that three rows of heat exchanger tubes each along an airflow direction are arranged side by side and each of the three rows includes two heat exchanger tubes aligned in the up and down direction. In addition, a first bank of tubes is disposed at the windward side, a second bank of tubes is disposed at the middle, and a third bank of tubes is disposed at the leeward side. That is, in each of the heat exchanger tube groups, the heat exchanger tubes are disposed in two stages in each row.

-Operation-

[0226] Operation of the air conditioner (140) will now be described. In the air conditioner (140), the refrigerant circuit (143) is switched between cooling operation and heating operation by switching the first and second four-way valves (175, 176). Reference numerals 1-18 in FIGS. 10 and 11 represent pressure states of refrigerant.

-Cooling Operation-

[0227] Cooling operation of the air conditioner (140) will be described with reference to FIG. 10. In FIG. 10, a refrigerant flow in this cooling operation is represented by arrows of continuous line. In the cooling operation, the outdoor heat exchanger (162) operates as a heat dissipator, and the indoor heat exchangers (211, 212) operate as evaporators, thereby performing a two-stage compression supercritical refrigeration cycle. The intermediate heat exchanger (161) operates as a cooler that cools high-pressure refrigerant discharged from the first compressor (151).

[0228] In the cooling operation, all the four-way valves (175, 176) are set in the first states, and the two-stage compressor (150) is driven. When the two-stage compressor (150) is driven, refrigerant is compressed in the compressors (161, 162). Refrigerant compressed in the first compressor (151) is discharged to the first discharge pipe (153) (see "2" in FIGS. 10 and 11). In this state, the oil separator (174) of the first discharge pipe (153) separates lubricating oil from gas refrigerant flowing in the first discharge pipe (153). The separated lubricating oil is sent from the oil outflow pipe (171) to the second suction pipe (156). Refrigerant flowing in the first discharge

pipe (153) passes through the first four-way valve (175) and flows into the intermediate heat exchanger (161). In the intermediate heat exchanger (161), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the intermediate heat exchanger (161) flows into the first refrigerant pipe (181). Refrigerant flowing in the first refrigerant pipe (181) (see "3" in FIGS. 10 and 11) passes through the check valve (CV4) and merges with refrigerant flowing in the injection pipe (188). The merged refrigerant flows into the second suction pipe (156) and is sucked into the second compressor (152) (see "4" in FIGS. 10 and 11).

[0229] Refrigerant compressed in the second compressor (152) (see "5" in FIGS. 10 and 11) is discharged into the second discharge pipe (154). The compression and cooling operations described above are alternately performed in order to make compression strokes of the two-stage compressor (150) approach those of isothermal compression to reduce compression power necessary for the two-stage compressor (150). At this time, the oil separator (174) of the second discharge pipe (154) separates lubricating oil from gas refrigerant flowing in the second discharge pipe (154). The separated lubricating oil is sent from the oil outflow pipe (171) to the first suction pipe (155). Refrigerant flowing in the second discharge pipe (154) passes through the second four-way valve (176) and flows into the outdoor heat exchanger (162). In the outdoor heat exchanger (162), refrigerant dissipates heat to the outdoor air to be cooled. Refrigerant cooled in the outdoor heat exchanger (162) flows into the second refrigerant pipe (182). Refrigerant flowing in the second refrigerant pipe (182) passes through the check valve (CV5) and flows into the inflow pipe (179).

[0230] Part of refrigerant flowing in the inflow pipe (179) (see "6" in FIGS. 10 and 11) flows into the first branch pipe (177). The pressure of refrigerant flowing in the first branch pipe (177) is reduced in the second expansion valve (202). Refrigerant whose pressure has been reduced in the second expansion valve (202) (see "7" in FIGS. 10 and 11) flows into the low-pressure channel (191b) of the first subcooling heat exchanger (191). On the other hand, the other part of refrigerant flowing in the inflow pipe (179) flows into the high-pressure channel (191a) of the first subcooling heat exchanger (191) (see "6" in FIGS. 10 and 11). In the first subcooling heat exchanger (191), heat exchange is performed between refrigerant flowing in the high-pressure channel (191a) and refrigerant flowing in the low-pressure channel (191b) to subcool refrigerant flowing in the high-pressure channel (191a).

[0231] Refrigerant that has flown out of the high-pressure channel (191a) of the first subcooling heat exchanger (191) flows in the inflow pipe (179) again, and refrigerant that has flown out of the low-pressure channel (191b) of the first subcooling heat exchanger (191) flows into the injection pipe (188). Refrigerant flowing in the injection pipe (188) (see "8" in FIGS. 10 and 11) flows into the first refrigerant pipe (181) and merges with re-

frigerant in the first refrigerant pipe (181) (see "4" in FIGS. 10 and 11). That is, refrigerant that has flown into the injection pipe (188) is injected toward a suction side of the second compressor (152).

[0232] Refrigerant that has flown out of the high-pressure channel (191a) of the first subcooling heat exchanger (191) flows in the inflow pipe (179) again (see "9" in FIGS. 1 and 2), and part of this refrigerant flows into the expander (193). The expander (193) expands the inflow refrigerant (see "9" to "11" in FIGS. 10 and 11), and sends the expanded refrigerant back to the inflow pipe (179). On the other hand, the other part of refrigerant that has flown out of the high-pressure channel (191a) of the first subcooling heat exchanger (191) branches off into the bypass pipe (183). Refrigerant flowing in the bypass pipe (183) is subjected to pressure reduction in the first expansion valve (201) (see "9" to "10" in FIGS. 10 and 11) and returns back to the inflow pipe (179). Refrigerant that has flown out of the expander (193) and refrigerant that has flown out of the bypass pipe (183) merge together in the inflow pipe (179) (see "12" in FIGS. 10 and 11) and flow into the gas-liquid separator (194). The gas-liquid separator (194) separates the inflow refrigerant into gas refrigerant (see "15" in FIGS. 10 and 11) and liquid refrigerant (see "13" in FIGS. 10 and 11).

[0233] The liquid refrigerant (see "13" in FIGS. 10 and 11) that has flown out of the gas-liquid separator (194) flows in the inflow pipe (179), and part of this refrigerant flows into the second branch pipe (178). On the other hand, the other part of refrigerant flowing in the inflow pipe (179) flows into the high-pressure channel (192a) of the second subcooling heat exchanger (192).

[0234] Refrigerant (see "15" in FIGS. 10 and 11) that has flown out of the gas-liquid separator (194) flows in the second outflow pipe (184), is subjected to pressure reduction in the fourth expansion valve (204) (see "18" in FIGS. 10 and 11), and flows into the second branch pipe (178). The pressure of refrigerant flowing in the second branch pipe (178) is reduced in the third expansion valve (203). The pressure-reduced refrigerant (see "17" in FIGS. 10 and 11) in the third expansion valve (203) merges with refrigerant flowing in the second outflow pipe (184).

[0235] The merged refrigerant flows into the low-pressure channel (192b) of the second subcooling heat exchanger (192). In the second subcooling heat exchanger (192), heat exchange is performed between refrigerant flowing in the high-pressure channel (192a) and refrigerant flowing in the low-pressure channel (192b) to subcool the liquid refrigerant flowing in the high-pressure channel (192a).

[0236] The liquid refrigerant that has flown out of the high-pressure channel (192a) of the second subcooling heat exchanger (192) (see "14" in FIGS. 10 and 11) flows in the first outflow pipe (180) again, passes through the check valve (CV7) of the bridge circuit (172), and flows into the liquid-side communication pipe (147). On the other hand, refrigerant that has flown out of the low-pressure

channel (192b) of the second subcooling heat exchanger (192) flows in the return pipe (185). Refrigerant that has flown out of the return pipe (185) merges with refrigerant that has flown out of the connection pipe (186). The merged refrigerant flows into a suction side of the first compressor (151).

[0237] Part of liquid refrigerant flowing in the liquid-side communication pipe (147) branches off, and is subjected to pressure reduction in the first indoor expansion valve (206). The pressure-reduced refrigerant (see "16a" in FIGS. 10 and 11) flows into the first indoor heat exchanger (211). In the first indoor heat exchanger (211), liquid refrigerant absorbs heat from indoor air and evaporates. The evaporated gas refrigerant flows into the gas-side communication pipe (146).

[0238] The pressure of the other part of liquid refrigerant flowing in the liquid-side communication pipe (147) is reduced in the second indoor expansion valve (207). The pressure-reduced refrigerant (see "16b" in FIGS. 10 and 11) flows into the second indoor heat exchanger (212). In the second indoor heat exchanger (212), liquid refrigerant absorbs heat from indoor air and evaporates. The evaporated gas refrigerant flows into the gas-side communication pipe (146).

[0239] In the gas-side communication pipe (146), refrigerant that has flown out of the first indoor heat exchanger (211) and refrigerant that has flown out of the second indoor heat exchanger (212) merge together. Refrigerant flowing in the gas-side communication pipe (146) passes through the second four-way valve (176) and flows into the connection pipe (186). Refrigerant flowing in the connection pipe (186) merges with refrigerant flowing in the return pipe (185) and is sucked into the first suction pipe (155). Refrigerant flowing in the first suction pipe (155) (see "1" in FIGS. 10 and 11) is compressed in the first compressor (151) of the two-stage compressor (150) again.

-Heating Operation-

[0240] Heating operation of the air conditioner (140) will now be described with reference to FIG. 13. In FIG. 13, a refrigerant flow in this heating operation is represented by arrows of broken line. In the heating operation, the indoor heat exchangers (211, 212) operate as heat dissipators, and the intermediate heat exchanger (161) and the outdoor heat exchanger (162) operate as evaporators, thereby performing a two-stage compression supercritical refrigeration cycle.

[0241] In the heating operation, all the four-way valves (175, 176) are set in the second states, and the two-stage compressor (150) is driven. When the two-stage compressor (150) is driven, refrigerant is compressed in the compressors (151, 152). Refrigerant compressed in the first compressor (151) is discharged to the first discharge pipe (153). The oil separator (174) of the first discharge pipe (153) separates lubricating oil from gas refrigerant flowing in the first discharge pipe (153). The separated

lubricating oil is sent from the oil outflow pipe (171) to the second suction pipe (156). Refrigerant flowing in the first discharge pipe (153) passes through the first four-way valve (175) and is sucked into the second compressor (152). Refrigerant is further compressed in the second compressor (152). In this manner, unlike the cooling operation, two-stage compression is performed without cooling in the heating operation. In this heating operation, the temperature of refrigerant discharged from the two-stage compressor (150) does not decrease, unlike the case of performing two-stage compression with cooling. As a result, the heating operation shows a larger heating capacity than that in the case of two-stage compression with cooling.

[0242] Refrigerant discharged from the second compressor (152) passes through the second four-way valve (176) and is sent to the first and second indoor heat exchangers (211, 212). In the first and second indoor heat exchangers (211, 212), refrigerant dissipates heat to the indoor air to be cooled. Refrigerant cooled in the indoor heat exchangers (211, 212) is subjected to pressure reduction in the first and second indoor expansion valves (206, 207) and then sent to the bridge circuit (172). This refrigerant passes through the check valve (CV6) and flows into the inflow pipe (179).

[0243] Part of refrigerant flowing in the inflow pipe (179) flows into the first branch pipe (177). The pressure of refrigerant flowing in the first branch pipe (177) is reduced in the second expansion valve (202). Refrigerant whose pressure has been reduced in the second expansion valve (202) flows into the low-pressure channel (191b) of the first subcooling heat exchanger (191). On the other hand, the other part of refrigerant flowing in the inflow pipe (179) flows into the high-pressure channel (191a) of the first subcooling heat exchanger (191). In the first subcooling heat exchanger (191), heat exchange is performed between refrigerant flowing in the high-pressure channel (191a) and refrigerant flowing in the low-pressure channel (191b) to subcool refrigerant flowing in the high-pressure channel (191a).

[0244] Refrigerant that has flown out of the high-pressure channel (191a) of the first subcooling heat exchanger (191) flows in the inflow pipe (179) again, and refrigerant that has flown out of the low-pressure channel (191b) of the first subcooling heat exchanger (191) flows into the injection pipe (188). Refrigerant flowing in the injection pipe (188) flows into the first refrigerant pipe (181) and merges with refrigerant in the first refrigerant pipe (181). That is, refrigerant that has flown into the injection pipe (188) is injected toward a suction side of the second compressor (152).

[0245] Refrigerant that has flown out of the high-pressure channel (191a) of the first subcooling heat exchanger (191) flows in the inflow pipe (179) again, and part of refrigerant flows into the expander (193). The expander (193) expands the inflow refrigerant, and sends the expanded refrigerant back to the inflow pipe (179). On the other hand, the other part of refrigerant that has flown

out of the high-pressure channel (191a) of the first sub-cooling heat exchanger (191) branches off into the bypass pipe (183). Refrigerant flowing in the bypass pipe (183) is subjected to pressure reduction in the first expansion valve (201) and returns back to the inflow pipe (179). Refrigerant that has flown out of the expander (193) and refrigerant that has flown out of the bypass pipe (183) merge together in the inflow pipe (179) and flow into the gas-liquid separator (194). The gas-liquid separator (194) separates the inflow refrigerant into gas refrigerant and liquid refrigerant.

[0246] The liquid refrigerant that has flown out of the gas-liquid separator (194) flows in the first outflow pipe (180), and part of this refrigerant flows into the second branch pipe (178). On the other hand, the other part of refrigerant flowing in the inflow pipe (179) flows into the high-pressure channel (192a) of the second subcooling heat exchanger (192).

[0247] Gas refrigerant that has flown out of the gas-liquid separator (194) flows in the second outflow pipe (184), is subjected to pressure reduction in the fourth expansion valve (204), and flows into the second branch pipe (178). The pressure of refrigerant flowing in the second branch pipe (178) is reduced in the third expansion valve (203). Refrigerant whose pressure has been reduced in the third expansion valve (203) merges with refrigerant in the second outflow pipe (184).

[0248] The merged refrigerant flows into the low-pressure channel (192b) of the second subcooling heat exchanger (192). In the second subcooling heat exchanger (192), heat exchange is performed between refrigerant flowing in the high-pressure channel (192a) and refrigerant flowing in the low-pressure channel (192b) to sub-cool the liquid refrigerant flowing in the high-pressure channel (192a).

[0249] The liquid refrigerant that has flown out of the high-pressure channel (192a) of the second subcooling heat exchanger (192) flows in the first outflow pipe (180) again, is subjected to pressure reduction in the fifth expansion valve (205) of the bridge circuit (172), and then is sent to the distributor (173). Refrigerant distributed in the distributor (173) passes through the capillary tube (170) and the check valves (CV2, CV3) and flows into the intermediate heat exchanger (161) and the outdoor heat exchanger (162). In the intermediate heat exchanger (161) the outdoor heat exchanger (162), liquid refrigerant absorbs heat from the outdoor air and evaporates. Refrigerant that has flown out of the intermediate heat exchanger (161) passes through the first four-way valve (175), flows into the junction pipe (187), and then flows into the connection pipe (186).

[0250] Refrigerant that has flown out of the outdoor heat exchanger (162) passes through the second four-way valve (176), flows into the connection pipe (186), and merges with refrigerant that has flown out of the intermediate heat exchanger (161). The merged refrigerant flows in the connection pipe (186) and merges with refrigerant flowing in the return pipe (185). The merged

refrigerant flows into the first suction pipe (155). Refrigerant flowing in the first suction pipe (155) is compressed again in the first compressor (151) of the two-stage compressor (150).

-Outdoor Unit-

[0251] As illustrated in FIG. 12, air taken into the outdoor casing (163) from the air inlet (164) is subjected to heat exchange in the intermediate heat exchanger (161) and the outdoor heat exchanger (162), flows to upper space in the outdoor casing (163), and is blown out through the air outlet (124).

[0252] The outdoor unit (3) is a so-called upward blow type in which air is sucked through the air inlet (164) in the side surface and is blown upward from the air outlet (124). Thus, the airflow velocity is higher in an upper portion of the air inlet (164) than in a lower portion of the air inlet (164). As illustrated in FIG. 11, the pressure of refrigerant flowing in the intermediate heat exchanger (161) is lower than that of refrigerant flowing in the outdoor heat exchanger (162), and thus, the density of refrigerant flowing in the intermediate heat exchanger (161) is lower than that of refrigerant flowing in the outdoor heat exchanger (162). In view of this, when the mass flow rate of refrigerant flowing in the intermediate heat exchanger (161) is substantially equal to that of refrigerant flowing in the outdoor heat exchanger (162), the volume flow rate of refrigerant in the intermediate heat exchanger (161) is higher than that of refrigerant flowing in the outdoor heat exchanger (162). Even when the number of refrigerant paths in the intermediate heat exchanger (161) is equal to that in the outdoor heat exchanger (162), the flow velocity of refrigerant flowing in the intermediate heat exchanger (161) is higher than that of refrigerant flowing in the outdoor heat exchanger (162), and thus, a pressure loss of refrigerant in the intermediate heat exchanger (161) is larger than that in the outdoor heat exchanger (162).

[0253] The outdoor heat exchanger (162) located in an upper portion of the outdoor casing (163) where the airflow velocity is high, has a high heat exchange efficiency, and can be reduced in size. On the other hand, the intermediate heat exchanger (161) located in a lower portion of the outdoor casing (163) where the airflow velocity is low, has a low heat exchange efficiency. Thus, to increase the amount of heat exchange, the intermediate heat exchanger (161) needs to be larger than that in a case where this exchanger is located in an upper portion.

[0254] For this reason, the size of the outdoor heat exchange unit (160) does not increase even when the size of the outdoor heat exchanger (162) and the intermediate heat exchanger (161) increases.

[0255] An increase in size of the intermediate heat exchanger (161) increases the number of refrigerant paths in the intermediate heat exchanger (161). Thus, in the intermediate heat exchanger (161), the flow velocity of refrigerant in each refrigerant path decreases, resulting

in a decrease in pressure loss of refrigerant passing through the refrigerant path. The flow velocity of refrigerant flowing in the intermediate heat exchanger (161) is originally high, and thus, a decrease in flow velocity due to an increase in the number of refrigerant paths relatively greatly reduces the pressure loss.

[0256] On the other hand, size reduction of the outdoor heat exchanger (162) reduces the number of refrigerant paths in the outdoor heat exchanger (162). The reduction of the number of refrigerant paths increases the flow velocity of refrigerant in each refrigerant path to increase the pressure loss of refrigerant passing through the refrigerant path.

[0257] However, since the flow velocity of refrigerant flowing in the outdoor heat exchanger (162) is originally low, a certain degree of increase in flow velocity due to the reduction of the number of refrigerant paths relatively slightly increases the pressure loss arising from the increase in flow velocity.

[0258] Thus, by disposing the outdoor heat exchanger (162) above the intermediate heat exchanger (161), the pressure loss of refrigerant in the intermediate heat exchanger (161) can be reduced with a reduced degree of increase in size of the outdoor heat exchange unit (160).

-Advantages of Third Embodiment-

[0259] In the third embodiment, since the outdoor heat exchanger (162) is located in an upper portion of the outdoor casing (163) where the airflow velocity is high, the heat exchange efficiency of the outdoor heat exchanger (162) can be increased. In addition, since the outdoor heat exchanger (162) having a low flow velocity of refrigerant is located in an upper portion of the outdoor casing (163) where the airflow velocity is high, the size of the outdoor heat exchanger (162) can be reduced without an increase in pressure loss of refrigerant.

[0260] On the other hand, the intermediate heat exchanger (161) is located in a lower portion of the outdoor casing (163) where the airflow velocity is low to increase the number of refrigerant paths, thereby ensuring prevention of an increase in pressure loss of refrigerant in the intermediate heat exchanger (161).

[0261] In the above-described configuration, the outdoor heat exchanger (162) where a pressure loss of refrigerant does not easily increase is located in the upper portion for size reduction, thereby reducing a pressure loss of refrigerant in the intermediate heat exchanger (161) with reduced size increase in the outdoor heat exchange unit (160). The other configurations, operations, and advantages are similar to those of the first and second embodiments.

-Variation of Third Embodiment-

[0262] A variation of the third embodiment of the present invention will now be described with reference to the drawings. An air conditioner according to this variation

is different in configuration of heat exchangers from that of the air conditioner (140) of the third embodiment. In this variation, only part of the configuration different from that of the third embodiment is described.

[0263] Specifically, as illustrated in FIGS. 14 and 15, the outdoor unit (142) includes the outdoor casing (163). The outdoor casing (163) is in the shape of a vertically elongated rectangular box, and has the air inlet (164) in a lower portion of the front surface and the air outlet (165) in an upper surface thereof. In the outdoor casing (163), the outdoor heat exchange unit (160) and the outdoor fan (166) are placed. The outdoor heat exchange unit (160) includes the outdoor heat exchanger (162) and the intermediate heat exchanger (161).

[0264] The outdoor fan (166) is a fan for sending air taken in the outdoor casing (163) to the heat exchangers (161, 162), and is a so-called sirocco fan. The outdoor fan (166) is located above the heat exchangers (161, 162) in the outdoor casing (163). The outdoor fan (166) causes air sucked through the air inlet (164) to pass through the heat exchangers (161, 162) and then to flow to the outside through the air outlet (165).

[0265] As illustrated in FIG. 14, in the outdoor casing (163), the intermediate heat exchanger (161) and the outdoor heat exchanger (162) are stacked in this order from the bottom.

-Configuration of Heat Exchanger-

[0266] As illustrated in FIGS. 14 and 15, each of the heat exchangers (161, 162) of this variation includes a first header concentrated pipe (240), a second header concentrated pipe (250), a large number of flat tubes (231), and a large number of fins (235). The first header concentrated pipe (240), the second header concentrated pipe (250), the flat tubes (231), and the fins (235) are made of an aluminium alloy, and brazed to one another.

[0267] The first header concentrated pipe (240) and the second header concentrated pipe (250) are hollow slender tubes. In each of the heat exchangers (161, 162), the first header concentrated pipe (240) stands at an end of the flat tubes (231) and the second header concentrated pipe (250) stands at the other end of the flat tubes (231). That is, each of the first header concentrated pipe (240) and the second header concentrated pipe (250) extends in the up and down direction such that the axis thereof extends vertically.

[0268] The first header concentrated pipe (240) has its upper and lower ends closed, and has its lower end connected to a first connection pipe (240b). The first connection pipe (240b) communicates with a liquid side of the refrigerant circuit (143). That is, the first header concentrated pipe (240) constitutes a liquid-side header in which liquid-containing refrigerant (liquid single-phase refrigerant or gas-liquid two-phase refrigerant) flows. The second header concentrated pipe (250) has its upper and lower ends closed, and a second connection pipe (250b) is connected to an upper portion of the second header

concentrated pipe (250). The second connection pipe (250b) is connected to a gas side of the refrigerant circuit (143). That is, the second header concentrated pipe (250) constitutes a gas-side header in which a gas refrigerant flows.

[0269] Each of the heat exchangers (161, 162) of this variation includes a plurality of flat tubes (231). Each of the flat tubes (231) is a heat exchanger tube whose shape in cross section perpendicular to the axis thereof is a flat ellipse or a rectangle. In each of the heat exchangers (161, 162), the flat tubes (231) extend in the transverse direction with flat side surfaces thereof facing one another. The flat tubes (231) are arranged side by side at predetermined intervals in the up and down direction. An end of each of the flat tubes (231) is placed in the first header concentrated pipe (240), and the other end thereof is placed in the second header concentrated pipe (250).

[0270] As illustrated in FIG. 15, each of the flat tubes (231) includes a plurality of refrigerant paths (232). The refrigerant paths (232) are passages extending in the direction in which the flat tubes (231) extend. In each of the flat tubes (231), the refrigerant paths (232) are arranged in a row along a transverse direction perpendicular to the direction in which the flat tubes (231) extend. Each of the refrigerant paths (232) of the flat tubes (231) has its one end communicate with the inner space of the first header concentrated pipe (240) and the other end communicate with the inner space of the second header concentrated pipe (250). The refrigerant paths (232) constitute fluid passages of the present invention.

[0271] Each of the fins (235) is a corrugated fin that bends up and down and is located between ones of the flat tubes (231) that are adjacent to each other in the up and down direction. Each of the fins (235) includes a plurality of heat transmission parts (236) arranged in the direction in which the flat tubes (231) extend. Each of the heat transmission parts (236) has a plate shape extending from one of the adjacent flat tubes (231) to the other. The heat transmission parts (236) includes a plurality of louvers (237) that bend out from the heat transmission parts (236). The louvers (237) extend in the up and down direction to be substantially in parallel with front edges (i.e., windward ends) of the heat transmission parts (236). In the heat transmission parts (236), the louvers (237) are arranged side by side from the windward side to the leeward side.

[0272] The leeward ends of the heat transmission parts (236) are joined to the projecting plate parts (238) further projecting leeward. Each of the projecting plate parts (238) is in the shape of a trapezoidal plate protruding from the heat transmission parts (236) in the up and down direction. In each of the heat exchangers (161, 162), adjacent ones of the projecting plate parts (238, 238) in the up and down direction overlap each other in the thickness direction, and are substantially in contact with each other.

[0273] The number of each of the flat tubes (231) and the fins (235, 235) are two or more. The fins (235, 235)

are disposed between the flat tubes (231) arranged in the up and down direction. In the intermediate heat exchangers (41, 42, 43, 161), air passes between the flat tubes (231) arranged in the up and down direction, and exchanges heat with fluid flowing in the fluid passages (232) in the flat tubes (231).

[0274] The intermediate heat exchanger (161) has a small stack loss (resistance of ventilation), and thus, has a high velocity of air flowing therein. In addition, the flat tubes (231) increase the heat transfer area of refrigerant, and thus, the heat exchange efficiency of refrigerant increases. Accordingly, the coefficient of performance (COP) of the refrigeration system is enhanced. Since the flat tubes (231) have pipe diameters smaller than those of conventional heat exchanger tubes, the flow velocity in the tubes increases. Thus, refrigerant passing through the refrigerant paths (232) has a large pressure loss.

[0275] However, in the intermediate heat exchanger (161) located in the lower portion of the outdoor casing (163) where the airflow velocity is low has a low heat exchange efficiency. Thus, to increase the amount of heat exchange, the intermediate heat exchanger (161) needs to be larger than that in a case where this exchanger is located in an upper portion. The larger intermediate heat exchanger (161) includes a larger number of the refrigerant paths (232), and thus, the flow velocity of refrigerant in the refrigerant paths (232) of the intermediate heat exchanger (161) decreases, thereby reducing the pressure loss of refrigerant occurring when refrigerant passes through the refrigerant paths (232). Consequently, reduction in pipe diameter of the flat tubes (231) relatively reduces the degree of increase in pressure loss of refrigerant.

[0276] The outdoor heat exchanger (162) has a small stack loss, and thus, has a high velocity of air flowing therein. In addition, the flat tubes (231) increase the heat transfer area of refrigerant, and thus, the heat exchange efficiency of refrigerant increases. Accordingly, the coefficient of performance (COP) of the refrigeration system is enhanced. Since the flat tubes (231) have pipe diameters smaller than those of conventional heat exchanger tubes, the flow velocity in the tubes increases. Thus, refrigerant passing through the refrigerant paths (232) has a large pressure loss.

[0277] However, since the flow velocity of refrigerant flowing in the outdoor heat exchanger (162) is originally low, even when the flow velocity increases to some degree due to a reduction in pipe diameter of the flat tubes (231), the amount of increase in pressure loss due to this increase is relatively small.

[0278] In this variation, since the intermediate heat exchanger (161) and the outdoor heat exchanger (162) include the flat tubes (231) each including the refrigerant paths (232) and the fins (235, 235), the stack loss (resistance of ventilation) can be reduced. As a result, the velocity of air flowing in the air passages increases. In addition, the flat tubes (231) increase the heat transfer area of refrigerant, the heat exchange efficiency of re-

frigerant increases. As a result, the coefficient of performance (COP) of the air conditioner can be enhanced. The other configurations, operations, and advantages are similar to those of the third embodiment.

<Reference Example>

[0279] Reference example will now be described. As illustrated in FIGS. 18 and 19, in this reference example, the airflow velocity distribution in the indoor unit is uniform in the up and down direction.

[0280] An outdoor heat exchange unit (40) of this reference example is configured such that an outdoor heat exchanger (44), a first intermediate heat exchanger (41), a second intermediate heat exchanger (42), and a third intermediate heat exchanger (43) are stacked in this order from the bottom. The first intermediate heat exchanger (41) and the second intermediate heat exchanger (42) may be replaced with each other in the up and down direction.

[0281] The heat exchanger size increases in the order of the outdoor heat exchanger (44), the third intermediate heat exchanger (43), the first intermediate heat exchanger (41), and the second intermediate heat exchanger (42).

[0282] The heat exchangers (41, 42, 43, 44) are so-called cross-fin type fin-and-tube heat exchangers. Each of the heat exchangers (41, 42, 43, 44) includes a plurality of heat exchanger tube groups (50) each including a plurality of heat exchanger tubes (52) and a plurality of U-shaped tubes, and also includes heat transmission fins (51).

[0283] The heat exchanger tube groups (50) are aligned in the up and down direction. In each of the heat exchanger tube groups (50), a plurality of heat exchanger tubes (52) are arranged such that three rows of heat exchanger tubes (52) each along an airflow direction are arranged side by side and each of the three rows includes two heat exchanger tubes (52) aligned in the up and down direction. In addition, a first bank of tubes (53) is disposed at the left in FIG. 19 (i.e., the windward side), a second bank of tubes (54) is disposed at the middle in FIG. 19, and a third bank of tubes (55) is disposed at the right in FIG. 19 (i.e., the leeward side). That is, in each of the heat exchanger tube groups (50), the heat exchanger tubes (52) are disposed in two stages in each row.

<Other Embodiments>

[0284] The present invention may have the following configurations with respect to the first and second embodiments.

[0285] In the first and second embodiments, the four-stage compressor (20) is used. However, the present invention is not limited to this configuration, and two two-stage compressors may be provided.

[0286] In the first through fourth embodiments, the two-stage compression supercritical refrigeration cycle and

the four-stage compression supercritical refrigeration cycle are used. However, the present invention is not limited to this, and is applicable to a supercritical refrigeration cycle of a three-stage compressor or a refrigeration cycle of another type of multistage compressor, for example.

[0287] In the first and second embodiments, the heat exchanger is the fin-and-tube heat exchanger. However, the present invention is not limited to this type.

[0288] Specifically, as illustrated in 16, the outdoor unit (3) may include the outdoor casing (121). The outdoor casing (121) is in the shape of a vertically rectangular box, and has an air inlet (123) in a lower portion of the front surface and an air outlet (124) in an upper surface thereof. The outdoor heat exchange unit (40) and the outdoor fan (122) are placed in the outdoor casing (121). The outdoor heat exchange unit (40) includes the outdoor heat exchanger (44), the first intermediate heat exchanger (41), the second intermediate heat exchanger (42), and the third intermediate heat exchanger (43).

[0289] As illustrated in FIG. 16, in the outdoor casing (121), the first intermediate heat exchanger (41), the second intermediate heat exchanger (42), the third intermediate heat exchanger (43), and the outdoor heat exchanger (162) are stacked in this order from the bottom.

That is, the outdoor heat exchanger (162) is located above the first through third intermediate heat exchangers (41, 42, 43). In this configuration, the first intermediate heat exchanger (41) and the second intermediate heat exchanger (42) may be replaced with each other in the up and down direction.

-Configuration of Heat Exchanger-

[0290] As illustrated in FIGS. 16 and 17, each of the heat exchangers (41, 42, 43, 44) of this embodiment includes a first header concentrated pipe (240), a second header concentrated pipe (250), a large number of flat tubes (231), and a large number of fins (235). The first header concentrated pipe (240), the second header concentrated pipe (250), the flat tubes (231), and the fins (235) are made of an aluminium alloy, and brazed to one another.

[0291] The first header concentrated pipe (240) and the second header concentrated pipe (250) are hollow slender tubes. In each of the heat exchangers (41, 42, 43, 44), the first header concentrated pipe (240) stands at an end of the flat tubes (231) and the second header concentrated pipe (250) stands at the other end of the flat tubes (231). That is, each of the first header concentrated pipe (240) and the second header concentrated pipe (250) extends in the up and down direction such that the axis thereof extends vertically.

[0292] The first header concentrated pipe (240) has its upper and lower ends closed, and its lower end connected to a first connection pipe (240b). The first connection pipe (240b) communicates with a liquid side of the refrigerant circuit (10). That is, the first header concentrated pipe (240) constitutes a liquid-side header in which liquid-

containing refrigerant (liquid single-phase refrigerant or gas-liquid two-phase refrigerant) flows. The second header concentrated pipe (250) has its upper and lower ends closed, and a second connection pipe (250b) is connected to an upper portion of the second header concentrated pipe (250). The second connection pipe (250b) is connected to a gas side of the refrigerant circuit (10). That is, the second header concentrated pipe (250) constitutes a gas-side header in which a gas refrigerant flows.

[0293] Each of the heat exchangers (41, 42, 43, 44) of this embodiment includes a plurality of flat tubes (231). Each of the flat tubes (231) is a heat exchanger tube whose shape in cross section perpendicular to the axis thereof is a flat ellipse or a rectangle. In each of the heat exchangers (41, 42, 43, 44), the flat tubes (231) extend in the transverse direction with flat side surfaces thereof facing one another. The flat tubes (231) are arranged side by side at predetermined intervals in the up and down direction. An end of each of the flat tubes (231) is placed in the first header concentrated pipe (240), and the other end thereof is placed in the second header concentrated pipe (250).

[0294] As illustrated in FIG. 17, each of the flat tubes (231) includes a plurality of refrigerant paths (232). The refrigerant paths (232) are fluid passages of the present invention extending in the direction in which the flat tubes (231) extend. In each of the flat tubes (231), the refrigerant paths (232) are arranged in a row along a transverse direction perpendicular to the direction in which the flat tubes (231) extend. Each of the refrigerant paths (232) of the flat tubes (231) has its one end communicate with the inner space of the first header concentrated pipe (240) and the other end communicate with the inner space of the second header concentrated pipe (250).

[0295] Each of the fins (235) is a corrugated fin that bends up and down and is located between ones of the flat tubes (231) that are adjacent to each other in the up and down direction. Each of the fins (235) includes a plurality of heat transmission parts (236) arranged in the direction in which the flat tubes (231) extend. Each of the heat transmission parts (236) has a plate shape extending from one of the adjacent flat tubes (231) to the other. The heat transmission parts (236) includes a plurality of louvers (237) that bend out from the heat transmission parts (236). The louvers (237) extend in the up and down direction to be substantially in parallel with front edges (i.e., windward ends) of the heat transmission parts (236). In the heat transmission parts (236), the louvers (237) are arranged side by side from the windward side to the leeward side.

[0296] The leeward ends of the heat transmission parts (236) are joined to the projecting plate parts (238) further projecting leeward. Each of the projecting plate parts (238) is in the shape of a trapezoidal plate protruding from the heat transmission parts (236) in the up and down direction. In each of the heat exchangers (41, 42, 43, 44), adjacent ones of the projecting plate parts (238, 238) in

the up and down direction overlap each other in the thickness direction, and are substantially in contact with each other. The other configurations, operations, and advantages are similar to those of the variation of the third embodiment.

[0297] The foregoing embodiments are merely preferred examples in nature, and are not intended to limit the scope, applications, and use of the invention.

10 INDUSTRIAL APPLICABILITY

[0298] As described above, the present invention is useful for a refrigeration system that performs a multistage compression refrigeration cycle.

15 DESCRIPTION OF REFERENCE CHARACTERS

[0299]

20	21	first compressor
	22	second compressor
	23	third compressor
	24	fourth compressor
	41	first intermediate heat exchanger
25	42	second intermediate heat exchanger
	43	third intermediate heat exchanger
	44	outdoor heat exchanger
	121	outdoor casing
	123	air inlet
30	151	first compressor
	152	second compressor
	161	outdoor heat exchanger
	162	intermediate heat exchanger
	163	outdoor casing
35	164	air inlet
	231	flat tube
	232	refrigerant path
	235	fin

40 Claims

1. An outdoor unit of a refrigeration system, the outdoor unit comprising:

a multistage compressor (20, 150) including a plurality of serially connected compression mechanisms (21-24, 151, 152) in which refrigerant discharged from a low-stage one (21, 22, 23, 151) of the compression mechanisms is sucked and compressed in a high-stage one (22, 23, 24, 152) of the compression mechanisms; an intermediate heat exchanger (41, 42, 43, 161) located between adjacent two of the compression mechanisms (21, 22, 23, 24, 151, 152) and configured to cause refrigerant flowing from the low-stage compression mechanism (21, 22, 23, 151) to the high-stage compression mech-

- anism (22, 23, 24, 152) to exchange heat with outdoor air to be cooled;
 an outdoor heat exchanger (44, 162) configured to cause refrigerant discharged from the highest-stage compression mechanism (24, 152) to exchange heat with outdoor air; and
 a casing (121, 163) having a side surface in which an air suction port (123, 164) is provided and an upper surface in which an air outlet (124, 165) is provided, and housing the compression mechanisms (21-24, 151, 152), the intermediate heat exchanger (41, 42, 43, 161), and the outdoor heat exchanger (44, 162), wherein the intermediate heat exchanger (41, 42, 43, 161) and the outdoor heat exchanger (44, 162) are disposed to stand along the suction port (123, 164) of the casing (121, 163), and the outdoor heat exchanger (44, 162) is located above the intermediate heat exchanger (41, 42, 43, 161).
2. The outdoor unit of claim 1, wherein the multistage compressor (20) includes three or more compression mechanisms (21-24), the intermediate heat exchanger comprises a plurality of intermediate heat exchangers (41, 42, 43), and the highest-stage intermediate heat exchanger (43) is located above the other intermediate heat exchangers (41, 42) and below the outdoor heat exchanger (44).
3. The outdoor unit of claim 2, wherein the intermediate heat exchangers (41, 42, 43) are stacked from the bottom in the order of increasing pressure of inflow refrigerant.
4. The outdoor unit of claim 1, wherein the intermediate heat exchanger (41, 42, 43, 161) includes a plurality of flat tubes (231) which are arranged in an up and down direction with their side surfaces facing one another and each of which includes a plurality of fluid passage (232) extending in a tube length direction, and also includes a plurality of fins (235, 235) dividing space between adjacent ones of the flat tubes (231) into a plurality of air passages in which air flows.
5. The outdoor unit of claim 4, wherein the outdoor heat exchangers (44, 162) includes a plurality of flat tubes (231) which are arranged in the up and down direction with their side surfaces facing one another, and each of which includes a plurality of fluid passage (232) extending in a tube length direction, and also includes a plurality of fins (235, 235) dividing space between adjacent ones of the flat tubes (231) into a plurality of air passages in which air flows.

FIG.1

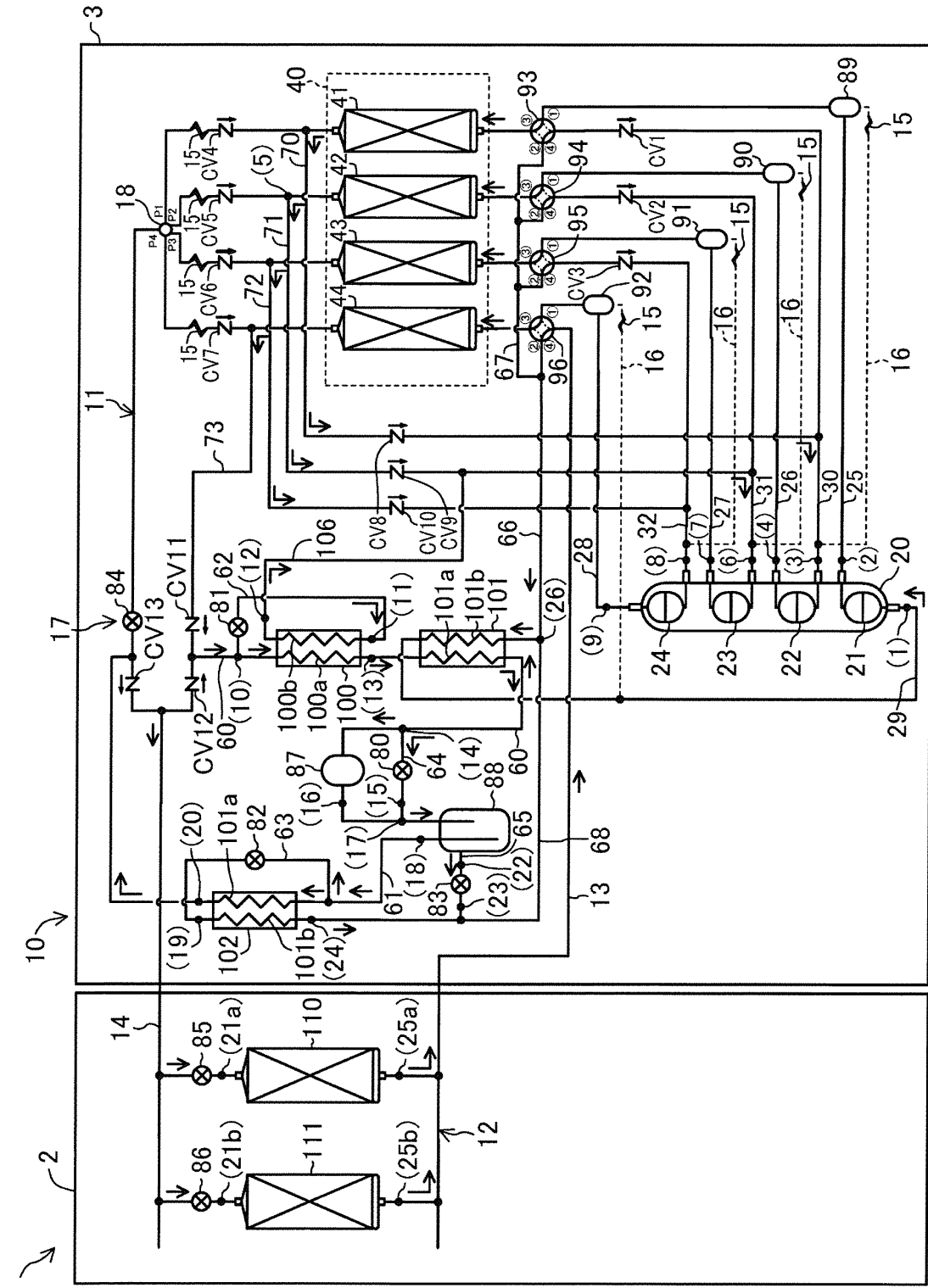


FIG.2

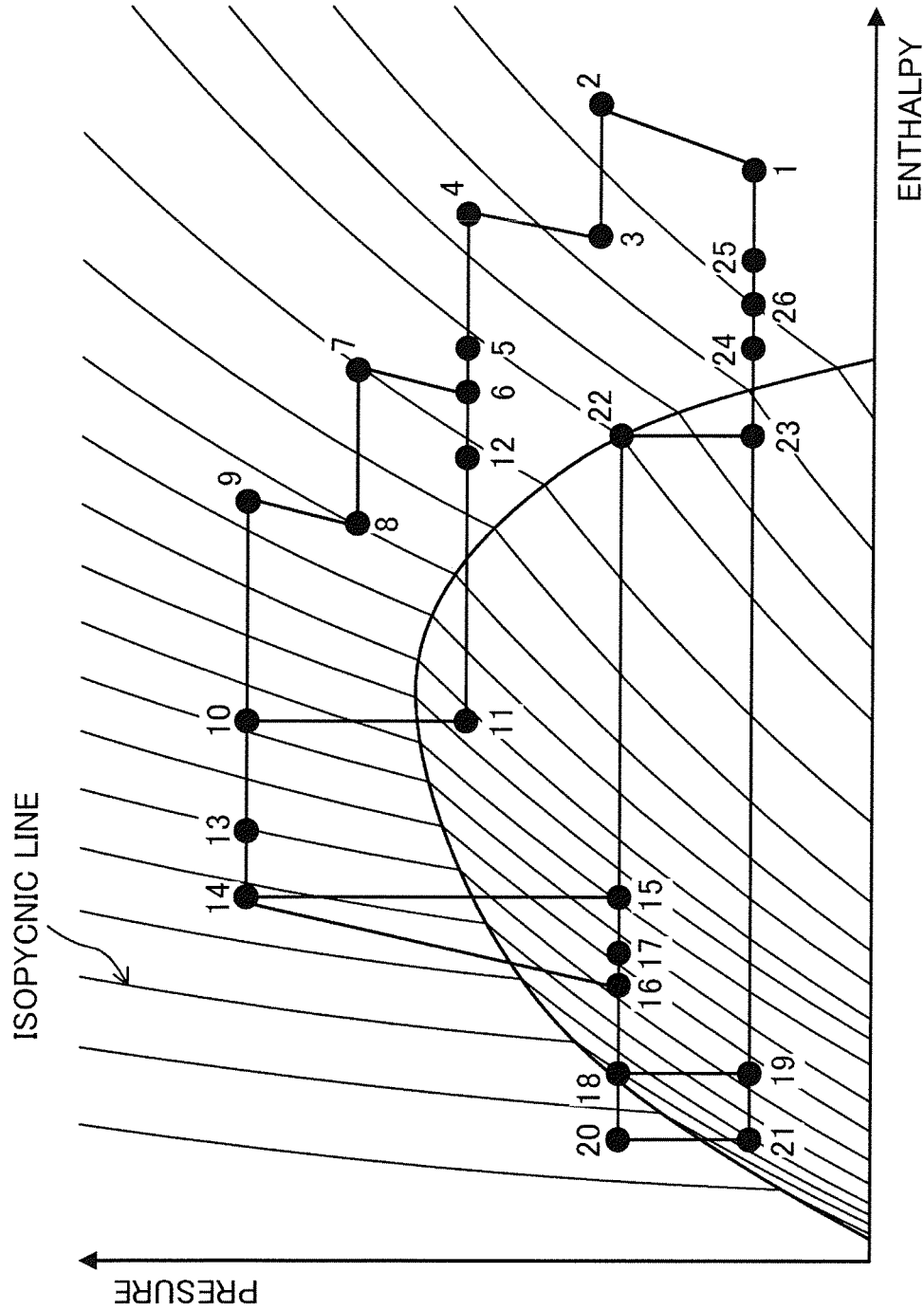


FIG.3

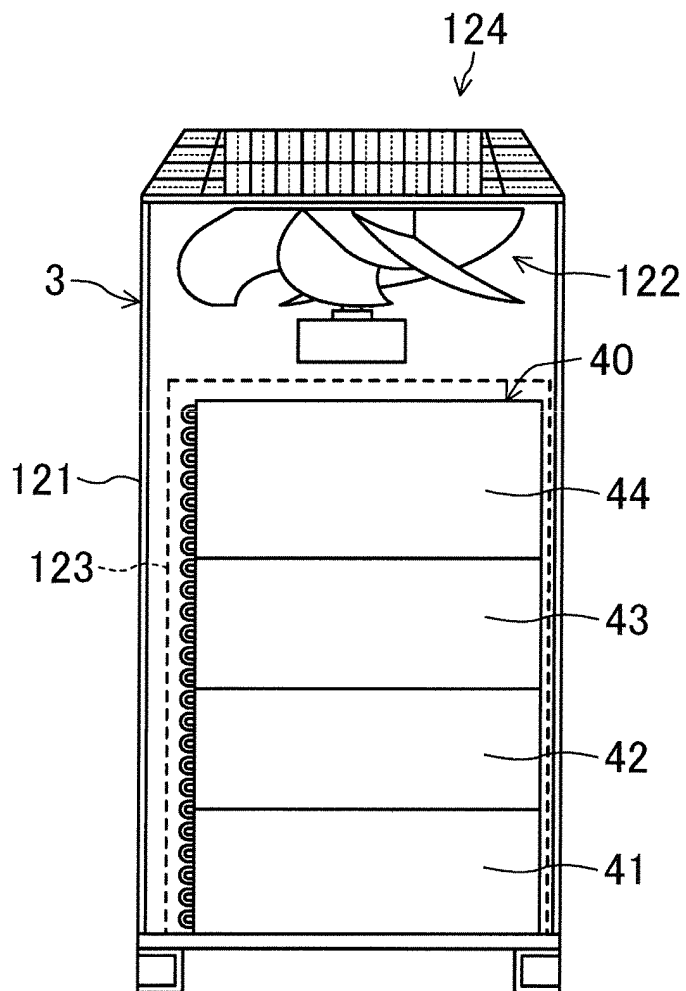


FIG.4

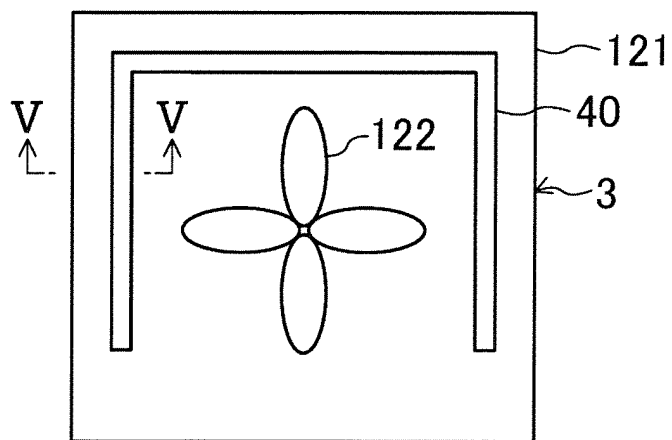


FIG.5

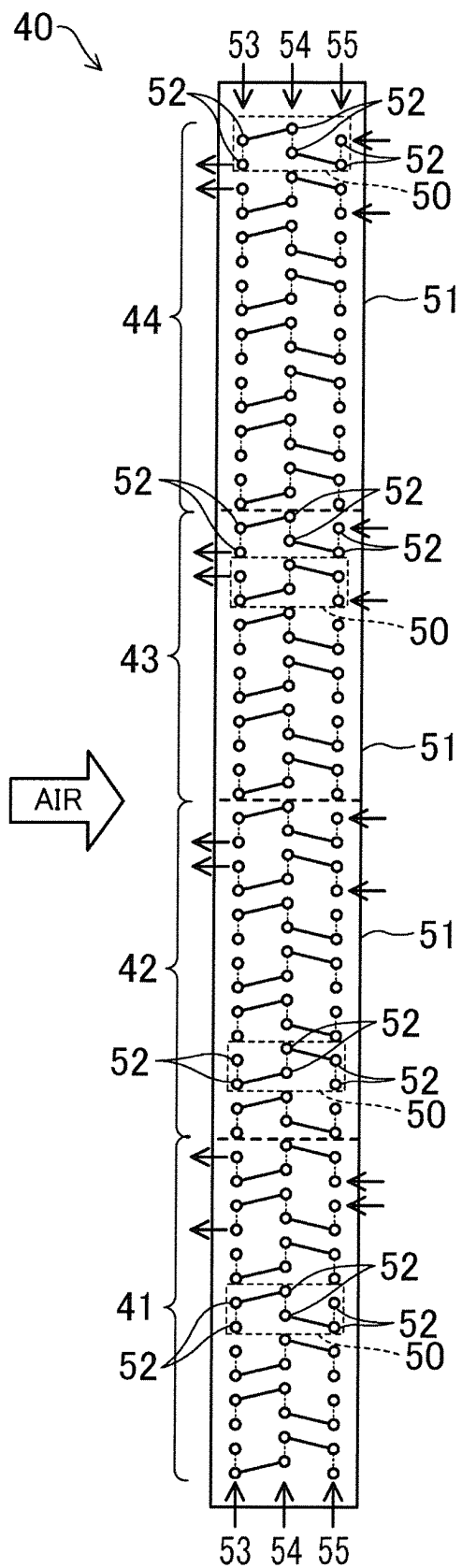


FIG.6

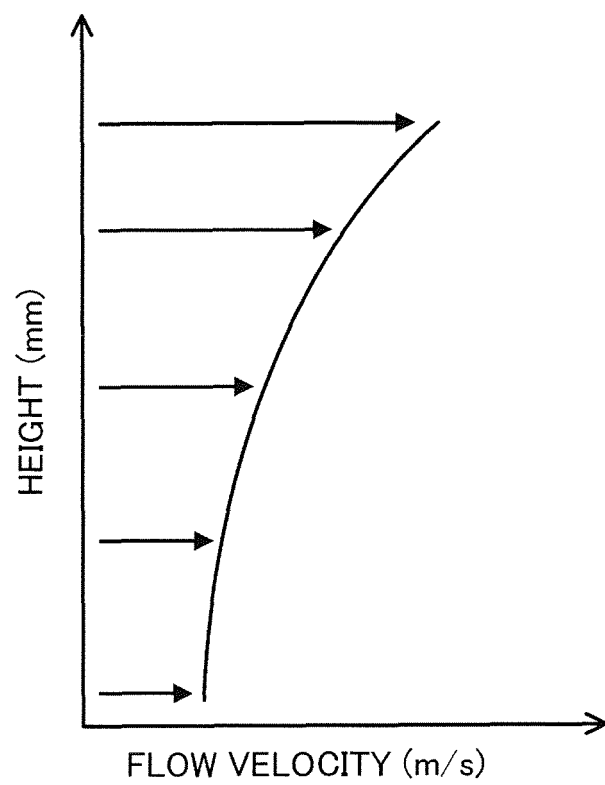


FIG. 7

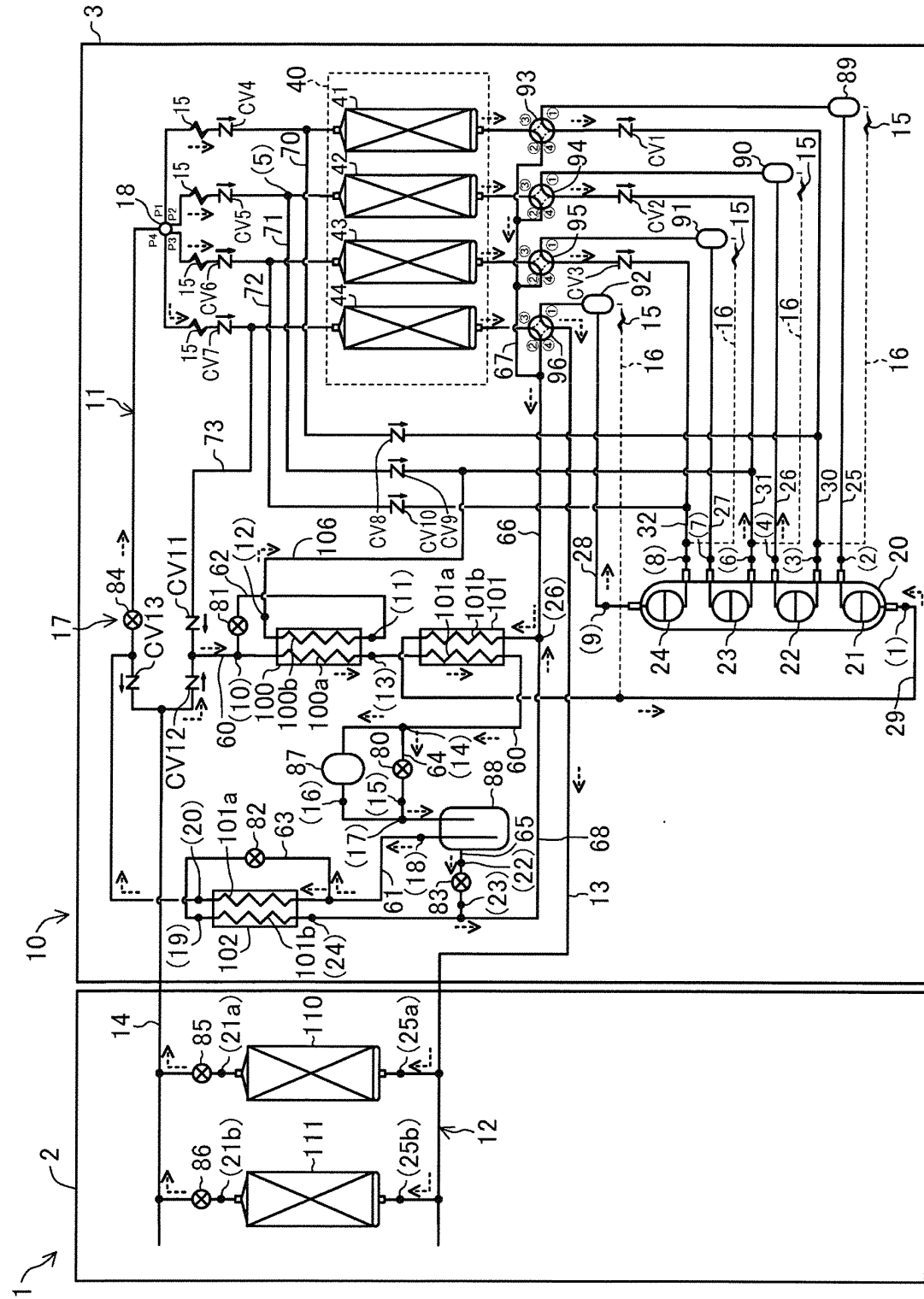


FIG.8

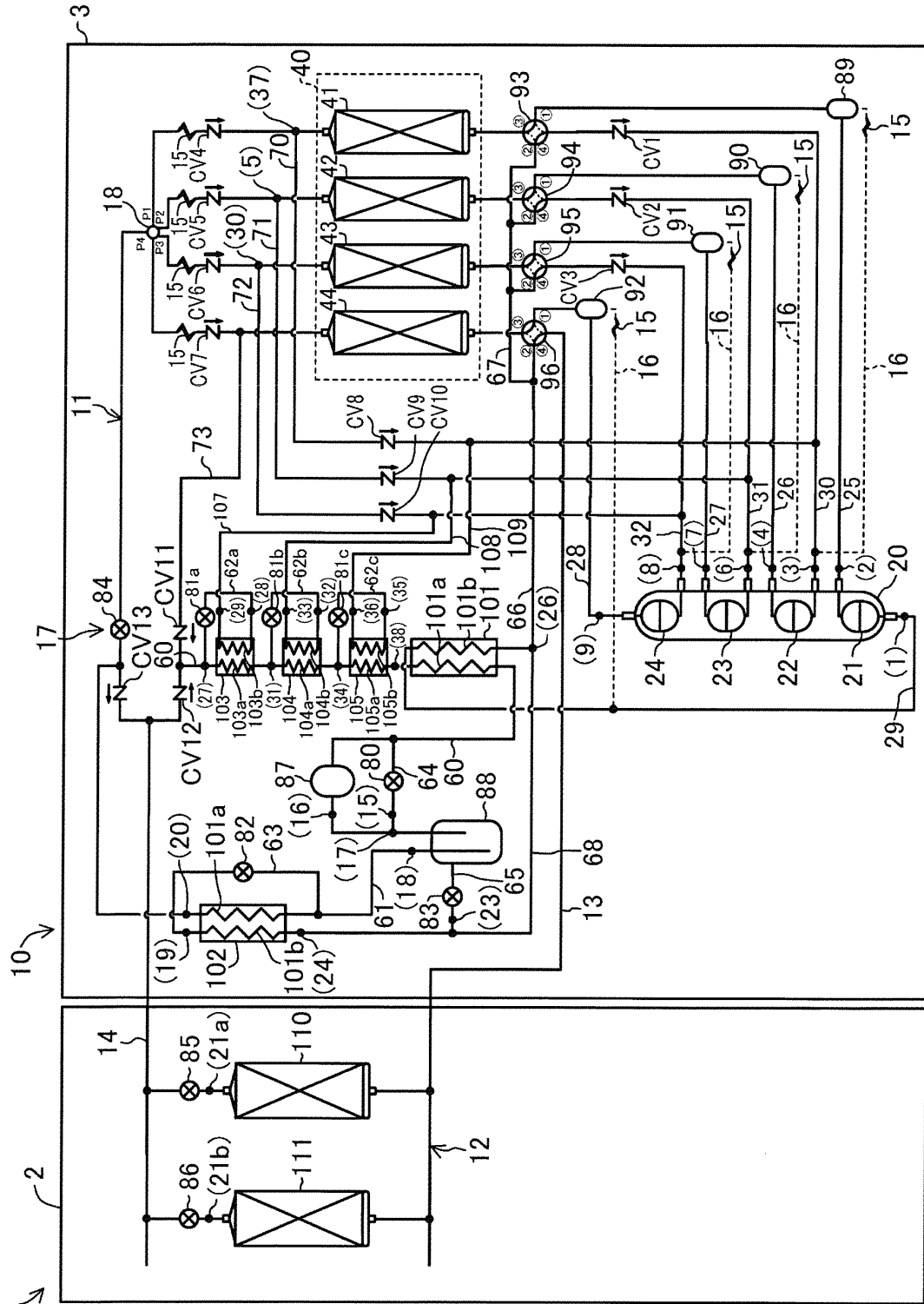


FIG.9

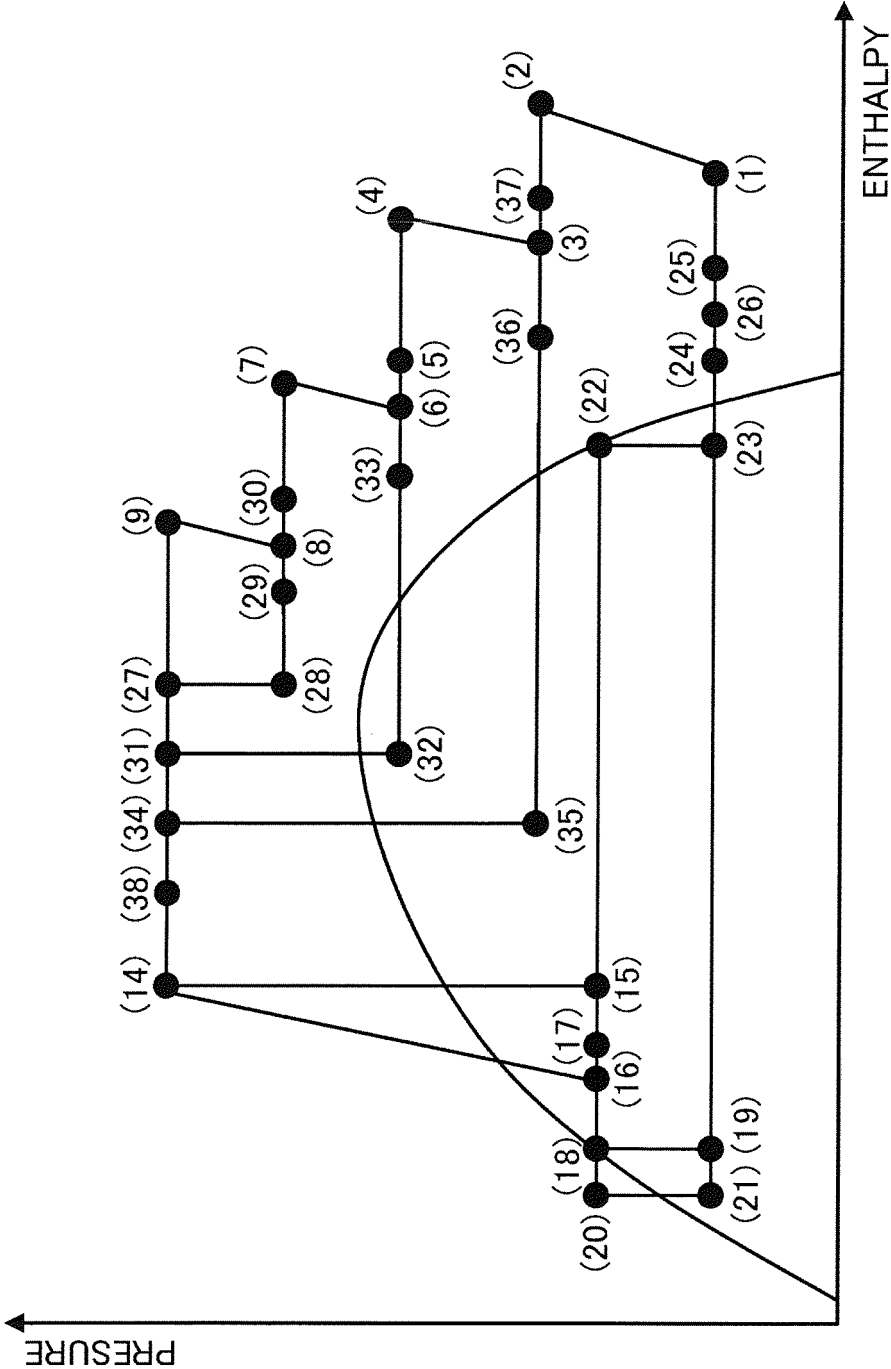


FIG.10

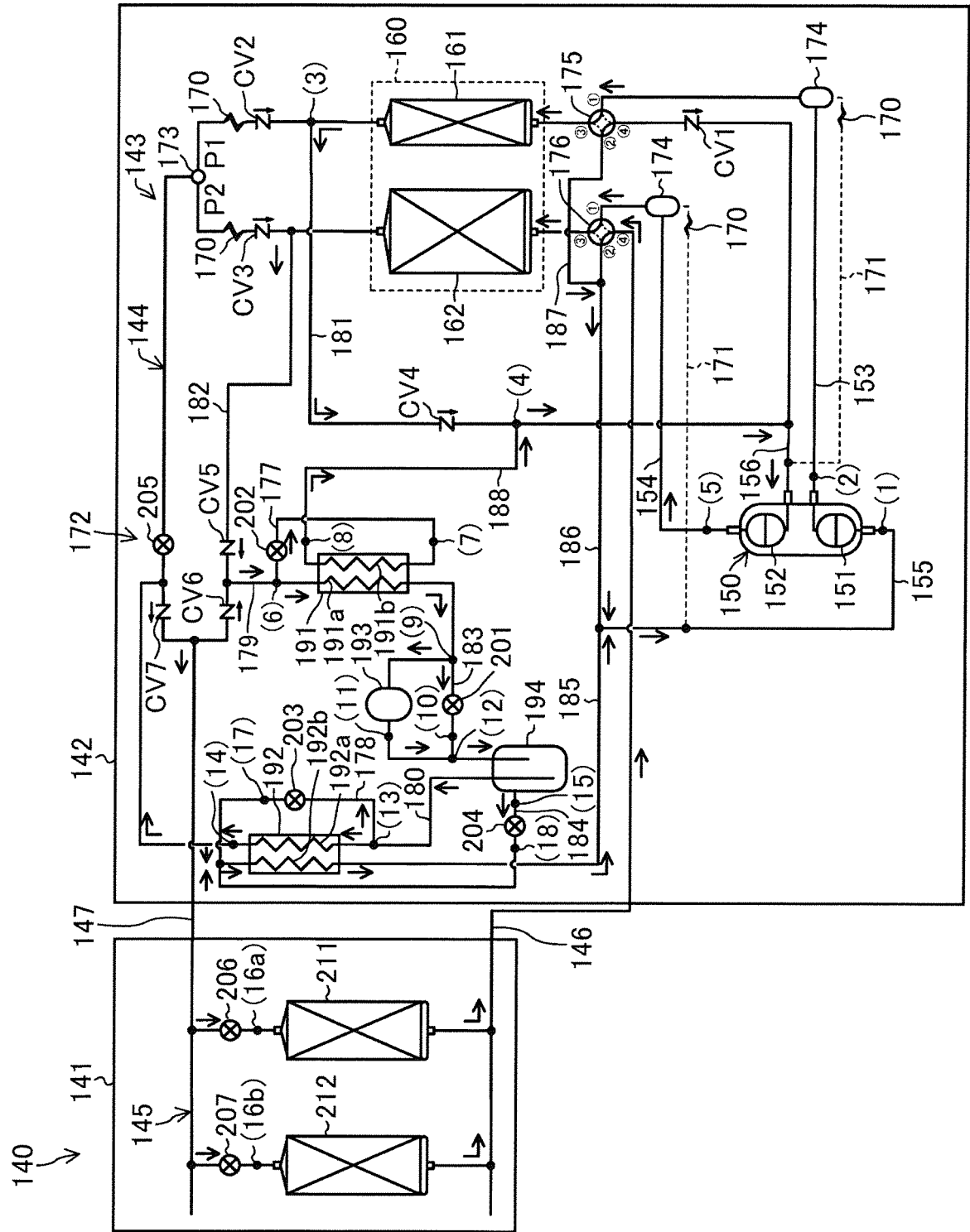


FIG.11

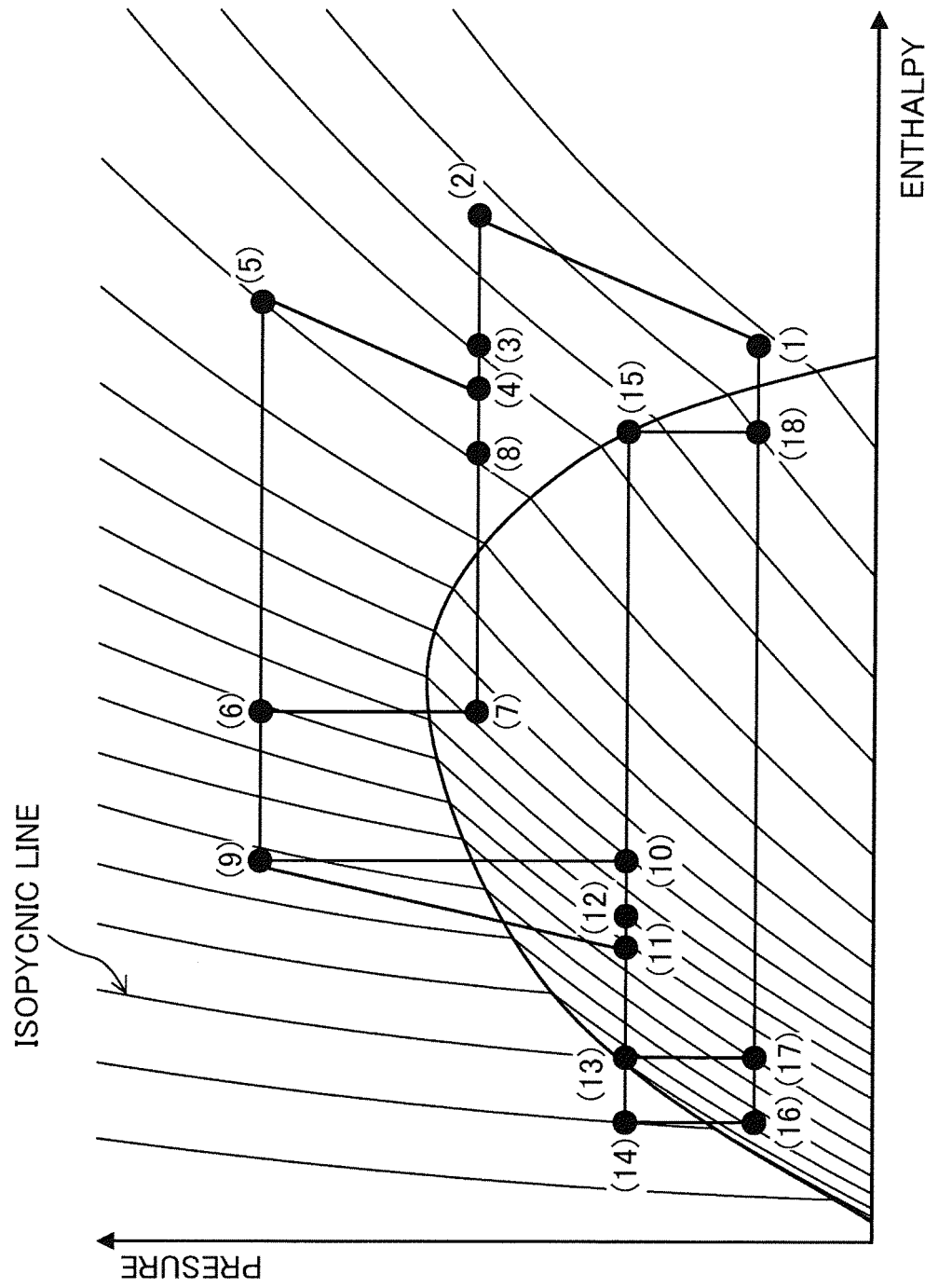


FIG. 12

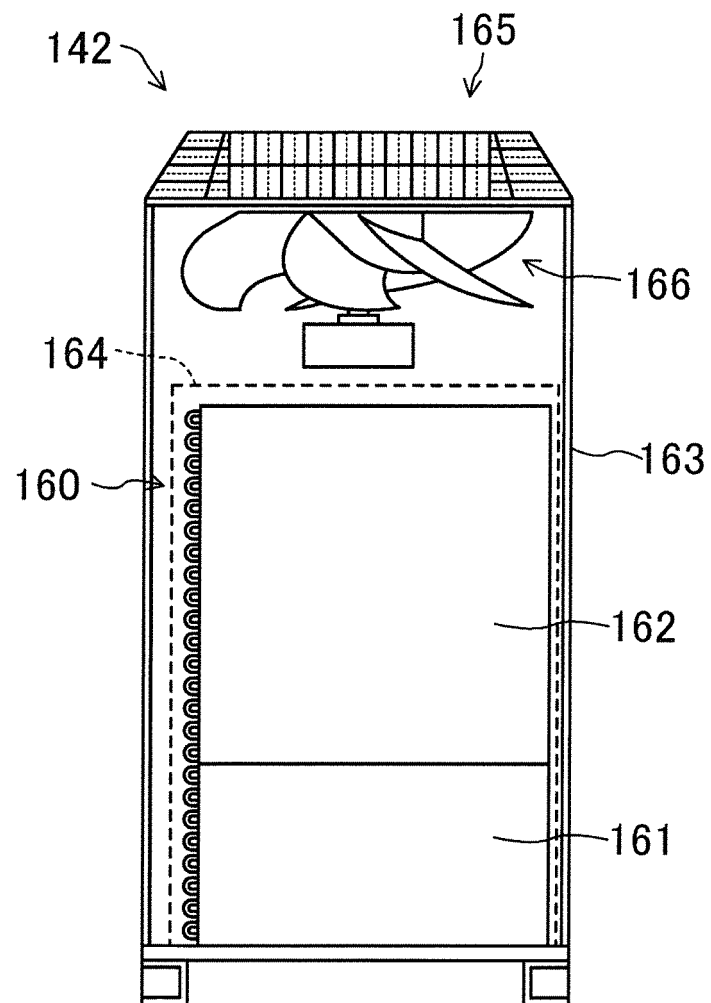
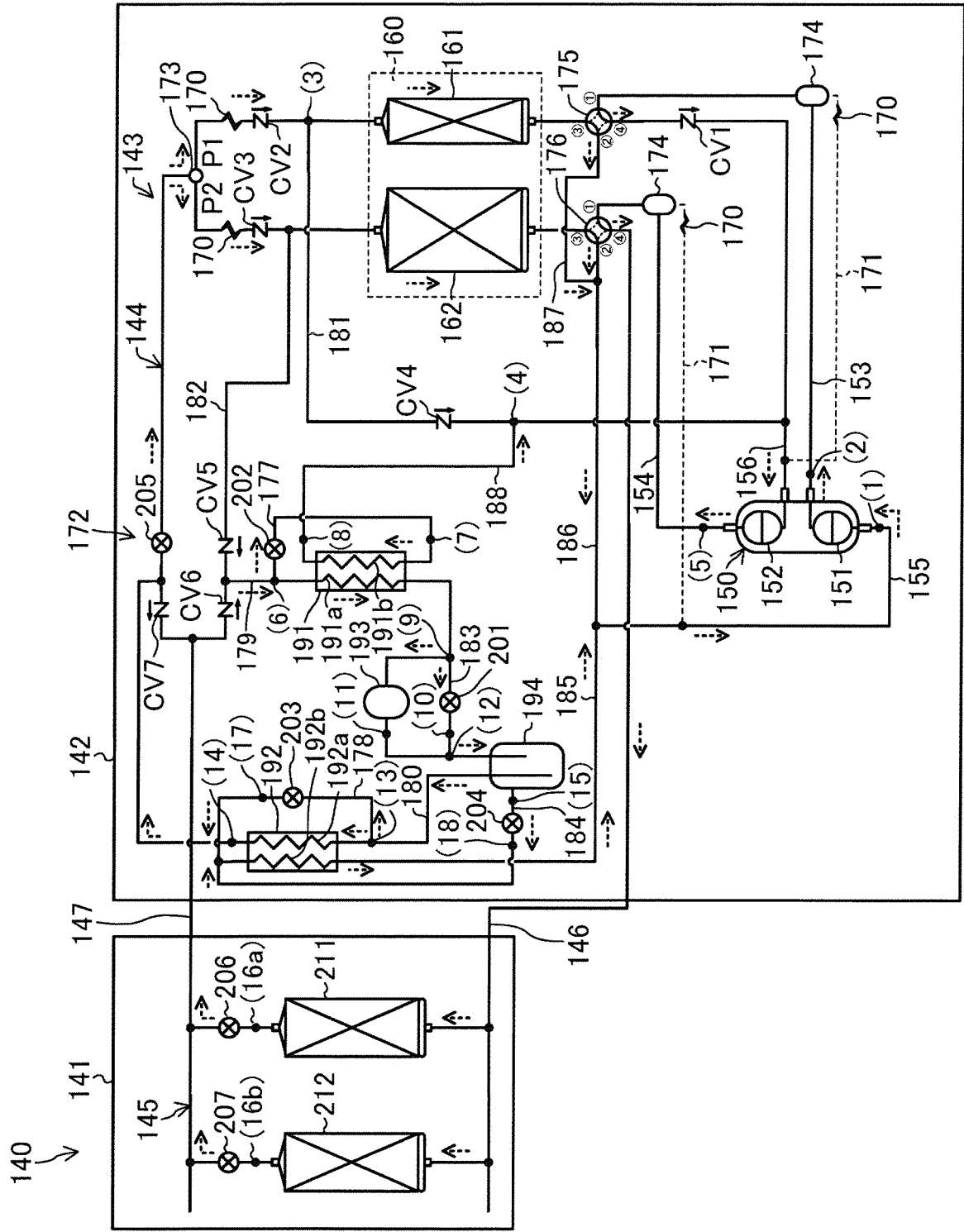


FIG.13



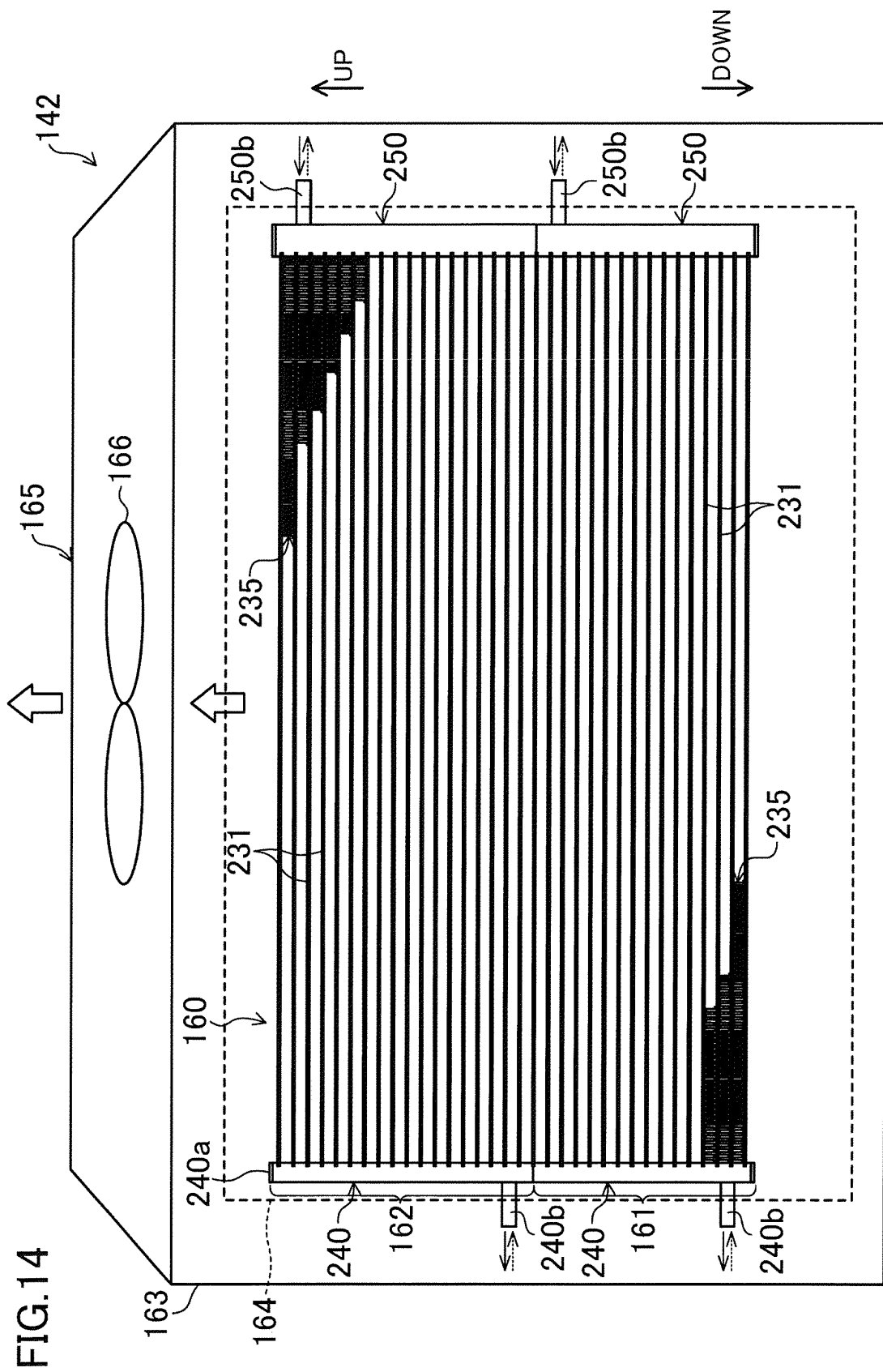
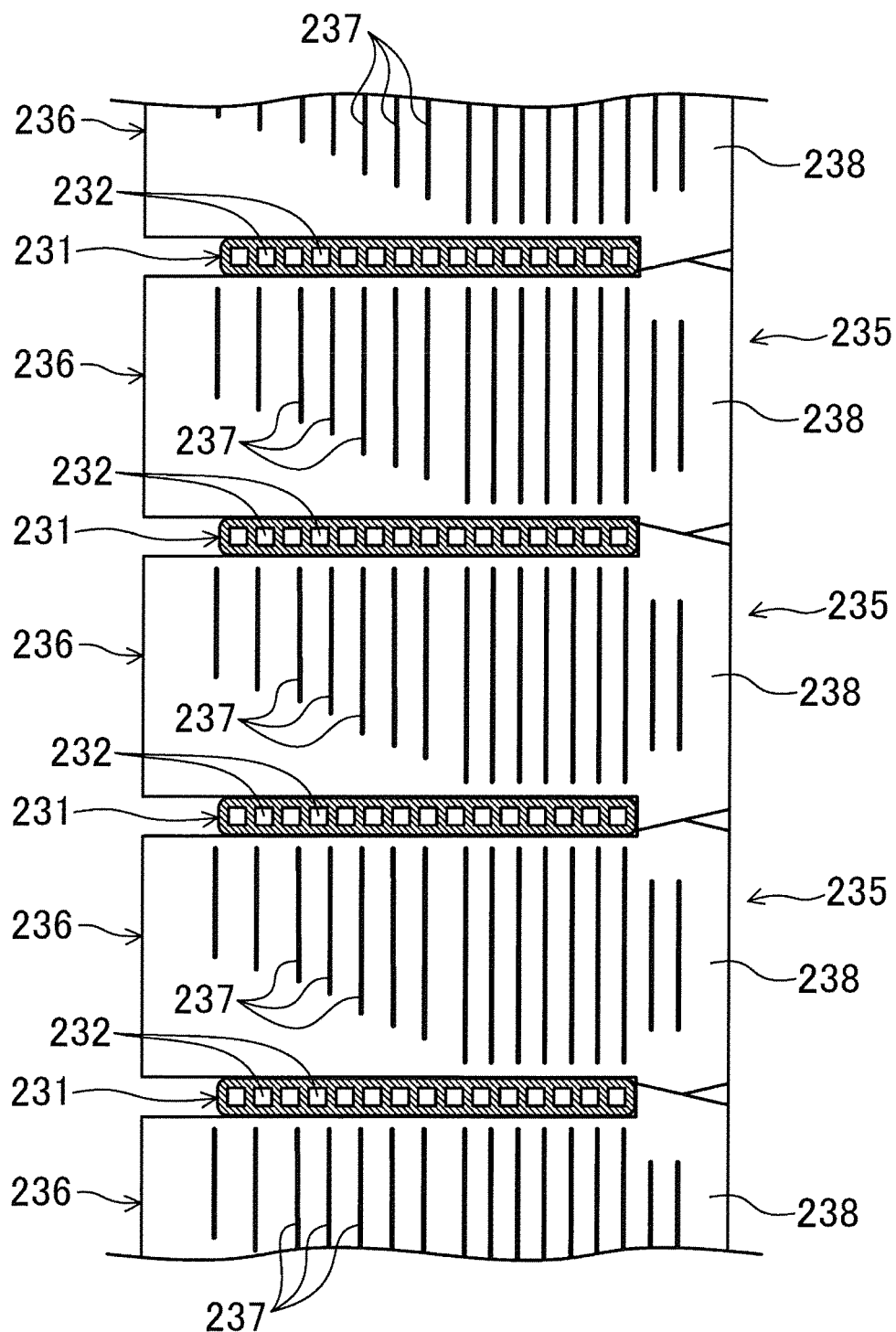


FIG.15



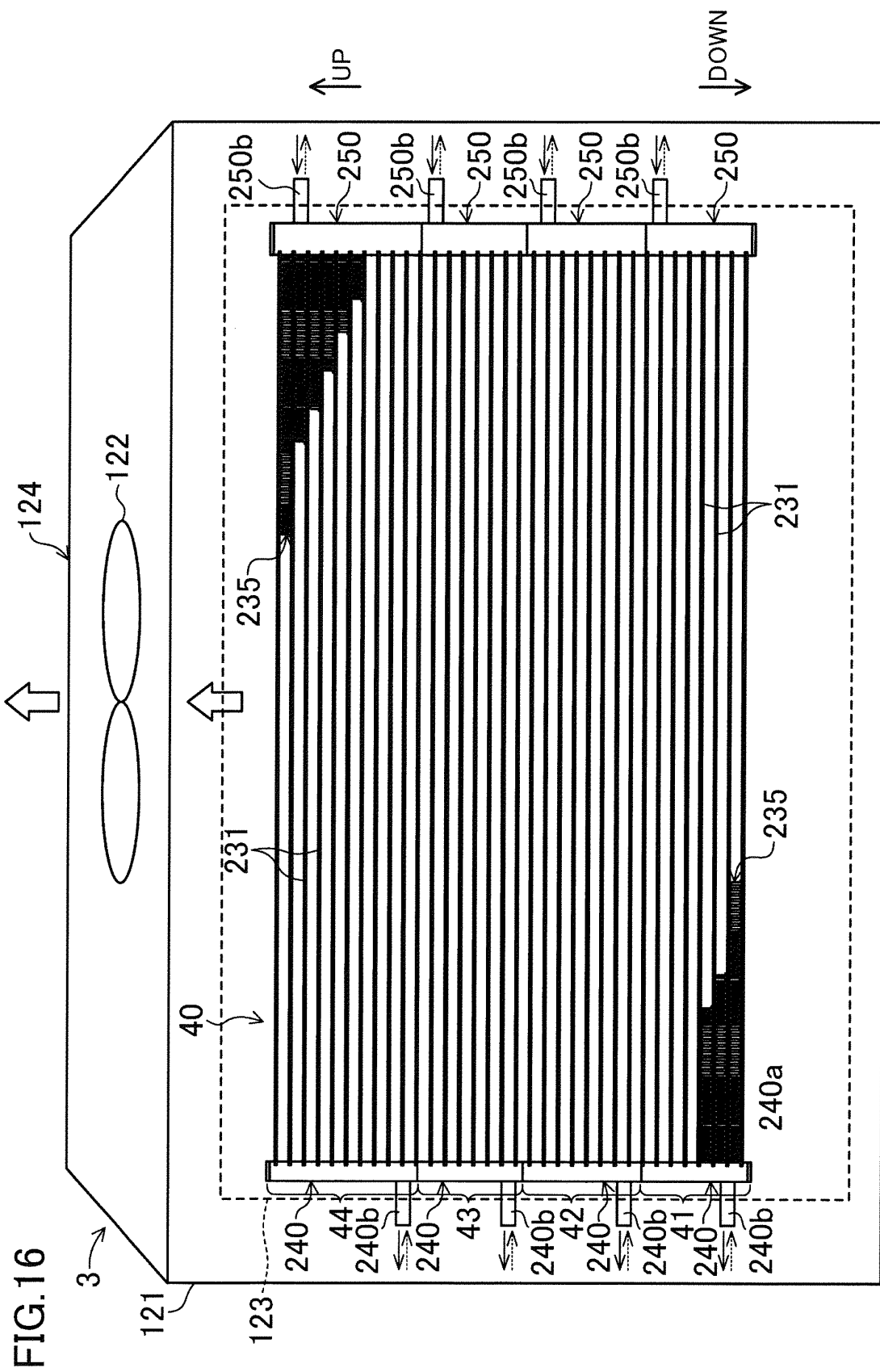


FIG.17

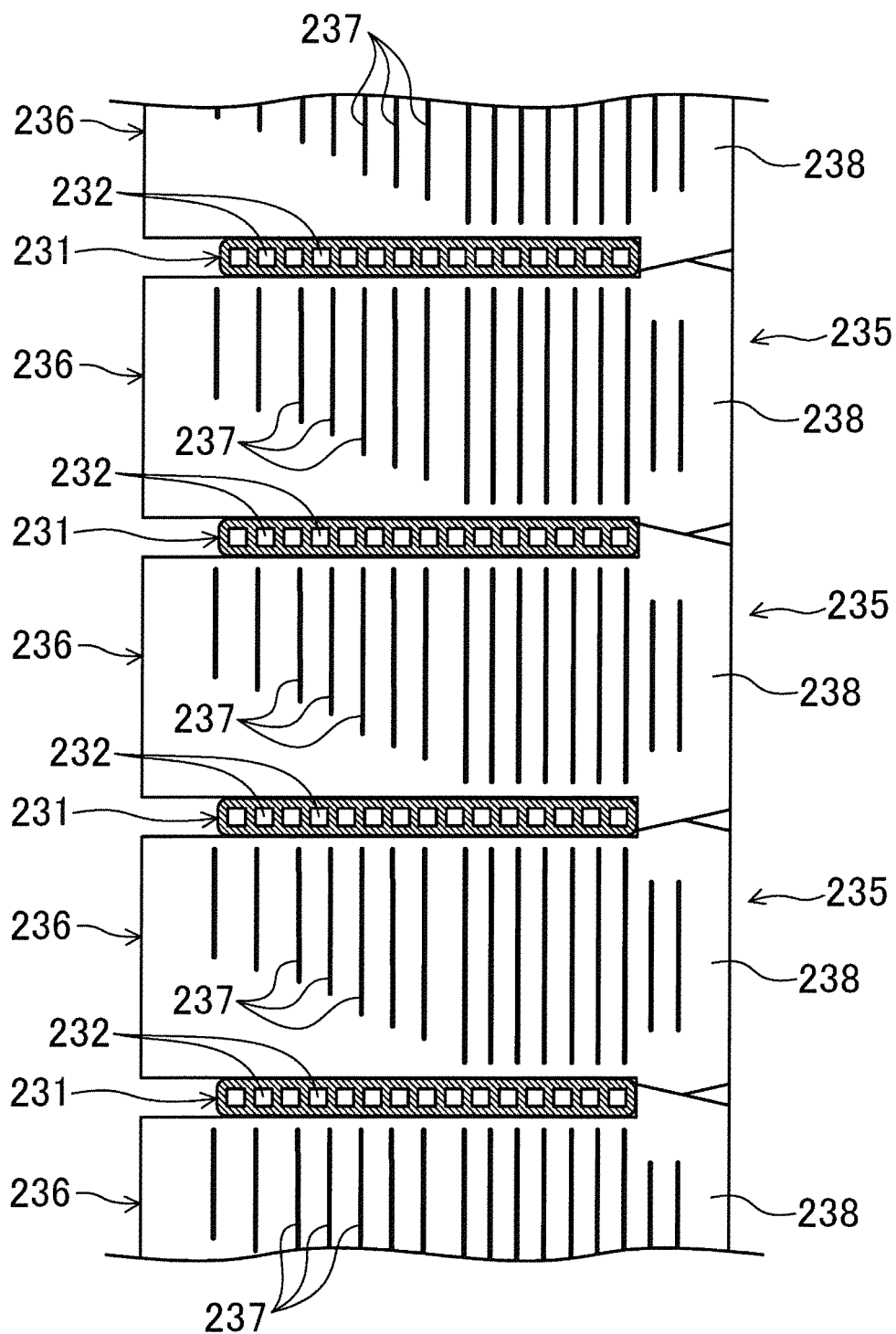


FIG.18A

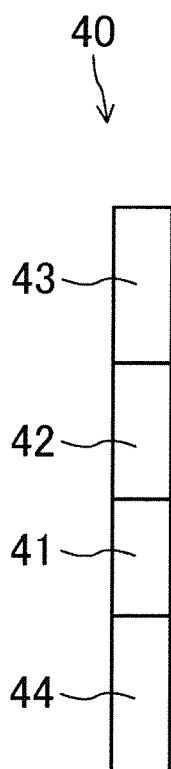


FIG.18B

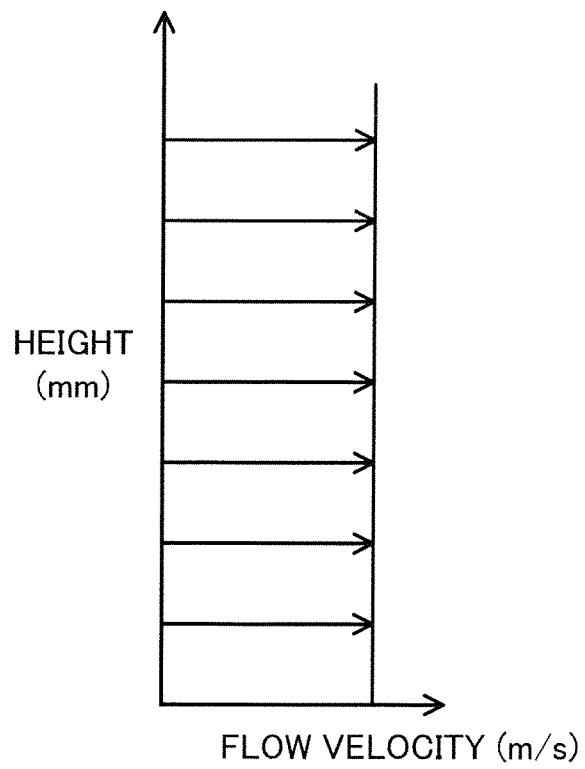


FIG.19

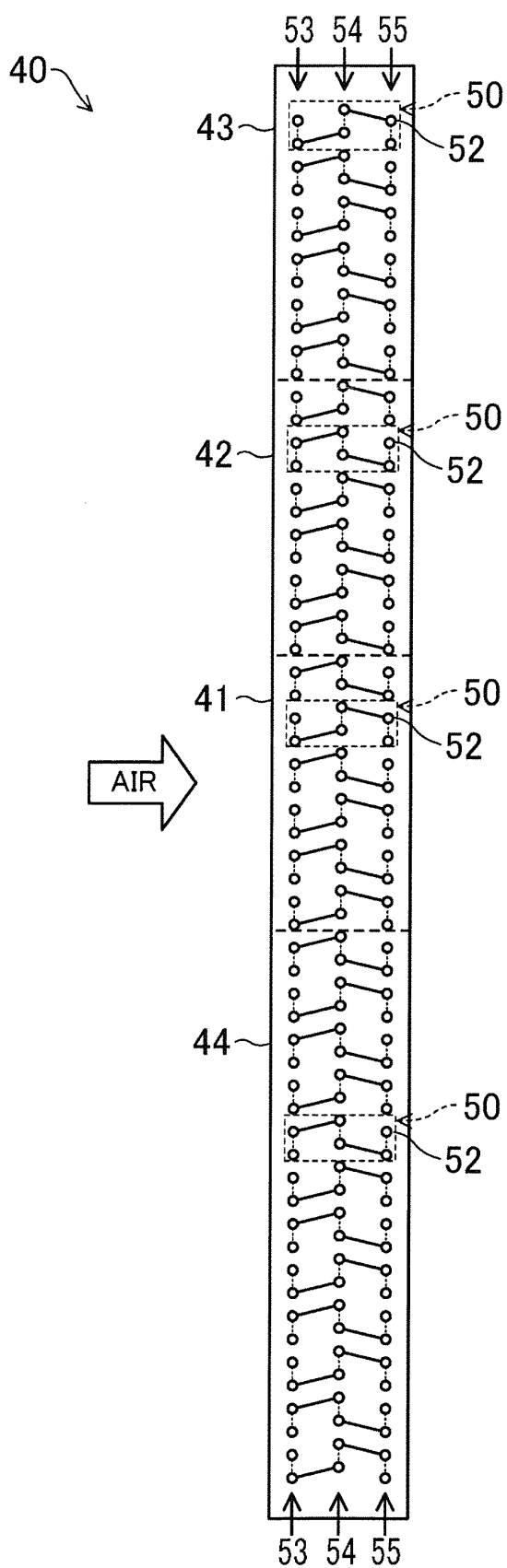


FIG.20

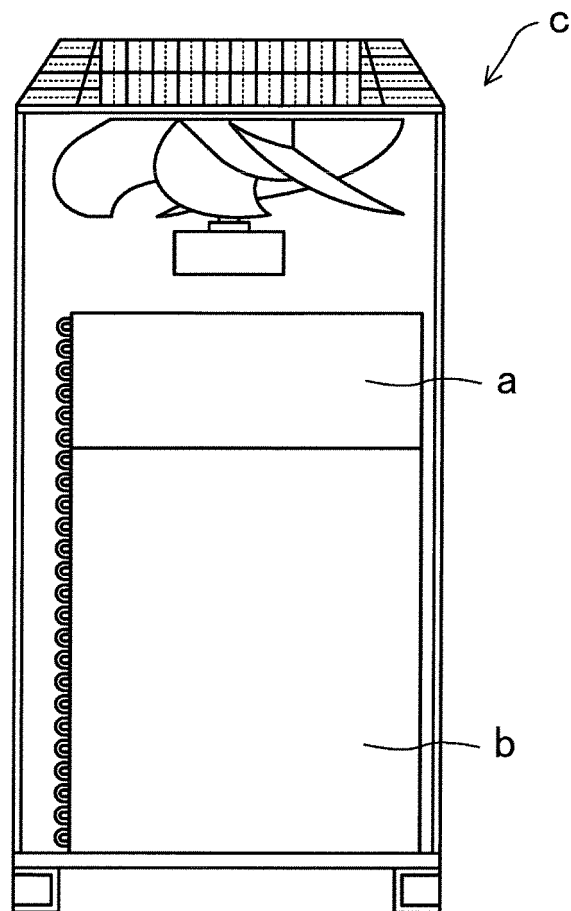


FIG.21A

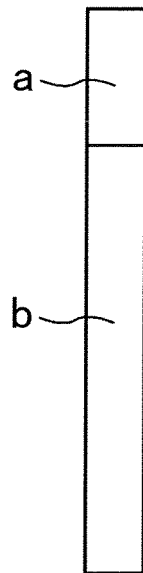
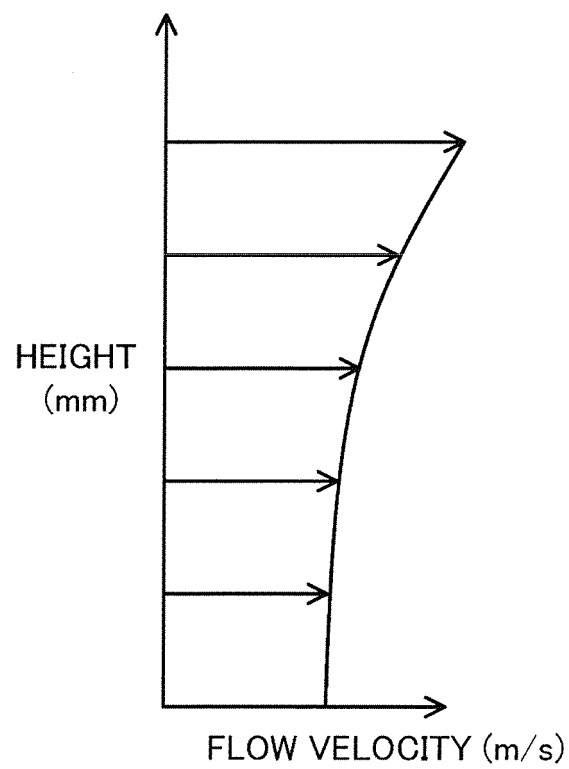


FIG.21B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/004185

A. CLASSIFICATION OF SUBJECT MATTER

F24F1/50(2011.01) i, F25B1/10(2006.01) i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24F1/50, F25B1/10

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2006-17116 A (The Tokyo Electric Power Co., Inc.), 19 January 2006 (19.01.2006), entire text; all drawings (Family: none)	1-5
Y	JP 2007-40605 A (Sanden Corp.), 15 February 2007 (15.02.2007), paragraphs [0031] to [0037]; fig. 5 to 7 (Family: none)	1-5
Y	JP 2003-279076 A (Sanyo Electric Co., Ltd.), 02 October 2003 (02.10.2003), entire text; all drawings (Family: none)	1-5

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

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"&" document member of the same patent family

Date of the actual completion of the international search
21 September, 2012 (21.09.12)Date of mailing of the international search report
02 October, 2012 (02.10.12)Name and mailing address of the ISA/
Japanese Patent Office

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REFERENCES CITED IN THE DESCRIPTION

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