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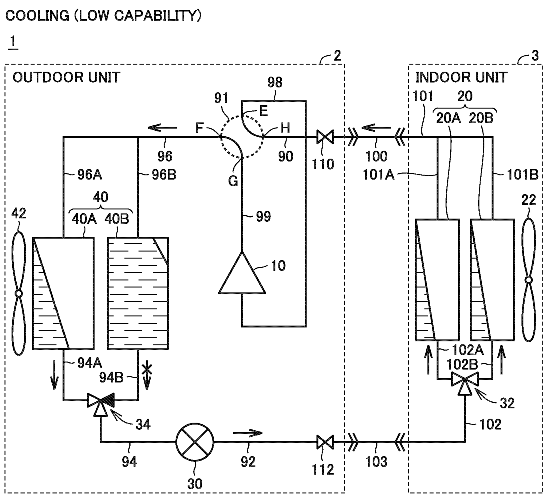
(54) **AIR CONDITIONER**

(57) In an air conditioner (1), refrigerant circulates sequentially through a compressor (10), a condenser (40/20), an expansion device (30), and an evaporator (20/40) in this order during an operation. The condenser (40/20) includes: a first heat exchange portion (40A/20A) and a second heat exchange portion (40B/20B) that are configured such that refrigerant in the first heat exchange portion flows in parallel with refrigerant in the second heat exchange portion; a flow rate restricting portion (34/32) configured to cause a flow rate difference between a flow rate of the refrigerant passing through the first heat exchange portion (40A/20A) and a flow rate of the refrigerant passing through the second heat exchange portion (40B/20B). The air conditioner (1) includes a controller (200) configured to control the compressor (10) and the flow rate restricting portion (34/32). When the controller (200) changes an air conditioning capability of the air conditioner (1), the controller (200) uses a combination of a frequency of the compressor (10) and the flow rate difference between the refrigerants passing through two heat exchange portions.

FIG.4



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Description

TECHNICAL FIELD

[0001] The present invention relates to an air conditioner.

BACKGROUND ART

[0002] In recent years, the widespread use of highly airtight and heat insulated houses have allowed significantly small air conditioning loads required to maintain comfortable rooms at comfortable temperatures. On the other hand, for maintaining the room temperature at an appropriate temperature by on/off control of air conditioning, the room temperature inevitably fluctuates. In order to reduce the fluctuation range of the room temperature, the air conditioner needs to be continuously operated with a relatively low air conditioning capability that balances with a small air conditioning load.

[0003] Therefore, such an air conditioner has been required to further decrease its lower limit capability during operation in addition to the rated capability for setting the room temperature at an appropriate temperature in an early stage.

CITATION LIST

PATENT LITERATURE

[0004] PTL 1: Japanese Patent No. 5639664

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] A compressor has an operating capability that can be raised or lowered by changing its operating frequency by inverter control, and thereby, the air conditioning capability can be lowered. However, since the lower limit of the operating frequency of the compressor is specified, the air conditioning operation with an extremely low capability cannot be continuously performed. Thus, even when inverter control is used, the room temperature may fluctuate by repeatedly starting and stopping the operation of the compressor.

[0006] On the other hand, it is conceivable to change the amount of refrigerant circulating in a refrigeration cycle in order to adjust the air conditioning capability. Japanese Patent No. 5639664 (PTL 1) discloses a technique for circulating a more appropriate amount of refrigerant in an air conditioner that allows switching between a natural circulation cycle and a forced circulation cycle. However, this technique is intended to regulate refrigerant at an appropriate amount in a circulation system, but not intended to actively regulate the amount of refrigerant for adjusting the air conditioning capability.

[0007] The present invention has been made in light of the above-described problems, and an object of the present invention is to provide an air conditioner capable of significantly lowering a lower limit capability during an operation than in the conventional case.

SOLUTION TO PROBLEM

[0008] The present disclosure relates to an air conditioner through which refrigerant circulates in order of a compressor, a condenser, an expansion device, and an evaporator during an operation. The condenser includes: a first heat exchange portion and a second heat exchange portion that are configured such that refrigerant in the first heat exchange portion flows in parallel with refrigerant in the second heat exchange portion; and a flow rate restricting portion configured to cause a flow rate difference between a flow rate of the refrigerant passing through the first heat exchange portion and a flow rate of the refrigerant passing through the second heat exchange portion. The air conditioner includes a controller configured to control the compressor and the flow rate restricting portion. The controller is configured to use a combination of a frequency of the compressor and the flow rate difference to change an air conditioning capability of the air conditioner.

ADVANTAGEOUS EFFECTS OF INVENTION

[0009] In the air conditioner according to the present disclosure, the condenser is divided into the first heat exchange portion and the second heat exchange portion, and refrigerant is stored in one of the heat exchange portions, so that the lower limit capability of air conditioning can be further lowered.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

Fig. 1 is a configuration diagram of an air conditioner 1 according to the present embodiment.
Fig. 2 is a diagram showing a flow of refrigerant during a cooling operation in a normal state.
Fig. 3 is a P-H diagram of a refrigeration cycle during an operation when a normal amount of refrigerant exists.
Fig. 4 is a diagram showing a flow of refrigerant during a cooling operation with a low capability.
Fig. 5 is a P-H diagram of a refrigeration cycle during an operation when refrigerant is stored in a heat exchanger.
Fig. 6 is a flowchart for illustrating refrigerant storage control during a cooling operation.
Fig. 7 is a diagram showing a flow of refrigerant during a heating operation in a normal state.
Fig. 8 is a diagram showing a flow of refrigerant during a heating operation with a low capability.
Fig. 9 is a flowchart for illustrating refrigerant storage control during a heating operation.
Fig. 10 is a diagram showing a comparison of lower limit capabilities between the control according to the present embodiment and the normal control.
Fig. 11 is a diagram showing a modification of a flow rate regulating valve.

DESCRIPTION OF EMBODIMENTS

[0011] The embodiments of the present invention will be hereinafter described in detail with reference to the accompanying drawings. As to a plurality of embodiments explained in the following description, it has been originally intended to combine the configurations described in respective embodiments as appropriate. In the accompanying drawings, the same or corresponding components will be denoted by the same reference characters, and the description thereof will not be repeated.

[0012] Fig. 1 is a configuration diagram of an air conditioner 1 according to the present embodiment. Referring to Fig. 1, air conditioner 1 includes a compressor 10, an indoor heat exchanger 20, an expansion valve 30, an outdoor heat exchanger 40, and a four-way valve 91. Outdoor heat exchanger 40 includes a first heat exchange portion 40A and a second heat exchange portion 40B. First heat exchange portion 40A and second heat exchange portion 40B are obtained, for example, by vertically dividing outdoor heat exchanger 40 into two portions. Indoor heat exchanger 20 includes a first heat exchange portion 20A and a second heat exchange portion 20B. First heat exchange portion 20A and second heat exchange portion 20B are obtained, for example, by vertically or horizontally dividing indoor heat exchanger 20 into two portions.

[0013] Outdoor unit 2 includes stop valves 110 and 112, a four-way valve 91, a compressor 10, an outdoor heat exchanger 40, an expansion valve 30, and pipes interconnecting these components.

[0014] A pipe 90 connects a port H of four-way valve 91 and stop valve 110 on the gas side. A pipe 92 connects stop valve 112 on the liquid side and expansion valve 30. Expansion valve 30 is disposed between pipes 92 and 94. Pipe 94 is branched at its intermediate portion into a pipe 94A and a pipe 94B, and connects expansion valve 30 to first heat exchange portion 40A and second heat exchange portion 40B. A flow rate regulating valve 34 is disposed at a branch portion between pipes 94A and 94B.

[0015] Compressor 10 has a discharge port and a suction port that are connected through respective pipes 99 and 98 to respective ports G and E of four-way valve 91. A pipe 96 has one end connected to a port F of four-way valve 91, and the other end branched at its intermediate portion into pipes 96A and 96B. Branched pipes 96A and 96B are connected to first heat exchange portion 40A and second heat exchange portion 40B, respectively.

[0016] Air conditioner 1 further includes a controller 200, a refrigerant pressure sensor (not shown), and a refrigerant temperature sensor.

[0017] Controller 200 includes a communication circuit 201, a processor 202, and a memory 203.

[0018] Memory 203 is configured, for example, to include a read only memory (ROM), a random access memory (RAM), and a flash memory. The flash memory stores an operating system, an application program, and various pieces of data.

[0019] Processor 202 controls the entire operation of air conditioner 1. The function of controller 200 is implemented by processor 202 executing an operating system and an application program stored in memory 203. During execution of the application program, various pieces of data stored in memory 203 are referred to. Communication circuit 201 is configured to transmit a control signal to compressor 10, four-way valve 91, expansion valve 30, a fan 42, and flow rate regulating valve 34, each of which is a target to be controlled. Communication circuit 201 is further configured to transmit a control signal to a fan 22 and a flow rate regulating valve 32, each of which is a target to be controlled.

[0020] Communication circuit 201 may be configured to receive a control signal from a remote controller (not shown) that remotely controls controller 200.

[0021] Controller 200 may be divided into a plurality of control units so as to be disposed in outdoor unit 2, indoor unit

3, and the remote controller. When the controller is divided into a plurality of control units, each of the control units includes a processor. In such a case, the processors cooperate with each other to entirely control air conditioner 1.

[0022] Compressor 10 is configured to change the operating frequency according to a control signal received from controller 200. The operating frequency of compressor 10 is changed to thereby adjust the output of compressor 10. Compressor 10 may be of various types such as a rotary type, a reciprocating type, a scroll type, and a screw type, for example.

[0023] In the configuration shown in Fig. 1, pipe 96 connects first heat exchange portion 40A and second heat exchange portion 40B to port F of four-way valve 91. In the cooling operation, as indicated by solid lines, four-way valve 91 allows communication between pipe 99 to which the discharge port of compressor 10 is connected and pipe 96, and also allows communication between pipe 98 to which the suction port of compressor 10 is connected and pipe 90. In the heating operation, as indicated by broken lines, four-way valve 91 allows communication between pipe 99 to which the discharge port of compressor 10 is connected and pipe 90, and also allows communication between pipe 98 to which the suction port of compressor 10 is connected and pipe 96.

[0024] Indoor unit 3 includes indoor heat exchanger 20, fan 22, pipes 101 and 102, and a room temperature sensor 24.

[0025] Pipe 101 has one end branched at its intermediate portion into pipes 101A and 101B. Pipe 101A and pipe 101B are connected to first heat exchange portion 20A and second heat exchange portion 20B, respectively. Pipe 101 has the other end connected to stop valve 110 through an extension pipe 100.

[0026] Pipe 102 has one end branched at its intermediate portion into a pipe 102A and a pipe 102B that are connected to first heat exchange portion 20A and second heat exchange portion 20B, respectively. Flow rate regulating valve 32 is disposed at a branch portion between pipes 102A and 102B. Pipe 102 has the other end connected to stop valve 112 through an extension pipe 103.

[0027] When connection of the refrigerant circuit completes during installation, stop valves 110 and 112 each are in a communication state.

[0028] Room temperature sensor 24 detects a room temperature and transmits the detected room temperature to controller 200. Room temperature sensor 24 does not necessarily have to be disposed inside indoor unit 3, but may be disposed in a remote controller or the like installed in a room where indoor unit 3 is installed.

(Refrigerant Amount Control during Cooling Operation)

[0029] First, the basic operation of the cooling operation will be described. Fig. 2 is a diagram showing a flow of refrigerant during a cooling operation in a normal state. In the cooling operation, the refrigerant flows in the direction indicated by arrows in Fig. 2. Compressor 10 draws refrigerant by suction from pipe 90 through four-way valve 91 and pipe 98, and then compresses the refrigerant. The compressed refrigerant flows through four-way valve 91 into pipe 96. The following also describes whether each heat exchanger functions as a condenser or an evaporator for easy understanding.

[0030] Outdoor heat exchanger 40 (condenser) condenses the refrigerant having flowed from compressor 10 through four-way valve 91 into pipe 96, and then, causes the condensed refrigerant to flow through pipe 94. Outdoor heat exchanger 40 (condenser) is configured such that the refrigerant discharged from compressor 10 and turned into high-temperature and high-pressure superheated vapor exchanges heat with the outside air so as to radiate heat. Through this heat exchange, the refrigerant is condensed and liquefied in the vicinity of the outlet of outdoor heat exchanger 40. Fan 42 is provided side by side with outdoor heat exchanger 40 (condenser), and controller 200 regulates the rotation speed of fan 42 according to the control signal. The rotation speed of fan 42 is changed to thereby allow regulation of the amount of heat exchanged between the refrigerant and the outside air in outdoor heat exchanger 40 (condenser).

[0031] Expansion valve 30 decompresses the refrigerant that has flowed from outdoor heat exchanger 40 (condenser) to pipe 94. The decompressed refrigerant flows through pipe 92. The opening degree of expansion valve 30 can be regulated according to the control signal received from controller 200. When the opening degree of expansion valve 30 is changed in the closing direction, the refrigerant pressure on the outlet side of expansion valve 30 lowers and the dryness of the refrigerant increases. On the other hand, when the opening degree of expansion valve 30 is changed in the opening direction, the refrigerant pressure on the outlet side of expansion valve 30 rises, and the dryness of the refrigerant decreases.

[0032] Indoor heat exchanger 20 (evaporator) evaporates the refrigerant that has flowed from expansion valve 30 through pipe 92, extension pipe 103, and pipe 102. The evaporated refrigerant flows through pipe 101, extension pipe 100, stop valve 110, and four-way valve 91 to pipe 98. Indoor heat exchanger 20 (evaporator) is configured such that the refrigerant decompressed by expansion valve 30 exchanges heat with the indoor air so as to absorb heat. Through this heat exchange, the refrigerant evaporates and turns into superheated vapor in the vicinity of the outlet of indoor heat exchanger 20. Fan 22 is provided side by side with indoor heat exchanger 20 (evaporator). Controller 200 regulates the rotation speed of fan 22 according to a control signal. By changing the rotation speed of fan 22, the amount of heat exchanged between the refrigerant and the indoor air in indoor heat exchanger 20 (evaporator) can be regulated.

[0033] Fig. 3 is a P-H diagram of the refrigeration cycle during operation when a normal amount of refrigerant exists. The following describes an example in which refrigerant is R32. In the P-H diagram shown in Fig. 3, a line from a point A1 to a point A2 corresponds to a compression process by compressor 10, a line from point A2 to a point A3 corresponds to a condensation process by the condenser, a line from point A3 to a point A4 corresponds to a decompression process by expansion valve 30, and a line from point A4 to point A1 corresponds to an evaporation process by the evaporator. The refrigeration capability has a value obtained by multiplying an enthalpy difference dH between point A1 and point A4 by a refrigerant circulation amount Gr per unit time.

[0034] In order to improve the performance and ensure the capability during the rated operation, a sufficient amount of refrigerant is sealed in the refrigerant circuit such that a subcool (SC) state can be sufficiently ensured at point A3 corresponding to the outlet portion of the condenser. Thus, a sufficient amount of refrigerant exists even during the operation with a low capability, so that the refrigerant is brought into a subcool state at point A3 corresponding to the outlet of the condenser. Accordingly, a refrigeration capability Q is represented by the following equation (1) using enthalpy difference dH and refrigerant circulation amount Gr per unit time.

$$Q = Gr * dH \qquad ... (1)$$

[0035] When a constant amount of refrigerant circulates, dH is fixed, and the operating frequency of the compressor is lowered to reduce circulating refrigerant amount Gr, thereby implementing a low capability. However, the lower limit frequency of the compressor is limited, for example, by supply of lubricating oil.

[0036] In the present embodiment, dH in the above-mentioned equation is decreased to thereby allow a significantly lower capability than in the conventional case.

[0037] Fig. 4 is a diagram showing a flow of refrigerant during a cooling operation with a low capability. The state shown in Fig. 4 is different from the state shown in Fig. 2 in that flow rate regulating valve 34 limits the flow rate in second heat exchange portion 40B. On the other hand, fan 42 continues to blow air. In second heat exchange portion 40B, the refrigerant is condensed but the liquefied refrigerant is not discharged. As a result, the liquid refrigerant is stored in second heat exchange portion 40B. The refrigerant in other portions flows in the same manner as in Fig. 2, and therefore, the description thereof will not be repeated with reference to Fig. 4.

[0038] As shown in Fig. 4, when liquid refrigerant is stored in second heat exchange portion 40B, the amount of refrigerant circulating through the refrigerant circuit decreases. In order to avoid liquid sealing in second heat exchange portion 40B, flow rate regulating valve 34 is preferably configured to ensure a very low flow rate without completely closing a section on the pipe 94B side. Further, as the amount of circulating refrigerant decreases, two-phase refrigerant flows into expansion valve 30. Thus, it is preferable to use expansion valve 30 having a larger aperture than in the conventional case.

[0039] Fig. 5 is a P-H diagram of a refrigeration cycle during an operation when refrigerant is stored in a heat exchanger. In the P-H diagram shown in Fig. 5, a line from a point B 1 to a point B2 corresponds to a compression process by compressor 10, a line from point B2 to a point B4 corresponds to a condensation process by a condenser, a line from point B4 to a point B5 corresponds to a decompression process by expansion valve 30, and a line from point B5 to point B1 corresponds to an evaporation process by an evaporator. In this case, the refrigeration capability has a value obtained by multiplying enthalpy difference dH between point B1 and point B5 by refrigerant circulation amount Gr per unit time.

[0040] When comparing Fig. 3 with Fig. 5, Fig. 5 shows smaller enthalpy difference dH of the evaporator with respect to the refrigeration capability. The amount of circulating refrigerant also decreases by the amount of liquid refrigerant stored in second heat exchange portion 40B. Thus, both enthalpy difference dH and refrigerant circulation amount Gr decrease. Accordingly, refrigeration capability Q represented by the product of enthalpy difference dH and refrigerant circulation amount Gr as shown in the equation (1) can be suppressed to be smaller than that in the conventional case.

[0041] The following describes the reason why the value of enthalpy H is larger at point B5 corresponding to the inlet of the evaporator in Fig. 5 than at point A3 in Fig. 3. A point B3 in Fig. 5 shows the state of the outlet of the condenser (second heat exchange portion 40B) in Fig. 4. Point B4 in Fig. 5 shows the state of the outlet of the condenser (first heat exchange portion 40A) in Fig. 4. An enthalpy Hj obtained after both two have merged is obtained by the following equation, using enthalpies H40A and H40B and refrigerant flow rates Gr40A and Gr40B at the outlets of first heat exchange portion 40A and second heat exchange portion 40B, respectively.

$$Hj = (H40A * Gr40A + H40B * Gr40B)/(Gr40A + Gr40B)$$

[0042] In other words, as shown in Fig. 5, when the flow rate is relatively low in the stat where flow rate regulating valve 34 on the pipe 94 B side is closed, enthalpy Hj after merging becomes approximately equal to enthalpy H40A on the pipe 94A side on which the flow rate of refrigerant is relatively high. Further, the enthalpy at point B4, i.e., the enthalpy at point B5 at the inlet of the evaporator, can be regulated by the flow rate of the refrigerant flowing on the pipe 94B side.

[0043] Fig. 6 is a flowchart for illustrating refrigerant storage control during a cooling operation. Referring to Figs. 1 and 6, in step S1, controller 200 determines whether the indoor temperature detected by room temperature sensor 24 is lower than a set temperature set by a remote controller or the like.

[0044] When the indoor temperature < the set temperature (YES in S1), then in step S2, controller 200 determines whether or not an operating frequency f of compressor 10 is higher than a lower limit frequency fmin. When f > fmin (YES in S2), then in step S3, controller 200 lowers operating frequency f of compressor 10 by $\delta 2$ to thereby lower the cooling capability of air conditioner 1.

[0045] Then in step S4, controller 200 determines whether or not the indoor temperature detected by room temperature sensor 24 is lower than the set temperature set by a remote controller or the like. When the indoor temperature < the set temperature (YES in S4), the process again returns to step S2. On the other hand, when the indoor temperature ≥ the set temperature (NO in S4), then in step S5, controller 200 raises operating frequency f of compressor 10 by $\delta 1$ to thereby raise the cooling capability of air conditioner 1.

[0046] The process of steps S1 to S5 described above is performed to adjust the operating frequency of compressor 10 by inverter control such that the air conditioning capability of air conditioner 1 during operation is set to the same level of the air conditioning load. However, when operating frequency f is equal to or less than lower limit value fmin (NO in S2), the air conditioning capability cannot be suppressed any more by lowering the operating frequency. Thus, the process proceeds to the steps subsequent to step 6 of regulating the refrigerant circulation amount.

[0047] Specifically, in step S6, the operation of storing the refrigerant in outdoor heat exchanger 40 is started. In step S6, controller 200 sets an opening degree L of flow rate regulating valve 34, at which the flow rate of second heat exchange portion 40B is determined, at a maximum opening degree Lmax. Maximum opening degree Lmax corresponds to opening degree L in an initial state. Then, in step S7, controller 200 determines whether or not the indoor temperature detected by room temperature sensor 24 is lower than the set temperature set by a remote controller or the like.

[0048] When the indoor temperature < the set temperature (YES in S7), then in step S8, controller 200 narrows opening degree L of flow rate regulating valve 34 by $\delta 3$ to thereby increase the amount of liquid refrigerant stored in second heat exchange portion 40B. Thus, refrigerant circulation amount Gr decreases. Then in step S9, controller 200 determines whether or not opening degree L of flow rate regulating valve 34 is equal to a lower limit opening degree Lmin.

[0049] When opening degree L of flow rate regulating valve 34 is not equal to lower limit opening degree Lmin (NO in S9), the process in step S7 is performed again. When the indoor temperature is equal to or higher than the set temperature in step S7 (NO in step S7), it is considered that the cooling capability does not need to be lowered any more and the air conditioning load balances with the air conditioning capability. Thus, the process of controlling the opening degree of flow rate regulating valve 34 ends in step S10, and then, the process returns to the main routine in step S11.

[0050] On the other hand, when opening degree L of flow rate regulating valve 34 is equal to lower limit opening degree Lmin (YES in S9), the refrigerant cannot be stored any more. Thus, in step S12, controller 200 stops compressor 10 to thereby prevent the indoor temperature from excessively lowering.

(Refrigerant Amount Control during Heating Operation)

[0051] Then, the basic operation of the heating operation will be described. Fig. 7 is a diagram showing a flow of refrigerant during the heating operation in a normal state. In the heating operation, refrigerant flows in a direction indicated by arrows in Fig. 7. Compressor 10 draws refrigerant by suction from pipe 96 through four-way valve 91 and pipe 98 and then compresses the refrigerant. The compressed refrigerant flows through four-way valve 91 into pipe 90. The following describes whether each heat exchanger functions as a condenser or an evaporator for easy understanding.

[0052] Indoor heat exchanger 20 (condenser) condenses the refrigerant having flowed from compressor 10 through four-way valve 91, pipe 90, and extension pipe 100 into pipe 101, and then causes the condensed refrigerant to flow through pipe 102. Indoor heat exchanger 20 (condenser) is configured such that the refrigerant discharged from compressor 10 and turned into high-temperature and high-pressure superheated vapor exchanges heat with the indoor air so as to radiate heat. Through this heat exchange, the refrigerant is condensed and liquefied in the vicinity of the outlet of indoor heat exchanger 20. Fan 22 is provided side by side with indoor heat exchanger 20 (condenser). Controller 200 regulates the rotation speed of fan 22 according to a control signal. By changing the rotation speed of fan 22, the amount of heat exchanged between the refrigerant and the indoor air in indoor heat exchanger 20 (condenser) can be regulated.

[0053] Expansion valve 30 decompresses the refrigerant that has flowed from indoor heat exchanger 20 (condenser) through pipe 102 and extension pipe 103 to pipe 92. The decompressed refrigerant flows through pipe 94. The opening degree of expansion valve 30 can be regulated according to a control signal received from controller 200. When the opening degree of expansion valve 30 is changed in the closing direction, the refrigerant pressure on the outlet side of expansion valve 30 lowers, and the dryness of the refrigerant increases. On the other hand, when the opening degree of expansion valve 30 is changed in the opening direction, the refrigerant pressure on the outlet side of expansion valve

30 rises, and the dryness of the refrigerant decreases.

[0054] Outdoor heat exchanger 40 (evaporator) evaporates the refrigerant that has flowed from expansion valve 30 to pipe 94. The evaporated refrigerant flows through pipe 96 and four-way valve 91 to pipe 98. Outdoor heat exchanger 40 (evaporator) is configured such that the refrigerant decompressed by expansion valve 30 exchanges heat with the outside air so as to absorb heat. Through this heat exchange, the refrigerant evaporates and turns into superheated vapor in the vicinity of the outlet of outdoor heat exchanger 40. Fan 42 is provided side by side with outdoor heat exchanger 40 (evaporator). Controller 200 regulates the rotation speed of fan 42 according to a control signal. By changing the rotation speed of fan 42, the amount of heat exchanged between the refrigerant and the outside air in outdoor heat exchanger 40 (evaporator) can be regulated.

[0055] Fig. 8 is a diagram showing a flow of refrigerant during a heating operation with a low capability. The state shown in Fig. 8 is different from the state shown in Fig. 7 in that the flow rate in second heat exchange portion 20B is limited by flow rate regulating valve 32. On the other hand, fan 22 continues to blow air. In second heat exchange portion 20B, the refrigerant is condensed but the liquefied refrigerant is not discharged. As a result, the liquid refrigerant is stored in second heat exchange portion 20B. The refrigerant in other portions flows in the same manner as in Fig. 7, and therefore, the description thereof will not be repeated with reference to Fig. 8.

[0056] As shown in Fig. 8, when the liquid refrigerant is stored in second heat exchange portion 20B, the amount of refrigerant circulating in the refrigerant circuit decreases. In order to avoid liquid in a sealed state in second heat exchange portion 20B, flow rate regulating valve 32 is preferably configured to ensure a very low flow rate without completely closing a section on the pipe 102B side.

[0057] The P-H diagram corresponding to Fig. 7 and the P-H diagram corresponding to Fig. 8 are different in condensation temperature, evaporation temperature, and the like from those in Figs. 3 and 5. However, when the refrigerant is R32, the enthalpy difference in the condenser is lower in the operation shown in Fig. 8 than in the operation shown in Fig. 7, which tends to establish the relation similar to that between Figs. 3 and 5.

[0058] Accordingly, since the enthalpy difference in the condenser during heating decreases, the condensing capability can be suppressed even during heating as compared with the conventional case.

[0059] Fig. 9 is a flowchart for illustrating refrigerant storage control during a heating operation. Referring to Figs. 1 and 9, in step S11, controller 200 determines whether the indoor temperature detected by room temperature sensor 24 is higher than the set temperature set by a remote controller or the like.

[0060] When the indoor temperature > the set temperature (YES in S11), then in step S12, controller 200 determines whether or not operating frequency f of compressor 10 is higher than lower limit frequency fmin. When f > fmin (YES in S12), then in step S13, controller 200 lowers operating frequency f of compressor 10 by $\delta 2$, to thereby lower the heating capability of air conditioner 1.

[0061] Then, in step S14, controller 200 determines whether or not the indoor temperature detected by room temperature sensor 24 is higher than the set temperature set by a remote controller or the like. When the indoor temperature > the set temperature (YES in S14), the process again returns to step S12. On the other hand, when the indoor temperature $\leq$ the set temperature (NO in S14), then in step S15, controller 200 raises operating frequency f of compressor 10 by $\delta 1$ to thereby raise the heating capability of air conditioner 1.

[0062] The process of steps S11 to S15 described above is performed to adjust the operating frequency of compressor 10 by inverter control such that the air conditioning capability of air conditioner 1 during operation is set to the same level of the air conditioning load. However, when operating frequency f is equal to or less than lower limit value fmin (NO in S2), the air conditioning capability cannot be suppressed any more by lowering the operating frequency. Thus, the process proceeds to the steps subsequent to step S16 of regulating the refrigerant circulation amount.

[0063] Specifically, in step S16, the operation of storing the refrigerant in indoor heat exchanger 20 is started. In step S16, controller 200 sets opening degree L of flow rate regulating valve 32, at which the flow rate of second heat exchange portion 20B is determined, at maximum opening degree Lmax. Maximum opening degree Lmax corresponds to opening degree L in an initial state. Then, in step S17, controller 200 determines whether or not the indoor temperature detected by room temperature sensor 24 is higher than the set temperature set by a remote controller or the like.

[0064] When the indoor temperature > the set temperature (YES in S17), then in step S18, controller 200 narrows opening degree L of flow rate regulating valve 32 by $\delta 3$ to thereby increase the amount of liquid refrigerant stored in second heat exchange portion 20B. In step S19, controller 200 determines whether or not opening degree L of flow rate regulating valve 32 is equal to lower limit opening degree Lmin.

[0065] When opening degree L of flow rate regulating valve 32 is not equal to lower limit opening degree Lmin (NO in S19), the process of step S17 is performed again. When the indoor temperature is equal to or lower than the set temperature in step S17 (NO in S17), it is considered that the heating capability does not need to be lowered any more and the air conditioning load balances with the air conditioning capability. Thus, the process of controlling the opening degree of flow rate regulating valve 32 ends in step S20, and the process returns to the main routine in step S21.

[0066] On the other hand, when opening degree L of flow rate regulating valve 32 is equal to lower limit opening degree Lmin (YES in S19), the refrigerant cannot be stored any more. Accordingly, controller 200 stops compressor 10 in step

S22 to thereby prevent the indoor temperature from excessively rising.

[0067] Fig. 10 is a diagram showing a comparison of the lower limit capabilities between the control according to the present embodiment and the normal control. Assuming that the rated capability is 100%, the lower limit capability is 15% when only the frequency of compressor 10 is controlled, whereas the lower limit capability is 10% when the amount of refrigerant stored in the heat exchanger is also controlled in addition to the control of the frequency in compressor 10. In the air conditioner of the present embodiment, the lower limit capability can be lowered to 66 .7 % as compared with a normal air conditioner.

[0068] Therefore, according to the air conditioner of the present embodiment, in a highly airtight and heat insulated house with a relatively small air conditioning load, temperature fluctuations can be suppressed as compared with conventional cases.

[0069] Fig. 11 is a diagram showing a modification of the flow rate regulating valve. In the modification shown in Fig. 11, flow rate regulating valves 32 and 34 shown in Fig. 1 are replaced with flow rate regulating portions 32A and 34A, respectively. Flow rate regulating valves 32 and 34 each are specifically intended as a three-way valve having a flow rate regulating function.

[0070] When a three-way valve is used as a flow rate regulating valve, the amount of circulating refrigerant can be regulated by slightly opening the three-way valve. Thus, by regulating the compressor frequency and the three-way valve, the variation width of the air conditioning capability can be increased (the lower limit capability can be further lowered).

[0071] However, a simpler configuration can also be adopted as flow rate regulating valves 32 and 34. Similar control is also allowed even in a configuration in which a flow rate regulating valve is provided only on the sides of second heat exchange portions 20B and 40B in which refrigerant is stored, as shown in Fig. 11.

[0072] Lastly, the present embodiment will be hereinafter summarized again with reference to the accompanying drawings.

[0073] The present disclosure relates to air conditioner 1 in which, during an operation, refrigerant circulates sequentially through compressor 10, a condenser (outdoor heat exchanger 40/indoor heat exchanger 20), an expansion device (expansion valve 30), and an evaporator (indoor heat exchanger 20/outdoor heat exchanger 40) in this order. The condenser (outdoor heat exchanger 40/indoor heat exchanger 20) includes first heat exchange portion 40A/20A and second heat exchange portion 40B/20B that are configured such that refrigerant in first heat exchange portion 40A/20A flows in parallel with refrigerant in second heat exchange portion 40B/20B; and a flow rate restricting portion (flow rate regulating valve 34/32) configured to cause a flow rate difference between a flow rate of the refrigerant passing through first heat exchange portion 40A/20A and a flow rate of the refrigerant passing through second heat exchange portion 40B/20B. Air conditioner 1 includes controller 200 configured to control compressor 10 and the flow rate restricting portion (flow rate regulating valve 34/32). Controller 200 uses a combination of the frequency of compressor 10 and the flow rate difference to change the air conditioning capability of air conditioner 1.

[0074] The heat exchanger corresponding to the condenser or the evaporator is different between the cooling operation and the heating operation, and also, the element corresponding to the flow rate restricting portion is different therebetween. Thus, the correspondence relation has been presented as described above. Also, the expansion device corresponds to expansion valve 30, but does not necessarily have to be a valve and may be a capillary tube, for example.

[0075] In such a configuration, a part of the condenser can be used like a container in which refrigerant is stored. Thus, the amount of circulating refrigerant can be increased or decreased without using a refrigerant container such as an accumulator or a receiver, and thereby, the lower limit capability can be suppressed. Further, even using a refrigerant container such as an accumulator and a receiver still allows a reduced size.

[0076] Preferably, (a) when controller 200 changes the air conditioning capability from a first capability to a second capability lower than the first capability, controller 200 lowers frequency f of compressor 10, and (b) when controller 200 reduces an amount of circulation of refrigerant to change the air conditioning capability from the second capability to a third capability lower than the second capability, controller 200 causes the flow rate restricting portion (flow rate regulating valve 34/32) to restrict the flow rate of the refrigerant passing through second heat exchange portion 40B/20B to be lower than the flow rate of the refrigerant passing through first heat exchange portion 40A/20A, in order to increase refrigerant stored in second heat exchange portion 40B/20B.

[0077] The responsiveness is more excellent when the air conditioning capability is lowered by changing the operating frequency of compressor 10 than when the air conditioning capability is lowered by increasing the refrigerant storage amount by the flow rate restricting portion. Thus, in order to lower the air conditioning capability, the operating frequency is first lowered, and at the same time or after that, the refrigerant storage amount is increased by the flow rate restricting portion so as to lower the air conditioning capability, which allows more excellent responsiveness and also allows less fluctuations in room temperature.

[0078] Preferably, air conditioner 1 further includes a four-way valve 91 configured to switch a circulation direction of the refrigerant between a cooling operation and a heating operation. Indoor heat exchanger 20 and outdoor heat exchanger 40 each are divided into two portions. Outdoor heat exchanger 40 functions as the condenser during the cooling operation. Indoor heat exchanger 20 functions as the condenser during the heating operation.

[0079] During the cooling operation, one of the flow paths of flow rate regulating valve 34 disposed on the outdoor heat exchanger 40 side is closed. Since fan 42 of outdoor heat exchanger 40 is rotating, the refrigerant is stored in the heat exchanger on the closed side (second heat exchange portion 40B in Fig. 4).

[0080] On the other hand, during the heating operation, one of the flow paths of flow rate regulating valve 32 disposed on the indoor heat exchanger 20 side is closed. Since the fan of indoor heat exchanger 20 is rotating, the refrigerant is stored in the heat exchanger on the closed side (second heat exchange portion 20B in Fig. 8).

[0081] In such a configuration, the lower limit of the air conditioning capability can be lowered in one air conditioner both during cooling and during heating.

[0082] In air conditioner 1 according to the present embodiment, it is also one of the characteristics that the fan of the condenser is kept rotating in order to actively accumulate refrigerant in the heat exchanger so as to lower the air conditioning capability. In an outdoor heat exchanger having a normal configuration, a condenser has a single fan shared by two divided heat exchange portions. In an indoor heat exchanger, a condenser may have a line flow fan as a common single fan. In a configuration in which the condenser has two propeller fans provided on the right and left sides, however, both the fans are to be rotated.

[0083] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims, rather than the description above, and is intended to include any modifications within the meaning and scope equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0084] 1 air conditioner, 2 outdoor unit, 3 indoor unit, 10 compressor, 20 indoor heat exchanger, 20A, 40A first heat exchange portion, 20B, 40B second heat exchange portion, 22, 42 fan, 24 room temperature sensor, 30 expansion valve, 32, 34 flow rate regulating valve, 32A flow rate regulating portion, 40 outdoor heat exchanger, 90, 92, 94, 94A, 94B, 96, 97A, 97B, 98, 99, 101, 101A, 101B, 102, 102A, 102B pipe, 91 four-way valve, 100, 103 extension pipe, 110, 112 stop valve, 200 controller, 201 communication circuit, 202 processor, 203 memory, E, F, G, H port.

Claims

1. An air conditioner through which refrigerant circulates in order of a compressor, a condenser, an expansion device, and an evaporator during an operation,

   the condenser including

      a first heat exchange portion and a second heat exchange portion that are configured such that refrigerant in the first heat exchange portion flows in parallel with refrigerant in the second heat exchange portion, and a flow rate restricting portion configured to cause a flow rate difference between a flow rate of the refrigerant passing through the first heat exchange portion and a flow rate of the refrigerant passing through the second heat exchange portion,

   the air conditioner comprising a controller configured to control the compressor and the flow rate restricting portion, wherein
   the controller is configured to use a combination of a frequency of the compressor and the flow rate difference to change an air conditioning capability of the air conditioner.

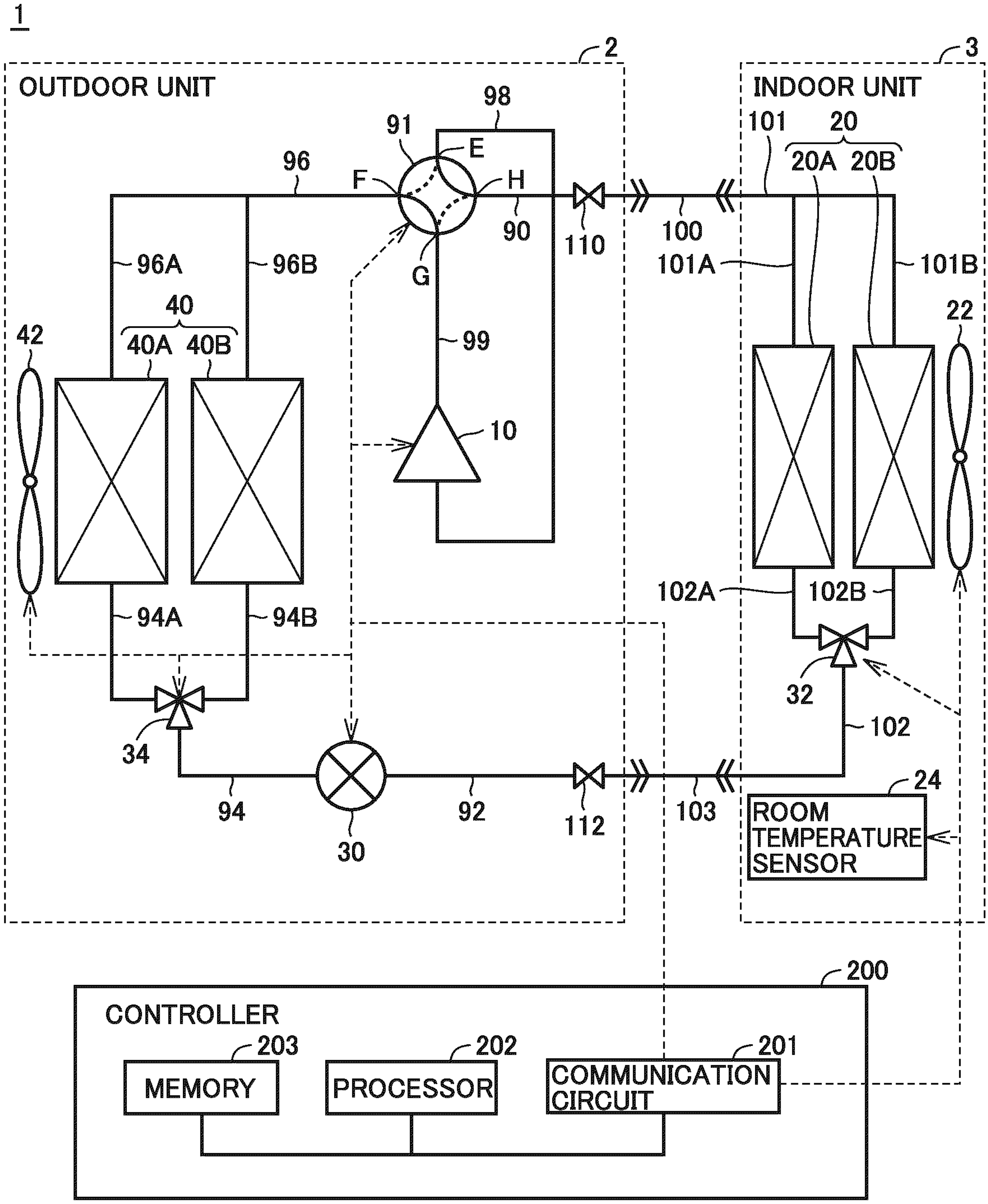
2. The air conditioner according to claim 1, wherein

   (a) when the controller changes the air conditioning capability from a first capability to a second capability lower than the first capability, the controller lowers the frequency of the compressor, and
   (b) when the controller reduces an amount of circulation of refrigerant to change the air conditioning capability from the second capability to a third capability lower than the second capability, the controller causes the flow rate restricting portion to restrict the flow rate of the refrigerant passing through the second heat exchange portion to be lower than the flow rate of the refrigerant passing through the first heat exchange portion, in order to increase refrigerant stored in the second heat exchange portion.

3. The air conditioner according to claim 1 or 2, further comprising a four-way valve configured to switch a circulation direction of the refrigerant between a cooling operation and a heating operation, wherein

an indoor heat exchanger and an outdoor heat exchanger each are divided into two portions,
the outdoor heat exchanger functions as the condenser during the cooling operation, and
the indoor heat exchanger functions as the condenser during the heating operation.

FIG.1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2
OUTDOOR UNIT
3
INDOOR UNIT
98
91
E
96
F
H
90
110
100
101
20
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20B
96A
96B
G
101A
101B
40
40A
40B
42
99
22
10
94A
94B
102A
102B
34
32
102
94
30
92
112
103
24
ROOM TEMPERATURE SENSOR
200
CONTROLLER
203
MEMORY
202
PROCESSOR
201
COMMUNICATION CIRCUIT

FIG.2

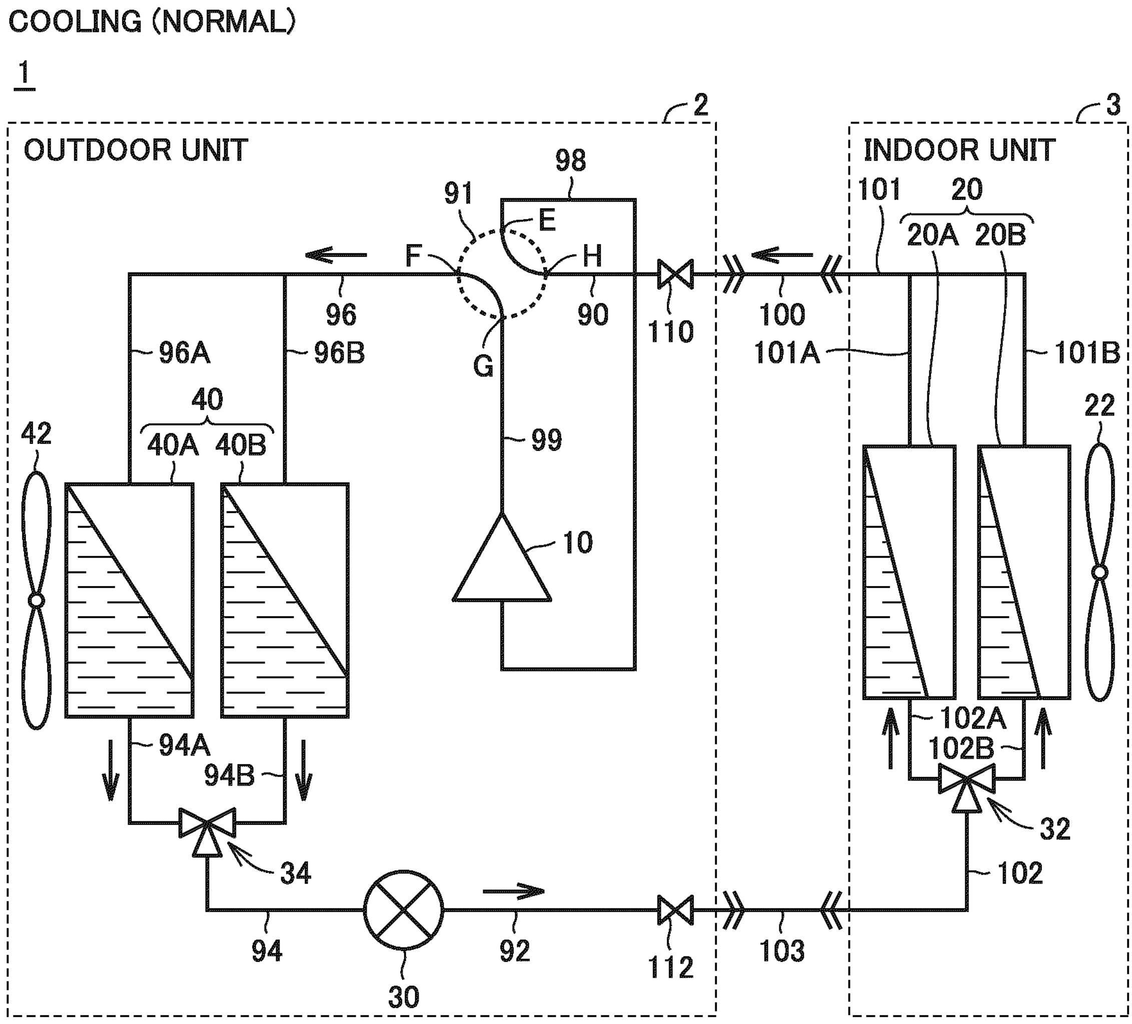

COOLING (NORMAL)
1
2
3
OUTDOOR UNIT
INDOOR UNIT
98
91
E
F
H
96
90
110
100
101
20
20A
20B
101A
101B
96A
96B
G
40
40A
40B
42
99
10
22
102A
102B
94A
94B
32
34
102
94
92
112
103
30

FIG.3

WHEN NORMAL AMOUNT OF REFRIGERANT EXISTS

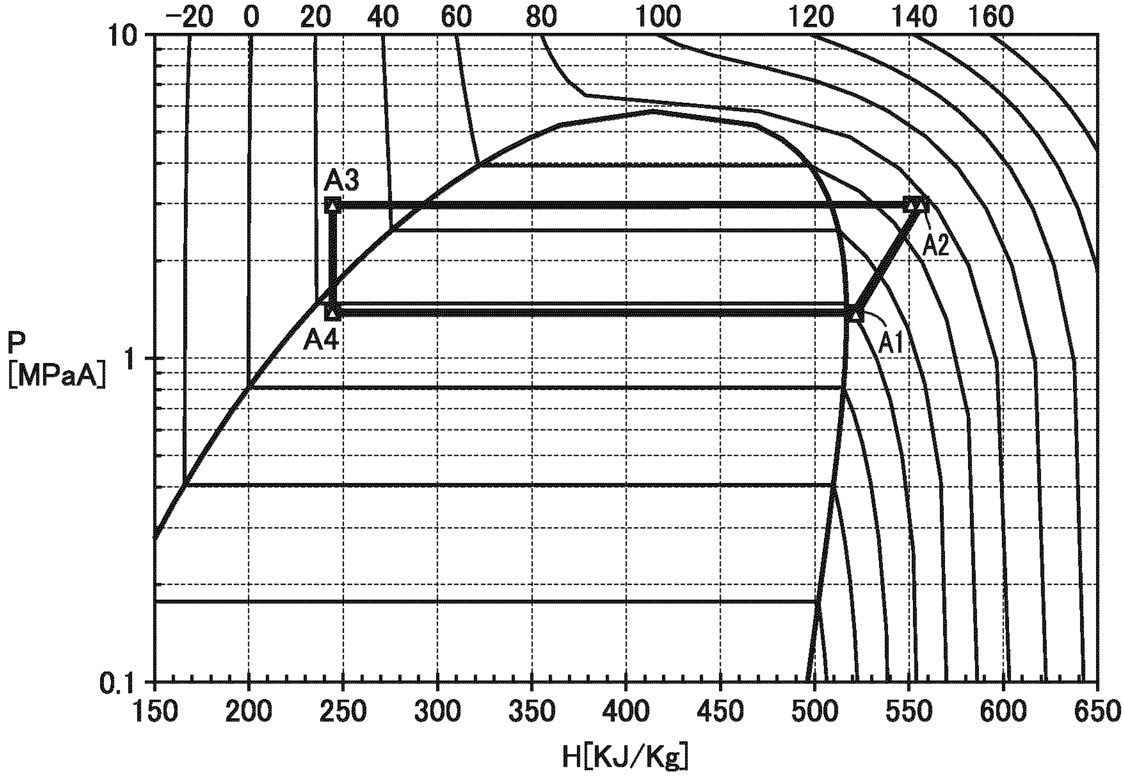


FIG.4

COOLING (LOW CAPABILITY)

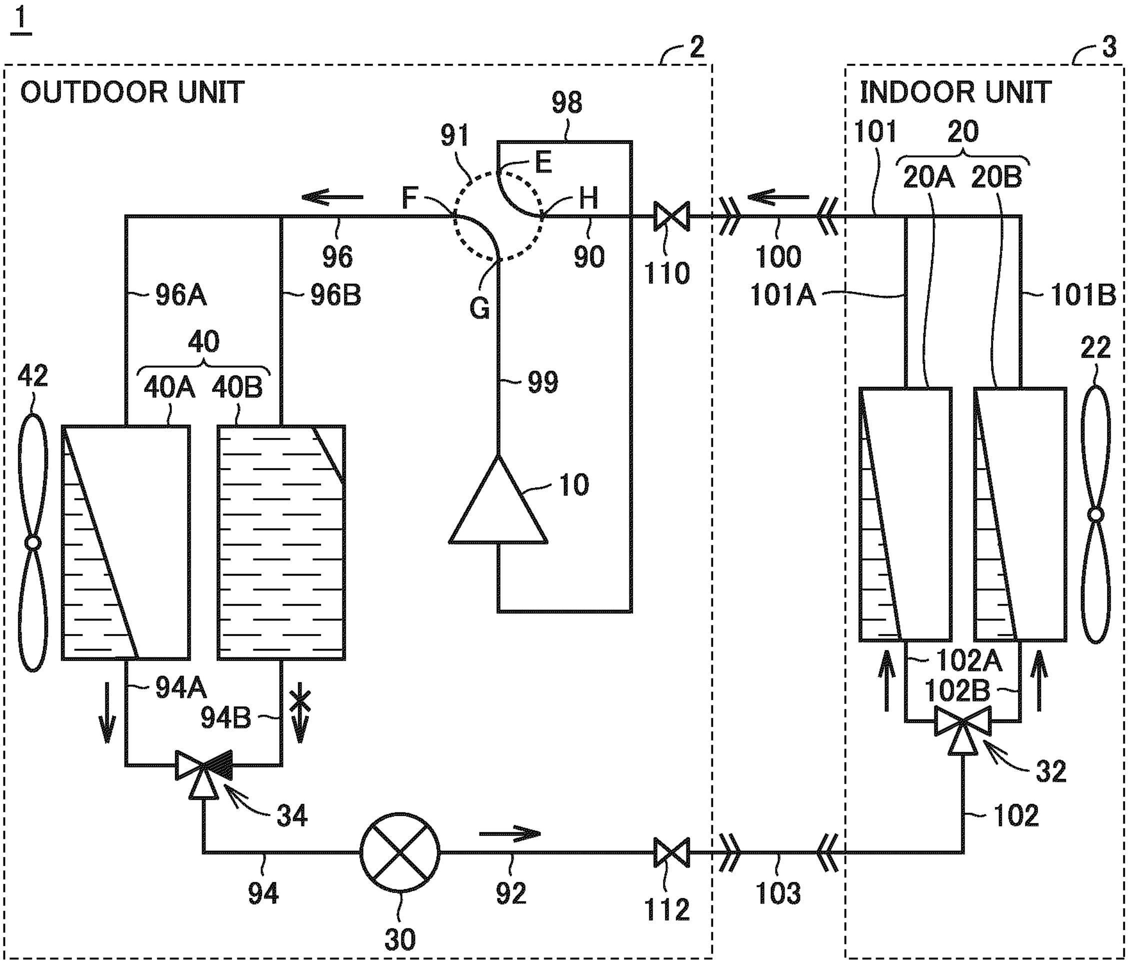


FIG.5

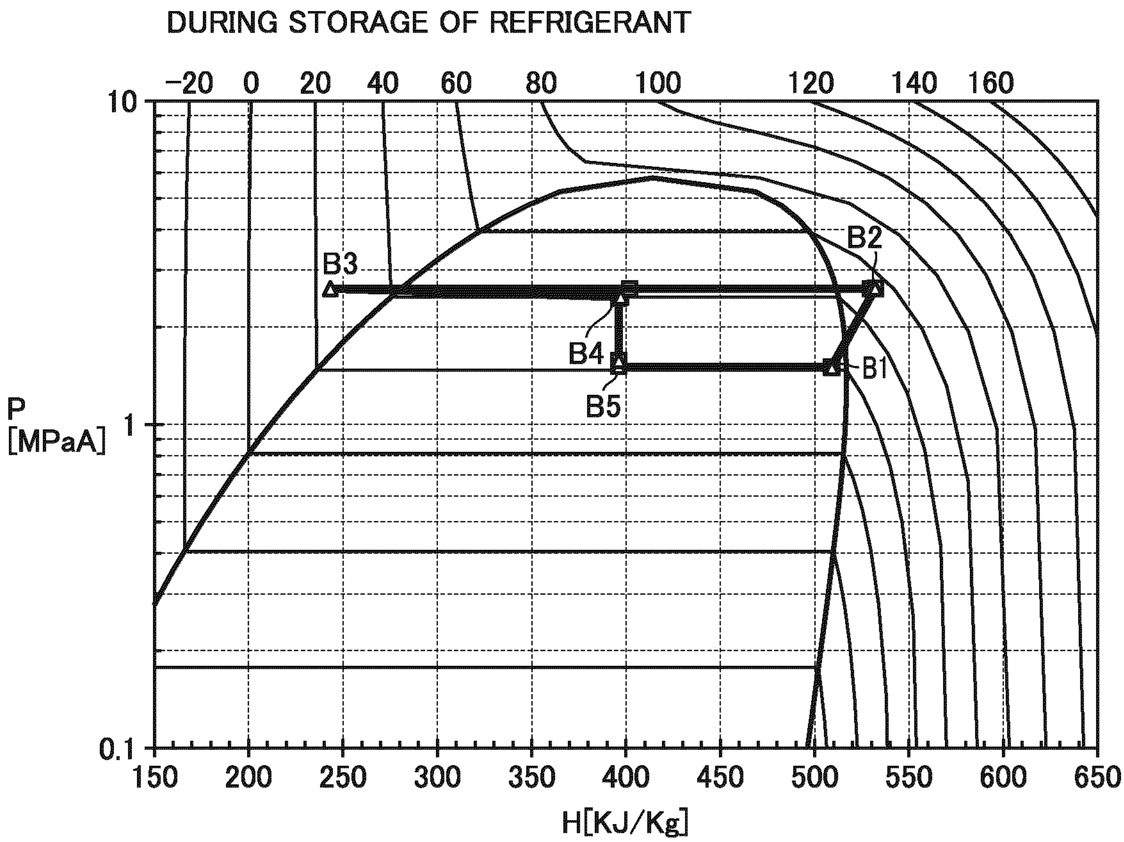

DURING STORAGE OF REFRIGERANT
−20
0
20
40
60
80
100
120
140
160
10
1
0.1
P
[MPaA]
B3
B2
B4
B1
B5
150
200
250
300
350
400
450
500
550
600
650
H[KJ/Kg]

FIG.6

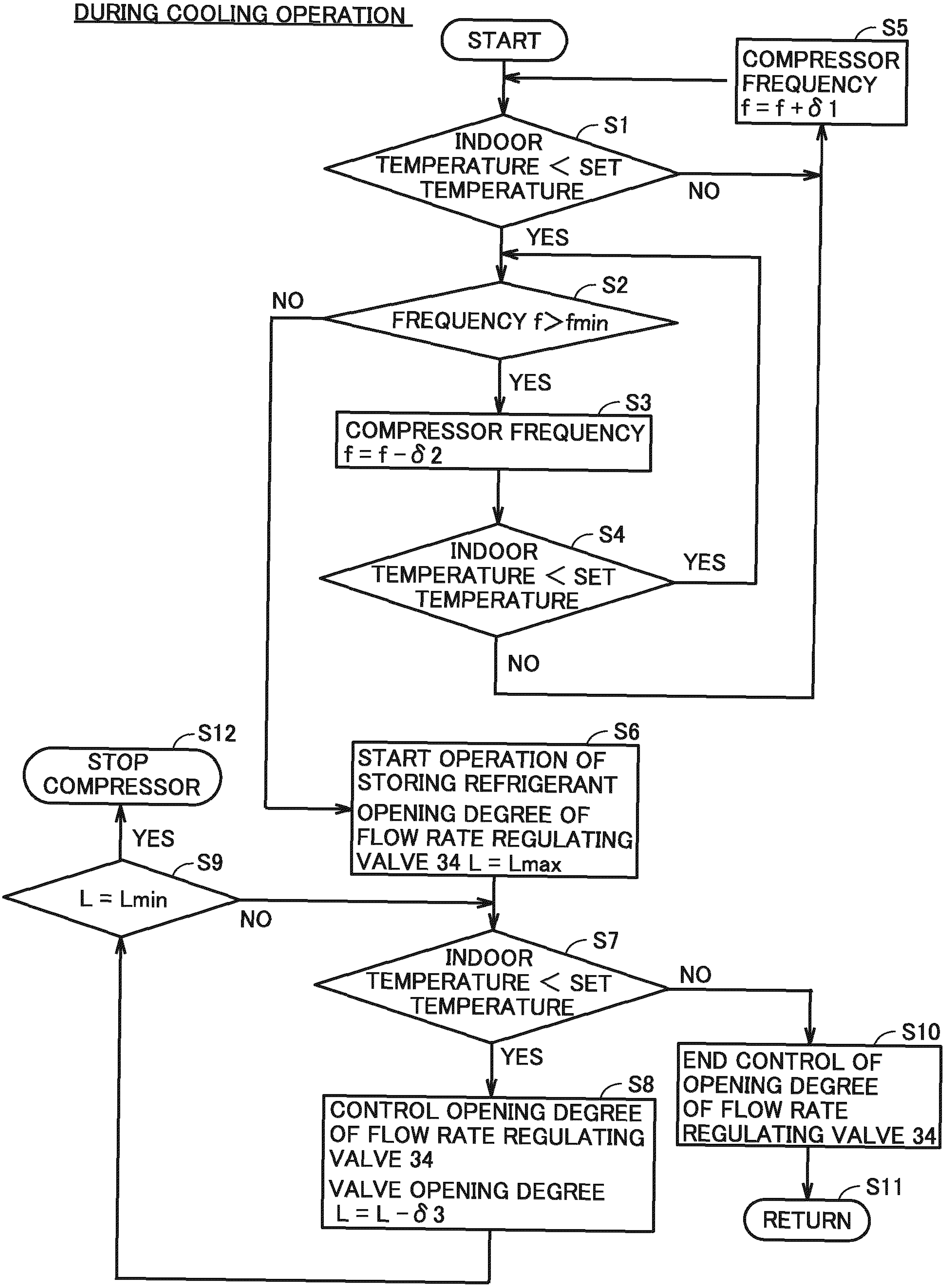

DURING COOLING OPERATION
START
S1
INDOOR TEMPERATURE < SET TEMPERATURE
NO
YES
S5
COMPRESSOR FREQUENCY f = f + δ 1
S2
FREQUENCY f>fmin
NO
YES
S3
COMPRESSOR FREQUENCY f = f − δ 2
S4
INDOOR TEMPERATURE < SET TEMPERATURE
YES
NO
S6
START OPERATION OF STORING REFRIGERANT
OPENING DEGREE OF FLOW RATE REGULATING VALVE 34 L = Lmax
S12
STOP COMPRESSOR
YES
S9
L = Lmin
NO
S7
INDOOR TEMPERATURE < SET TEMPERATURE
NO
YES
S8
CONTROL OPENING DEGREE OF FLOW RATE REGULATING VALVE 34
VALVE OPENING DEGREE L = L − δ 3
S10
END CONTROL OF OPENING DEGREE OF FLOW RATE REGULATING VALVE 34
S11
RETURN

FIG.7

HEATING (NORMAL)

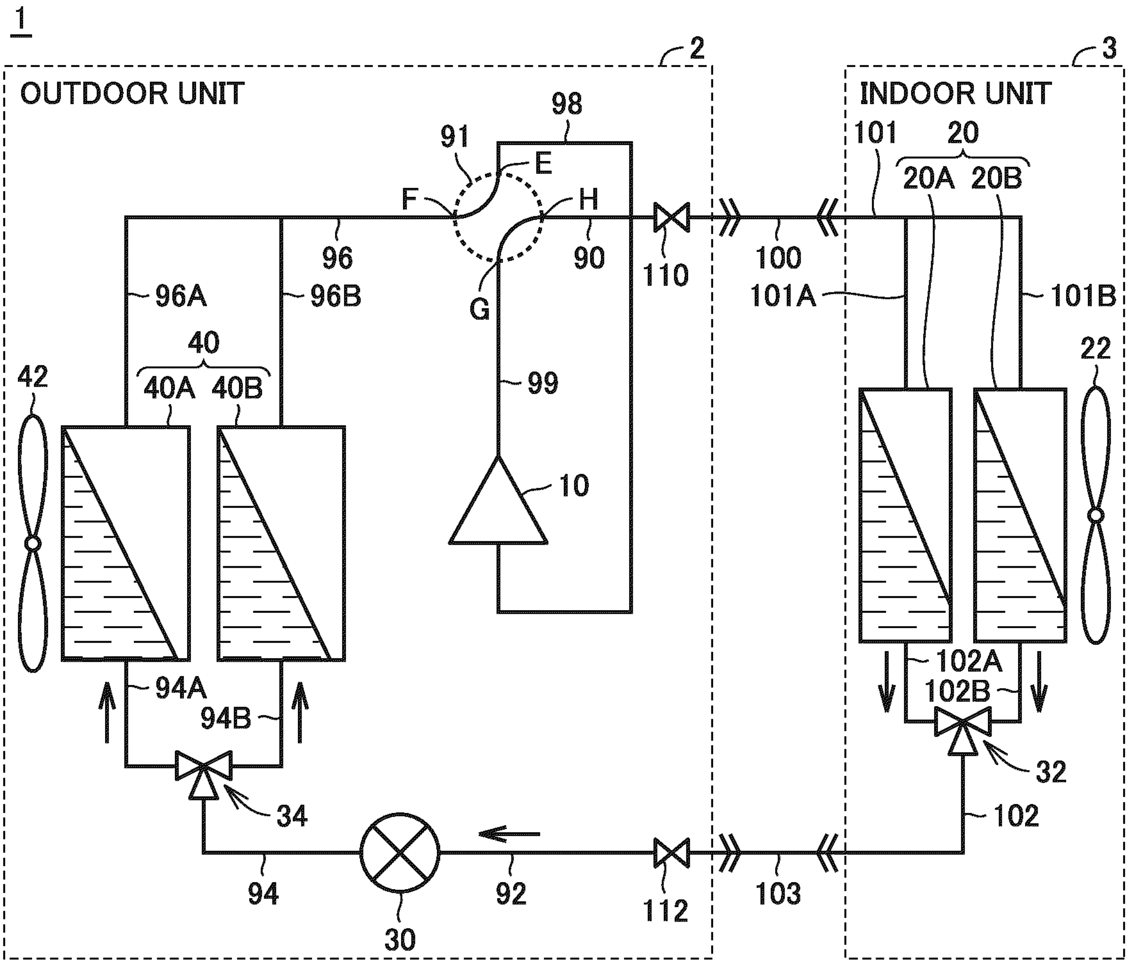
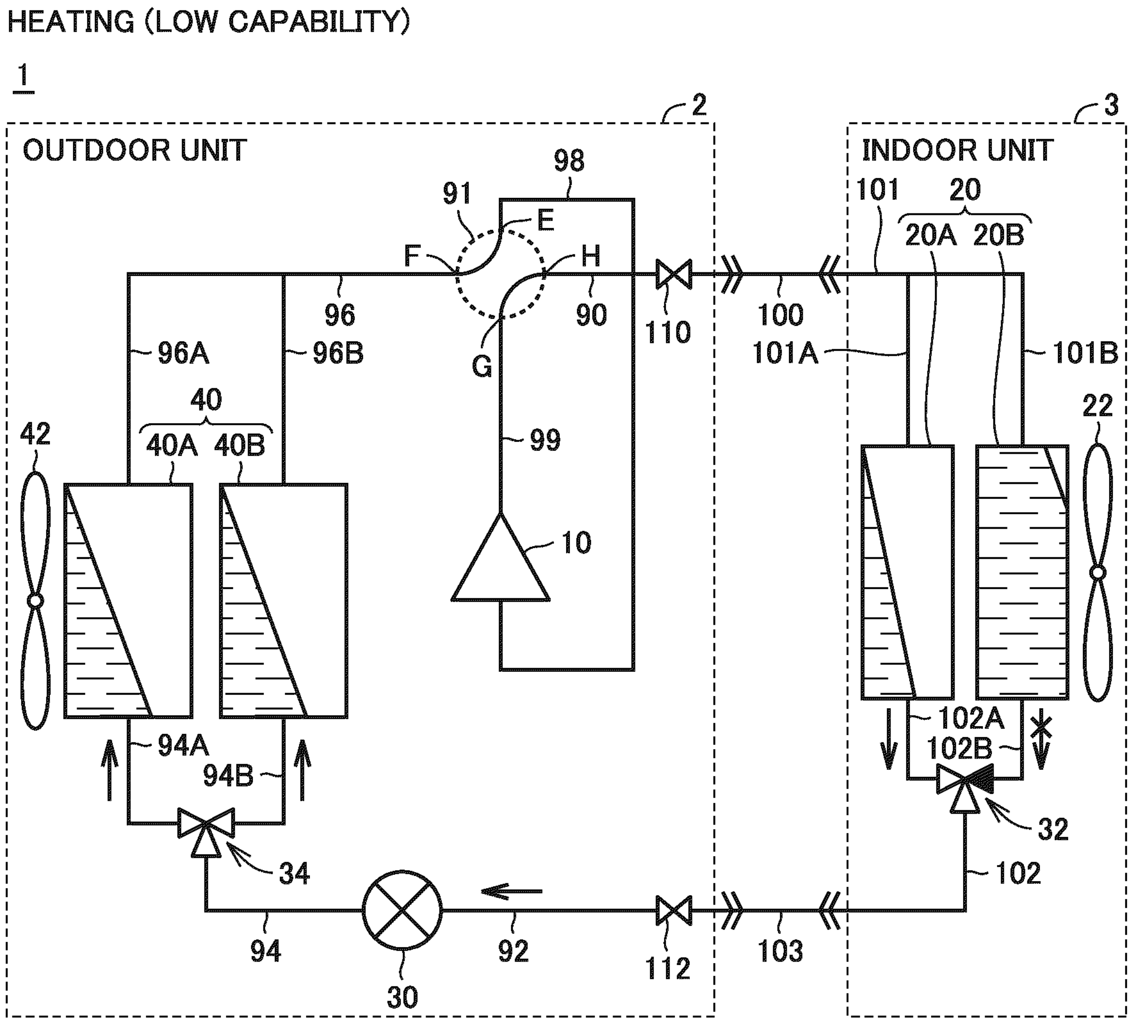


FIG.8


HEATING (LOW CAPABILITY)
1
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OUTDOOR UNIT
INDOOR UNIT
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E
F
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96
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100
101
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20A
20B
96A
96B
G
101A
101B
40
40A
40B
42
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102A
102B
94A
94B
32
34
102
94
30
92
112
103

FIG.9

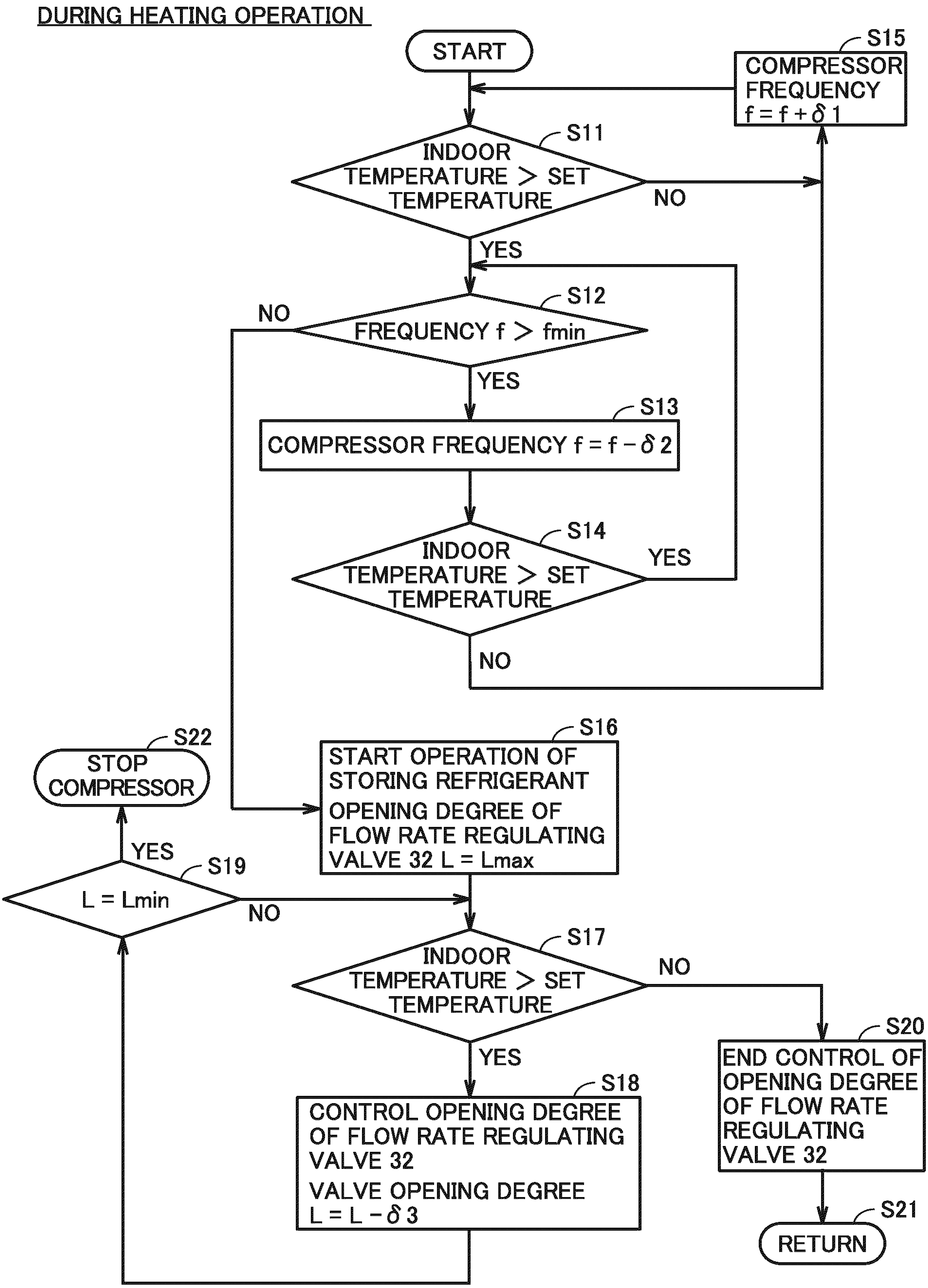
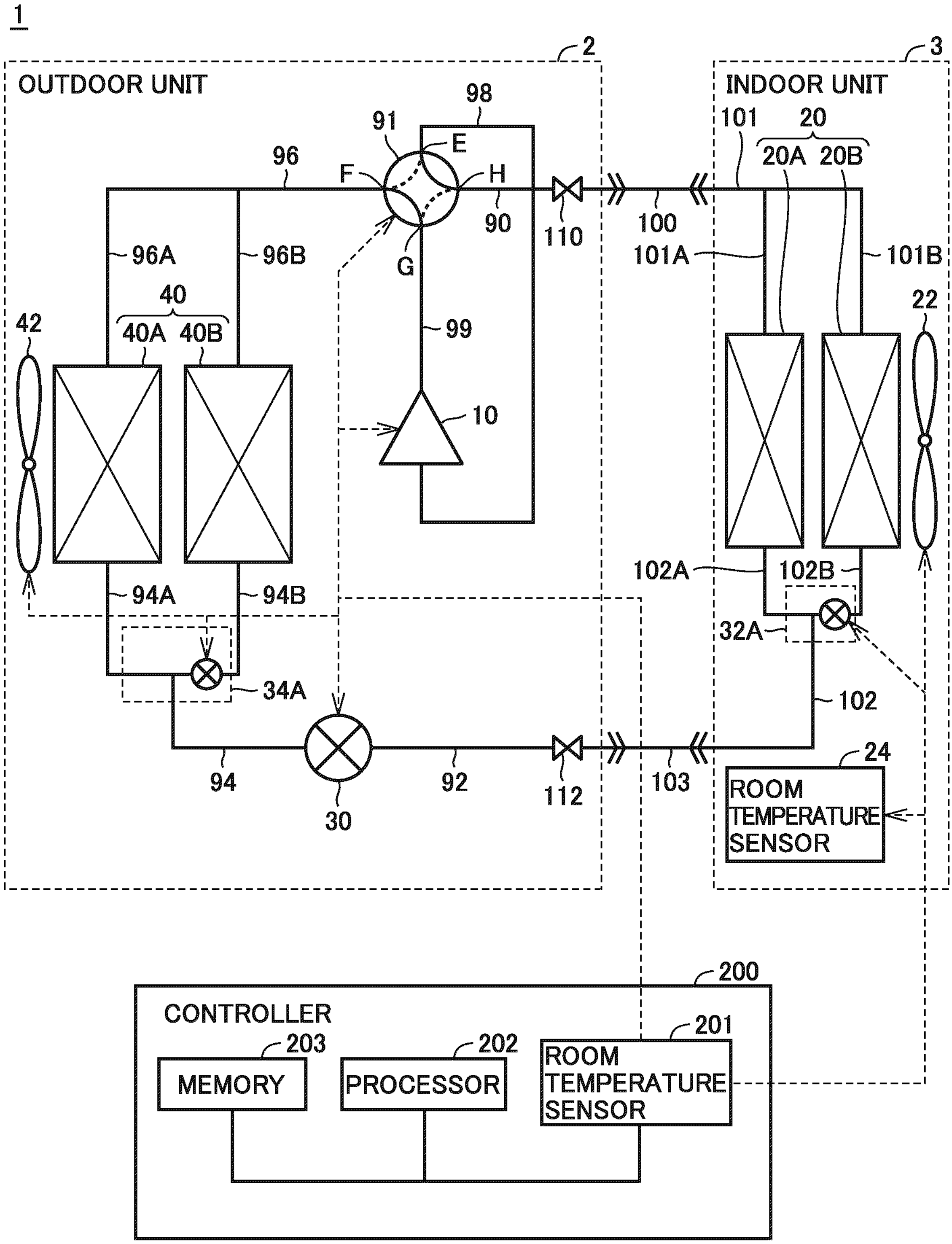

DURING HEATING OPERATION
START
S11
INDOOR TEMPERATURE > SET TEMPERATURE
NO
YES
S12
FREQUENCY f > fmin
NO
YES
S13
COMPRESSOR FREQUENCY f = f − δ2
S14
INDOOR TEMPERATURE > SET TEMPERATURE
YES
NO
S15
COMPRESSOR FREQUENCY f = f + δ1
S16
START OPERATION OF STORING REFRIGERANT
OPENING DEGREE OF FLOW RATE REGULATING VALVE 32 L = Lmax
S17
INDOOR TEMPERATURE > SET TEMPERATURE
YES
NO
S18
CONTROL OPENING DEGREE OF FLOW RATE REGULATING VALVE 32
VALVE OPENING DEGREE L = L − δ3
S19
L = Lmin
YES
NO
S22
STOP COMPRESSOR
S20
END CONTROL OF OPENING DEGREE OF FLOW RATE REGULATING VALVE 32
S21
RETURN

FIG.10

	NORMAL AIR CONDITIONER (COMPRESSOR CONTROL ONLY)	COMPRESSOR CONTROL + REFRIGERANT STORAGE CONTROL
LOWER LIMIT CAPABILITY (RATED CAPABILITY RATIO)	15%	10% (RATIO TO NORMAL AIR CONDITIONER: 66.7%)

FIG.11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OUTDOOR UNIT
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96B
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40A 40B
42
99
10
22
94A
94B
102A
102B
32A
34A
102
30
94
92
112
103
24
ROOM TEMPERATURE SENSOR
200
CONTROLLER
203
MEMORY
202
PROCESSOR
201
ROOM TEMPERATURE SENSOR

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/002650

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F25B1/00(2006.01)i, F25B5/02(2006.01)i, F25B6/02(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int. Cl. F25B1/00, F25B5/02, F25B6/02

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2019
Registered utility model specifications of Japan	1996-2019
Published registered utility model applications of Japan	1994-2019

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 61-44259 A (HITACHI, LTD.) 03 March 1986, page 2, upper right column, line 9 to page 5, lower right column, line 3, fig. 1-5 (Family: none)	1-2 3
Y	JP 64-6657 A (MATSUSHITA REFRIGERATION CO.) 11 January 1989, page 3, upper left column, line 14 to page 4, lower right column, line 17, fig. 1, 2 (Family: none)	3

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

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27.03.2019	09.04.2019

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

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Patent documents cited in the description

- JP 5639664 B **[0004] [0006]**