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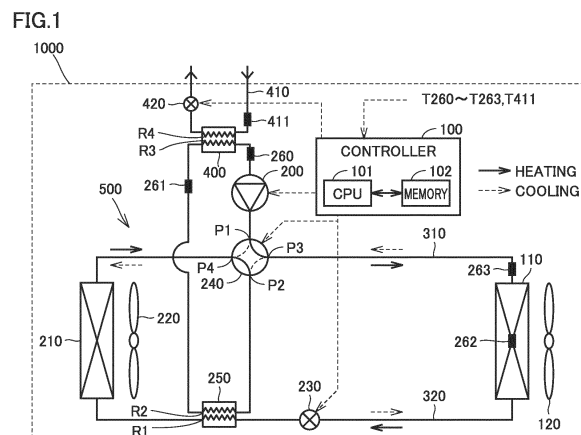
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(54) **AIR CONDITIONER**

(57) An air conditioner (1000) includes: a refrigerant circuit (500) configured to circulate refrigerant; a first heat exchanger (250) having a first flow path (R1) in which the refrigerant having passed through a condenser (210) flows, and a second flow path (R2) in which the refrigerant to be suctioned into a compressor (200) flows; a second heat exchanger (400) having a third flow path (R3) in which the refrigerant directed from an outlet of the second flow path (R2) toward the compressor (200) flows, and

a fourth flow path (R4) in which a heat medium flows; a flow rate adjusting device (420) configured to adjust an amount of the heat medium supplied to the second heat exchanger (400); a temperature sensor (411) configured to detect a temperature of the heat medium; and a controller (100) configured to control the flow rate adjusting device (420) in accordance with an output of the temperature sensor (411).



Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] Due to requirements by European refrigerant regulations and the like, it has been required to use refrigerant having a low global warming potential (GWP) also as refrigerant used for a refrigeration cycle of an air conditioner. Japanese Patent Laying-Open No. 2009-162403 (PTL 1) discloses an air conditioner that uses HC refrigerant having a low GWP, that is, propane (R290) or isobutane, as refrigerant for a refrigerant circuit. This air conditioner uses an internal heat exchanger in order to increase efficiency.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Patent Laying-Open No. 2009-162403

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] However, when the internal heat exchanger is used, the density of the refrigerant suctioned into a compressor decreases. Accordingly, there may be a case where the performance of a refrigeration cycle is not sufficiently improved even though the internal heat exchanger is provided. Further, in a case where an attempt is made to increase the amount of heat exchange in the internal heat exchanger, as heat exchange between high-temperature refrigerant and low-temperature refrigerant within the internal heat exchange proceeds, the temperature difference between the refrigerants decreases, and thus heat exchange efficiency is worsened. Accordingly, it is necessary to increase lengths of flow paths for the refrigerants that exchange heat in the internal heat exchanger, and there has been a problem that the internal heat exchanger becomes too large.

[0005] The present disclosure has been made in order to solve the aforementioned problem, and an object thereof is to disclose an air conditioner capable of achieving further improved performance of a refrigeration cycle that uses an internal heat exchanger, while keeping the internal heat exchanger to have a small size.

SOLUTION TO PROBLEM

[0006] The present disclosure relates to an air conditioner. The air conditioner includes: a refrigerant circuit

including at least a compressor, a condenser, an expansion valve, and an evaporator, the refrigerant circuit being configured to circulate refrigerant; a first heat exchanger having a first flow path in which the refrigerant that has passed through the condenser flows, and a second flow path in which the refrigerant that is to be suctioned into the compressor flows, and being configured to exchange heat between the refrigerant flowing through the first flow path and the refrigerant flowing through the second flow path; a second heat exchanger having a third flow path in which the refrigerant directed from an outlet of the second flow path toward the compressor flows, and a fourth flow path in which a heat medium flows, and being configured to exchange heat between the refrigerant flowing through the third flow path and the heat medium flowing through the fourth flow path; a flow rate adjusting device configured to adjust an amount of the heat medium supplied to the second heat exchanger; a temperature sensor configured to detect a temperature of the heat medium; and a controller configured to control the flow rate adjusting device in accordance with an output of the temperature sensor.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] The air conditioner according to the present disclosure can obtain an effect caused by an increase in enthalpy difference in the evaporator without reducing the density of the refrigerant suctioned into the compressor. This enables further improved performance of a refrigeration cycle that uses an internal heat exchanger.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is a view showing a configuration of an air conditioner 1000 according to a first embodiment.

Fig. 2 is a view showing a configuration of an air conditioner 2000 in a study example.

Fig. 3 is a PH diagram of a refrigeration cycle that uses R290 refrigerant and has no internal heat exchanger, in the configuration in the study example.

Fig. 4 is a PH diagram of a refrigeration cycle that uses the R290 refrigerant and has an internal heat exchanger, in the configuration in the study example.

Fig. 5 is a PH diagram of a refrigeration cycle that uses the R290 refrigerant and has an internal heat exchanger and an external heat exchanger, in the configuration in the first embodiment.

Fig. 6 is a perspective view showing an external appearance of an internal heat exchanger 250.

Fig. 7 is a cross-sectional view of internal heat exchanger 250 in a cross section F1 in Fig. 6.

Fig. 8 is a perspective view showing an external appearance of an external heat exchanger 400.

Fig. 9 is a cross-sectional view of external heat exchanger 400 in a cross section F2 in Fig. 8.

Fig. 10 is a flowchart for illustrating control of a flow rate adjusting device 420 during cooling.

Fig. 11 is a flowchart for illustrating control of an expansion valve 230 during cooling.

Fig. 12 is a view showing a configuration of an air conditioner 1001 having sensors used during heating added thereto.

Fig. 13 is a flowchart for illustrating control of flow rate adjusting device 420 during heating.

Fig. 14 is a view showing a configuration of an air conditioner 1002 according to a second embodiment.

DESCRIPTION OF EMBODIMENTS

[0009] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the drawings. In the following, a plurality of embodiments will be described, and it is originally intended from the time of filing the present application to combine configurations described in the embodiments as appropriate. It should be noted that identical or corresponding parts in the drawings will be designated by the same reference characters, and the description thereof will not be repeated. In the following drawings, the relation between components in terms of size may be different from the actual one.

First Embodiment

[0010] Fig. 1 is a view showing a configuration of an air conditioner 1000 according to a first embodiment. Air conditioner 1000 shown in Fig. 1 includes a refrigerant circuit 500, an internal heat exchanger 250, an external heat exchanger 400, a flow rate adjusting device 420, and a controller 100.

[0011] Refrigerant circuit 500 includes at least a compressor 200, an outdoor heat exchanger 210, an expansion valve 230, and an indoor heat exchanger 110, and is configured to circulate refrigerant. As the refrigerant, R290 is used, for example. In the example in Fig. 1, refrigerant circuit 500 is constituted by compressor 200, outdoor heat exchanger 210, an outdoor blower 220, expansion valve 230, a four-way valve 240, indoor heat exchanger 110, and an indoor blower 120. Four-way valve 240 has ports P1 to P4. As expansion valve 230, an electronic expansion valve (LEV: Linear Expansion Valve) can be used, for example.

[0012] Compressor 200 is configured to change its operating frequency, in accordance with a control signal received from controller 100. Specifically, compressor 200 includes therein a drive motor variable in rotational speed under inverter control and, when the operating frequency is changed, the rotational speed of the drive motor is changed. By changing the operating frequency of compressor 200, an output of compressor 200 is adjusted. Compressor 200 of any of various types such as rotary type, reciprocating type, scroll type, and screw type, for example, may be employed.

[0013] Four-way valve 240 is controlled into one of a cooling operation state and a heating operation state, by a control signal received from controller 100. The cooling operation state refers to a state in which port P1 and port P4 communicate with each other and port P2 and port P3 communicate with each other, as indicated by broken lines. The heating operation state refers to a state in which port P1 and port P3 communicate with each other and port P2 and port P4 communicate with each other, as indicated by solid lines. By operating compressor 200 in the cooling operation state, the refrigerant circulates through the refrigerant circuit in a direction indicated by broken-line arrows. Further, by operating compressor 200 in the heating operation state, the refrigerant circulates through the refrigerant circuit in a direction indicated by solid-line arrows.

[0014] Internal heat exchanger 250 includes a flow path R1 and a flow path R2. In flow path R1, high-pressure and high-temperature refrigerant that has passed through a condenser (outdoor heat exchanger 210) flows during cooling. In flow path R2, low-pressure and low-temperature refrigerant that is suctioned by compressor 200 flows. Internal heat exchanger 250 is configured to exchange heat between the high-pressure and high-temperature refrigerant having passed through the condenser (outdoor heat exchanger 210) and the low-pressure and low-temperature refrigerant to be suctioned by compressor 200, during cooling.

[0015] External heat exchanger 400 includes a flow path R3 and a flow path R4. In flow path R3, the refrigerant directed from an outlet of second flow path R2 toward compressor 200 flows. In flow path R4, external heat medium for cooling conveyed through a flow path 410 flows. External heat exchanger 400 is configured to exchange heat between the refrigerant that flows through flow path R3 and the external heat medium for cooling that flows through flow path R4. Here, water is used as the heat medium for cooling. The water may be circulated such that it passes through internal heat exchanger 250, then is cooled at a cooling tower or the like, and thereafter is supplied again through flow path 410, for example. Further, drain water from an evaporator, tap water, groundwater, or the like may flow without circulation. It is sufficient as long as the heat medium can cool the internal heat exchanger, and a flow path through which the heat medium passes may not necessarily be provided inside. For example, external heat exchanger 400 may be cooled by spraying water from outside.

[0016] Flow rate adjusting device 420 adjusts the amount of the heat medium such as water supplied to external heat exchanger 400 to cool external heat exchanger 400. As flow rate adjusting device 420, a control valve having an opening degree that changes from 0 to 100% in accordance with a control signal, or the like can be used, for example.

[0017] Air conditioner 1000 further includes temperature sensors 260 to 263 and 411. Temperature sensor 260 is arranged on a suction pipe of compressor 200 to

measure a suction temperature T260 of the refrigerant. Temperature sensor 261 is arranged on a pipe that connects flow path R2 of internal heat exchanger 250 and flow path R3 of external heat exchanger 400 to measure a refrigerant temperature T261. Temperature sensor 262 is arranged in indoor heat exchanger 110 to measure a refrigerant temperature T262, which serves as an evaporation temperature during cooling and as a condensation temperature during heating. Temperature sensor 263 is arranged on a pipe that connects indoor heat exchanger 110 and port P3 of four-way valve 240 to measure a refrigerant temperature T263.

[0018] Temperature sensor 411 detects a temperature T411 of the heat medium such as water. If the water temperature is lower than the temperature of the low-pressure refrigerant at an inlet portion of external heat exchanger 400 obtained by temperature sensor 261, the water can cool external heat exchanger 400. Thus the temperature of the low-pressure refrigerant having its temperature increased through heat exchange with the high-pressure refrigerant in internal heat exchanger 250 can be reduced.

[0019] Controller 100 is configured to control flow rate adjusting device 420 in accordance with an output of temperature sensor 411. Further, controller 100 controls the opening degree of expansion valve 230 to adjust an SH (superheat) of the refrigerant at an outlet portion of the evaporator.

[0020] Controller 100 has a configuration including a CPU (Central Processing Unit) 101, a memory 102 (ROM (Read Only Memory) and a RAM (Random Access Memory)), input/output buffers (not shown), and the like. CPU 101 expands programs stored in the ROM onto the RAM or the like and executes the programs. The programs stored in the ROM are programs describing processing procedures of controller 100. In accordance with these programs, controller 100 performs control of devices in air conditioner 1000. This control can be processed not only by software but also by dedicated hardware (electronic circuitry).

[0021] Fig. 2 is a view showing a configuration of an air conditioner 2000 in a study example. Air conditioner 1000 in Fig. 1 includes external heat exchanger 400 that can be cooled with water, whereas air conditioner 2000 differs from air conditioner 1000 in that air conditioner 2000 does not include external heat exchanger 400. Internal heat exchanger 550 shown in Fig. 2 is configured to exchange heat between high-temperature and high-pressure refrigerant that has flowed out of an outlet of outdoor heat exchanger 210 and low-temperature and low-pressure refrigerant that is suctioned into compressor 200 during cooling.

[0022] How the PH diagram changes due to such a difference in the internal heat exchanger will be described below using Figs. 3 to 5.

[0023] Fig. 3 is a PH diagram of a refrigeration cycle that uses R290 refrigerant and has no internal heat exchanger, in the configuration in the study example. Fig.

4 is a PH diagram of a refrigeration cycle that uses the R290 refrigerant and has an internal heat exchanger, in the configuration in the study example. Fig. 5 is a PH diagram of a refrigeration cycle that uses the R290 refrigerant and has an internal heat exchanger and an external heat exchanger, in the configuration in the first embodiment.

[0024] The result in the case of having no internal heat exchanger shown in Fig. 3 was calculated under the conditions of a suction superheat (SH) of 5 deg, a supercool (SC) of 5 deg, an evaporation temperature (ET) of 17°C, a condensation temperature (CT) of 40°C, and a compressor efficiency of 1. On the other hand, the result in the case of having an internal heat exchanger shown in Fig. 4 was calculated assuming that the low-temperature and low-pressure refrigerant at an outlet of an evaporator exchanged heat with the high-temperature and high-pressure refrigerant at an outlet of a condenser by means of internal heat exchanger 550, and as a result the temperature thereof increased by 10°C. Since the capacity of the compressor is the same in both Figs. 3 and 4, evaporation temperature (ET) is the same regardless of the evaporator outlet temperature.

[0025] Here, the reason why the performance of the refrigeration cycle is improved by using external heat exchanger 400 for the refrigeration cycle that uses the R290 refrigerant will be described. It can be seen from the comparison between Fig. 3 and Fig. 4 that, in the case of using external heat exchanger 400, an enthalpy difference between an inlet and the outlet of the evaporator increases by Δh [kJ/kg]. Actually, enthalpy difference Δh_e of the evaporator in Fig. 3 is represented by $\Delta h_e = h(A1) - h(D1) = 309.7$, whereas enthalpy difference Δh_e of the evaporator in Fig. 4 is represented by $\Delta h_e = h(A2) - h(D2) = 328.8$, indicating that enthalpy difference Δh_e of the evaporator increases by $\Delta h = 19.1$ (6.2%) which is the amount of heat exchange in the internal heat exchanger.

[0026] On the other hand, a suction density ρ_s [kg/m³] in the case of having no internal heat exchanger is represented by $\rho_s = 16.22$, whereas suction density ρ_s in the case of having an internal heat exchanger is represented by $\rho_s = 15.38$, indicating a decrease by $\Delta \rho = 0.84$ (5.2%). A capability Q is represented by $Q = Gr \Delta h_e$ ($\propto \rho_s \Delta h_e$) using a circulation flow rate Gr. Therefore, it is found that capability Q can be increased if an increased amount of evaporator enthalpy difference Δh_e acts more greatly than a decreased amount of suction density ρ_s by using an internal heat exchanger.

[0027] As capability Q increases, a COP of air conditioning equipment increases. Actually, in the case of using the R290 refrigerant, the increased amount of evaporator enthalpy difference Δh_e acts more greatly than the decreased amount of suction density ρ_s as described above, and thus it is possible to improve the COP of the air conditioning equipment by using an internal heat exchanger.

[0028] However, when internal heat exchanger 550 is

used, a compressor suction point deviates to the right to cross an isothermal line, a gas temperature rises, and the suction density decreases. Accordingly, the effect caused by the increase in evaporator enthalpy difference cannot necessarily be enjoyed to the maximum. For example, in the case of using refrigerant such as R32 or R410, the decrease in suction density and the increase in evaporator enthalpy difference offset each other, and thus the effect of the internal heat exchanger cannot be obtained. Further, in a case where an attempt is made to increase the amount of heat exchange in the internal heat exchanger, as heat exchange between high-temperature refrigerant and low-temperature refrigerant within the internal heat exchange proceeds, the temperature difference between the refrigerants decreases, and thus heat exchange efficiency is worsened. Accordingly, it is necessary to increase lengths of flow paths for the refrigerants that exchange heat in the internal heat exchanger, and the internal heat exchanger becomes too large.

[0029] In contrast, in the present embodiment, the refrigerant to be suctioned into compressor 200 is cooled by external heat exchanger 400. While the compressor suction point is deviated to the right to cross the isothermal line in Fig. 4, this deviation can be eliminated. Thus, reduction of the suction density can be avoided. When the PH diagram of the refrigerant circuit in the present embodiment is calculated under the same conditions as those in Fig. 4 (an evaporation temperature of 17°C, a condensation temperature of 40°C, an evaporator superheat of 5 deg, a supercool of 5 deg, and a compressor efficiency of 1), the PH diagram as shown in Fig. 5 is obtained. It should be noted that the calculation was made assuming that the temperature of the water as an external cooling source was 22°C.

[0030] In the example shown in Fig. 5, the enthalpy at the high-pressure side refrigerant outlet of internal heat exchanger 250 becomes smaller than that in the case of using ordinary internal heat exchanger 550, and the evaporator enthalpy difference increases to $h(D3)-h(A3)$.

[0031] Concerning suction density ρ_s , in the case of using ordinary internal heat exchanger 550, it is represented by $\rho_s = 15.4 \text{ kg/m}^3$ as described above, whereas in the case of using internal heat exchanger 250 and external heat exchanger 400, it increases to $\rho_s = 16.2 \text{ kg/m}^3$ because a suction temperature also decreases to 22°C.

[0032] As described above, in the configuration shown in Fig. 1, it is possible to decrease a specific enthalpy at the inlet of the evaporator to increase enthalpy difference Δh_e in the evaporator and improve COP. More preferably, when the temperature of the water is lower than the temperature of the low-pressure refrigerant obtained by temperature sensor 261, heat exchange using the water is performed in external heat exchanger 400. In this manner, in addition to the effect of the increase in evaporator enthalpy difference, the suction density of compressor 200 can be increased, and further, COP can be improved,

when compared with the case of using internal heat exchanger 550 that does not use an external cooling medium. Further, when the temperature of the water is higher than the temperature of the high-pressure refrigerant at the inlet of internal heat exchanger 250, it is more preferable to prevent the water from being conveyed to internal heat exchanger 250.

[0033] Fig. 6 is a perspective view showing an external appearance of internal heat exchanger 250. Fig. 7 is a cross-sectional view of internal heat exchanger 250 in a cross section F1 in Fig. 6. Internal heat exchanger 250 shown in Figs. 6 and 7 has a double-tube structure including an inner tube 251 and an outer tube 252. Inner tube 251 serves as a flow path R1 through which the low-pressure refrigerant returning to a suction portion of compressor 200 flows. Outer tube 252 serves as a flow path R2 through which the high-pressure refrigerant that has flowed out of the outlet of outdoor heat exchanger 210 flows. As indicated by arrows in Fig. 7, the refrigerant that flows through flow path R1 and the refrigerant that flows through flow path R2 have a relation of counterflows.

[0034] Fig. 8 is a perspective view showing an external appearance of external heat exchanger 400. Fig. 9 is a cross-sectional view of external heat exchanger 400 in a cross section F2 in Fig. 8. External heat exchanger 400 shown in Figs. 8 and 9 has a double-tube structure including an inner tube 401 and an outer tube 402. Inner tube 401 serves as a flow path R3 through which the low-pressure refrigerant returning to the suction portion of compressor 200 flows. Flow path R3 is located between flow path R2 and the suction portion of compressor 200. Outer tube 402 serves as a flow path R4 through which water externally conveyed through flow path 410 flows. As indicated by arrows in Fig. 9, the refrigerant that flows through flow path R3 and the refrigerant that flows through flow path R4 have a relation of counterflows.

[0035] It should be noted that, although the water may flow through inner tube 401 and the low-pressure refrigerant may flow through outer tube 402, flowing the water through outer tube 402 is more advantageous in the following point.

[0036] For example, if a crack appears in the outer circumference of outer tube 402, it is the water that may leak to the outside of external heat exchanger 400, which is less problematic than the case where the refrigerant flows through outer tube 402. In particular, when an inflammable refrigerant is used as the refrigerant, the inflammable refrigerant can be prevented from being discharged to the outside. Further, when a chlorofluorocarbon-based refrigerant is used, the refrigerant is less likely to leak to the outside, which can suppress influence on global warming.

[0037] In the present embodiment, external heat exchanger 400 includes flow path R4, the cooling medium that flows through flow path R4 is water, and external heat exchanger 400 is of a double-tube type. It should be noted that the cooling medium may not be water. Fur-

ther, external heat exchanger 400 may not be of a double-tube type, but may be a plate-type heat exchanger or the like. Further, a flow path through which the cooling medium such as water flows may not be a closed space. For example, flow path R3 of internal heat exchanger 250 may be a tube, and the tube may be immersed in a groove-like water channel to cool refrigerant flowing through flow path R3. Moreover, the pipe to the suction inlet of compressor 200 may be cooled by spraying water. Furthermore, although internal heat exchanger 250 is installed to act during cooling, no problem occurs when it is installed to act during heating.

[0038] Regarding internal heat exchanger 250 as well, internal heat exchanger 250 may be a plate heat exchanger or the like, for example, instead of the double tube. It may also be in the form where a low-pressure pipe and a high-pressure pipe contact each other by means of solder or the like to allow heat to be exchanged.

[0039] Moreover, instead of using temperature sensor 260 that measures the temperature of the refrigerant to be suctioned, the water temperature at the outlet may be obtained to estimate the suction temperature from the amount of heat exchange by the water.

[0040] In Fig. 1, the flow of the refrigerant during heating is indicated by solid-line arrows, and the flow of the refrigerant during cooling is indicated by broken-line arrows. As in an ordinary air conditioner, controller 100 changes the frequency of compressor 200 such that a room temperature reaches a target (setting) temperature. Further, controller 100 controls flow rate adjusting device 420 during cooling, as described below.

[0041] Fig. 10 is a flowchart for illustrating control of flow rate adjusting device 420 during cooling. First, in step S11, controller 100 obtains refrigerant temperature T261 at the outlet of flow path R2 of internal heat exchanger 250 from temperature sensor 261, and obtains temperature T411 of the water from temperature sensor 411. In step S12, controller 100 determines whether or not temperature T261 obtained from temperature sensor 261 is higher than temperature T411 obtained from temperature sensor 411.

[0042] When $T261 > T411$ is not satisfied (NO in S12), the temperature of the water is higher and thus cannot be used to cool the refrigerant in external heat exchanger 400, and therefore, in step S13, controller 100 controls flow rate adjusting device 420 to be fully closed, to prevent the water from flowing to external heat exchanger 400. On the other hand, when $T261 > T411$ is satisfied (YES in S12), in step S14, controller 100 controls flow rate adjusting device 420 to be fully opened.

[0043] Subsequently, in step S15, controller 100 determines whether a superheat of the suctioned refrigerant (hereinafter referred to as a suction SH) is smaller than a determination value α (> 0). The suction SH is calculated by subtracting the evaporation temperature obtained by temperature sensor 262 from the suction temperature obtained by temperature sensor 260. Here, determination value α is set to a value at which it is possible

to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, for example, 5K.

[0044] When the suction $SH \geq \alpha$ is satisfied (NO in S15), it is possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, and thus controller 100 exits the flowchart in Fig. 10. On the other hand, when the suction $SH < \alpha$ is satisfied (YES in S15), it is not possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, that is, liquid refrigerant may be suctioned into compressor 200. Therefore, in step S16, controller 100 closes flow rate adjusting device 420 by a certain opening degree. By decreasing the flow rate of the water in this manner to reduce the amount of heat exchange, the value of the suction SH can be increased. Thereafter, the processing in step S15 is performed again.

[0045] It should be noted that, although the flow rate of the water to internal heat exchanger 250 is adjusted using flow rate adjusting device 420 in the present embodiment, the flow rate of the water may be controlled using a pump.

[0046] Next, control of expansion valve 230 during cooling will be described. Fig. 11 is a flowchart for illustrating control of expansion valve 230 during cooling.

[0047] First, in step S21, controller 100 determines whether or not a superheat of the refrigerant at the outlet portion of the evaporator (hereinafter referred to as an evaporator outlet SH) is smaller than a determination value β (≥ 0). The evaporator outlet SH is calculated by subtracting evaporation temperature T262 obtained by temperature sensor 262 from evaporator outlet temperature T263 obtained by temperature sensor 263. Here, determination value β is set to a value smaller than determination value α . For example, when determination value α is 5K, determination value β is set to 2K. The reason for setting determination value β to be smaller than determination value α is that, since the evaporator has a good heat exchange efficiency when it is used with the refrigerant being in a gas-liquid two phase state, it is desired to control the state of the refrigerant in the evaporator to minimize gas refrigerant.

[0048] When the evaporator outlet $SH \geq \beta$ is satisfied (NO in S21), it is possible to determine that the refrigerant at the outlet of the evaporator is gasified. Therefore, in step S22, controller 100 opens the opening degree of expansion valve 230 by a certain value. Thereby, the value of the evaporator outlet SH can be decreased. Thereafter, the processing in step S21 is performed again.

[0049] On the other hand, when the evaporator outlet $SH < \beta$ is satisfied (YES in S21), it is determined that the refrigerant at the outlet of the evaporator is not gasified (i.e., the evaporator is used efficiently). Therefore, in step S23, controller 100 determines whether flow rate adjusting device 420 is fully closed.

[0050] When flow rate adjusting device 420 is not fully closed (NO in S23), the suction SH is controlled to an appropriate value by flow rate adjusting device 420 as

shown in steps S15 and S16 in Fig. 10, and thus controller 100 temporarily exits the processing of the flowchart in Fig. 11. On the other hand, when flow rate adjusting device 420 is fully closed (YES in S23), heat exchange with the externally supplied water is not performed in external heat exchanger 400, and thereby the evaporator outlet $SH \approx$ the suction SH is satisfied. Accordingly, the suction $SH \approx \beta (< \alpha)$ is satisfied, which leads to a state where the refrigerant suctioned into compressor 200 is not heated appropriately. Therefore, in step S24, controller 100 closes the opening degree of expansion valve 230 by a certain value to increase the value of the suction SH , and thereafter performs determination processing in step S25.

[0051] In step S25, controller 100 determines whether or not the suction SH is smaller than determination value $\alpha (> 0)$. When the suction $SH \geq \alpha$ is satisfied (NO in S25), it is possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, and thus controller 100 temporarily exits the processing of the flowchart in Fig. 11. On the other hand, when the suction $SH < \alpha$ is satisfied (YES in S25), it is not possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, that is, liquid refrigerant may be suctioned into compressor 200. Therefore, in step S26, controller 100 closes the opening degree of expansion valve 230 by a certain value. By controlling the opening degree of expansion valve 230 in this manner, the value of the suction SH can be increased. Thereafter, the processing in step S25 is performed again.

[0052] The flows of control of flow rate adjusting device 420 and expansion valve 230 during cooling have been described above.

[0053] During heating, flow rate adjusting device 420 may be fully closed and controlled as in an ordinary air conditioner, or flow rate adjusting device 420 may be controlled as described below.

[0054] Fig. 12 is a view showing a configuration of an air conditioner 1001 having sensors used during heating added thereto. Specifically, air conditioner 1001 further includes temperature sensors 264, 265 in addition to the configuration of air conditioner 1000 shown in Fig. 1. Fig. 13 is a flowchart for illustrating control of flow rate adjusting device 420 during heating.

[0055] First, in step S31, controller 100 obtains outlet refrigerant temperature T_{261} of flow path R2 of internal heat exchanger 250 from temperature sensor 261, and obtains temperature T_{411} of the water from temperature sensor 411. In step S32, controller 100 determines whether or not temperature T_{261} obtained from temperature sensor 261 is higher than temperature T_{411} obtained from temperature sensor 411.

[0056] When $T_{261} > T_{411}$ is not satisfied (NO in S32), the temperature of the water is higher and thus cannot be used to cool the refrigerant in external heat exchanger 400. Therefore, in step S33, controller 100 controls flow rate adjusting device 420 to be fully closed, to prevent the water from flowing to external heat exchanger 400.

On the other hand, when $T_{261} > T_{411}$ is satisfied (YES in S32), in step S34, controller 100 controls flow rate adjusting device 420 to be fully opened.

[0057] Subsequently, in step S35, controller 100 determines whether the superheat of the suctioned refrigerant (suction SH) is smaller than determination value $\alpha (> 0)$. The suction SH is calculated by subtracting an evaporation temperature T_{264} obtained by temperature sensor 264 from suction temperature T_{260} obtained by temperature sensor 260. Here, determination value α is set to a value at which it is possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, for example, 5K.

[0058] When the suction $SH \geq \alpha$ is satisfied (NO in S35), it is possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, and thus controller 100 temporarily exits the flowchart in Fig. 13. On the other hand, when the suction $SH < \alpha$ is satisfied (YES in S35), it is not possible to determine that the refrigerant suctioned into compressor 200 is sufficiently gasified, that is, liquid refrigerant may be suctioned into compressor 200. Therefore, in step S36, controller 100 closes flow rate adjusting device 420 by a certain opening degree. By decreasing the flow rate of the water in this manner to reduce the amount of heat exchange, the value of the suction SH can be increased. Thereafter, the processing in step S35 is performed again.

[0059] It should be noted that, also during heating, the flow rate of the water may be controlled using a pump instead of flow rate adjusting device 420.

[0060] For the control of expansion valve 230 during heating, it is only necessary to perform the same processing as that performed during cooling shown in Fig. 11. However, the evaporator outlet SH is calculated by subtracting the evaporation temperature obtained by temperature sensor 264 from the value of temperature sensor 265.

[0061] As has been described above, according to the air conditioner in the first embodiment, the coefficient of performance, COP, of the air conditioner that uses R290 as the refrigerant and uses an internal heat exchanger can be improved. Further, while using R290 as the refrigerant is most effective, even when R32 or R410 is used as the refrigerant, the effect caused by an internal heat exchanger can be obtained and COP can be improved, because the suction density changes from that in the case shown in Fig. 2.

[0062] Further, also when internal heat exchanger 250 is used during heating, the evaporator enthalpy difference increases as is the case during cooling, and improved efficiency can be expected.

Second Embodiment

[0063] In the configuration in Fig. 1 described in the first embodiment, an air heat exchanger is employed as outdoor heat exchanger 210, considering the case that

the cooling source for the refrigeration cycle is not in a situation where it can always be used. For example, when tap water is employed, there may be a case where it cannot be used due to suspension of water supply or the like. Therefore, in order to cause the refrigeration cycle to always function, it is appropriate to employ outdoor air, which can always be utilized, as a target of heat exchange of outdoor heat exchanger 210. Further, when a water-refrigerant heat exchanger is employed as outdoor heat exchanger 210, it is also necessary to draw a water pipe. Accordingly, the configuration as in Fig. 1 is employed to achieve a simple configuration.

[0064] However, when the cooling source can be stably secured, it may be better to downsize the outdoor heat exchanger. Fig. 14 is a view showing a configuration of an air conditioner 1002 according to a second embodiment.

[0065] Only a difference from the configuration shown in Fig. 1 will be described. In air conditioner 1002 shown in Fig. 14, outdoor heat exchanger 210 in Fig. 1 is changed to a heat exchanger 270. Unlike outdoor heat exchanger 210, heat exchanger 270 is configured to exchange heat with the water as the external cooling source. The water may be circulated and cooled at a cooling tower or the like, and then is supplied again through a water supply pipe, for example. When hot water warmed by heat exchanger 270 is used, tap water or the like may newly be supplied. Heat exchanger 270 is a plate heat exchanger, for example. Further, the water used by heat exchanger 270 and internal heat exchanger 250 is supplied through the same water supply pipe.

[0066] It should be noted that, since the control of flow rate adjusting device 420 and expansion valve 230 is the same as that in the first embodiment, the description thereof will not be repeated.

[0067] In air conditioner 1002 in the second embodiment, the same effect as that in the first embodiment is obtained. In addition, since the amount of heat exchange by the water increases when compared with the configuration shown in the first embodiment, the returned water has a higher temperature and can be used for hot-water supply or the like. Further, since plate heat exchanger 270 is employed as the outdoor heat exchanger and thereby heat exchange performance is improved, the heat exchanger can be downsized when compared with the first embodiment.

(Supplement)

[0068] Although the refrigerant circuit includes a four-way valve in the first and second embodiments described above, external heat exchanger 400 may be used for an air conditioner for cooling only that does not include a four-way valve.

[0069] Further, although the first and second embodiments have provided the description based on an example where the R290 refrigerant is used as refrigerant circulating through the refrigerant circuit, another refriger-

ant such as R32 or R410 may be used. For example, in the case of using R32 refrigerant, since influence of the increase in enthalpy difference in the evaporator and influence of the decrease in the density of the suctioned refrigerant offset each other in internal heat exchanger 550 shown in the study example in Fig. 2, there is no merit in introducing the R32 refrigerant. In contrast, since external heat exchanger 400 shown in Fig. 1 can suppress the decrease in the density of the suctioned refrigerant using the external cooling source, the performance of the air conditioner can be improved even in the case of using the R32 refrigerant.

(Conclusion)

[0070] The present embodiment will be summarized below with reference to the drawings again. It should be noted that items within parentheses describe units applicable during cooling.

[0071] Air conditioner 1000 shown in Fig. 1 includes: refrigerant circuit 500 including at least compressor 200, a condenser (outdoor heat exchanger 210), expansion valve 230, and an evaporator (indoor heat exchanger 110), the refrigerant circuit being configured to circulate refrigerant; a first heat exchanger (internal heat exchanger 250) having first flow path R1 in which the refrigerant that has passed through the condenser (outdoor heat exchanger 210) flows, and second flow path R2 in which the refrigerant that is to be suctioned into compressor 200 flows, and being configured to exchange heat between the refrigerant flowing through first flow path R1 and the refrigerant flowing through second flow path R2; a second heat exchanger (external heat exchanger 400) having third flow path R3 in which the refrigerant directed from an outlet of second flow path R2 toward compressor 200 flows, and fourth flow path R4 in which a heat medium flows, and being configured to exchange heat between the refrigerant flowing through third flow path R3 and the heat medium flowing through fourth flow path R4; flow rate adjusting device 420 configured to adjust an amount of heat medium supplied to the second heat exchanger (external heat exchanger 400); temperature sensor 411 configured to detect a temperature of the heat medium; and controller 100 configured to control flow rate adjusting device 420 in accordance with an output of temperature sensor 411.

[0072] Preferably, as shown in Fig. 10, controller 100 is configured to control flow rate adjusting device 420 such that the heat medium is supplied to the second heat exchanger (external heat exchanger 400) when temperature T411 of the heat medium is lower than temperature T261 of the refrigerant flowing into the second heat exchanger (external heat exchanger 400). Controller 100 is configured to control flow rate adjusting device 420 such that the heat medium is not supplied to the second heat exchanger (external heat exchanger 400) when temperature T411 of the heat medium is higher than temperature T261 of the refrigerant flowing into the second

heat exchanger (external heat exchanger 400).

[0073] Preferably, as shown in Figs. 8 and 9, the second heat exchanger (external heat exchanger 400) is a double-tube heat exchanger in which inner tube 401 and outer tube 402 are arranged. Inner tube 401 is third flow path R3 in which refrigerant flows, and outer tube 402 is fourth flow path R4 in which the heat medium flows.

[0074] Preferably, as shown in Fig. 14, the condenser (outdoor heat exchanger 270) is configured to exchange heat between the heat medium and the refrigerant.

[0075] Preferably, the refrigerant is propane.

[0076] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present disclosure is defined by the scope of the claims, rather than the description of the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the scope of the claims.

REFERENCE SIGNS LIST

[0077] 100: controller; 101: CPU; 102: memory; 110, 210, 250, 270, 325, 400, 550: heat exchanger; 120: indoor blower; 200: compressor; 220: outdoor blower; 230: expansion valve; 240: four-way valve; 251, 401: inner tube; 252, 402: outer tube; 260 to 265, 411: temperature sensor; 410, R1, R2, R3, R4: flow path; 420: flow rate adjusting device; 500: refrigerant circuit; 1000, 1001, 1002, 2000: air conditioner; P1, P2, P3, P4: port.

Claims

1. An air conditioner comprising:

a refrigerant circuit including at least a compressor, a condenser, an expansion valve, and an evaporator, the refrigerant circuit being configured to circulate refrigerant;
a first heat exchanger having a first flow path in which the refrigerant that has passed through the condenser flows, and a second flow path in which the refrigerant to be suctioned into the compressor flows, and being configured to exchange heat between the refrigerant flowing through the first flow path and the refrigerant flowing through the second flow path;
a second heat exchanger having a third flow path in which the refrigerant directed from an outlet of the second flow path toward the compressor flows, and a fourth flow path in which a heat medium flows, and being configured to exchange heat between the refrigerant flowing through the third flow path and the heat medium flowing through the fourth flow path;
a flow rate adjusting device configured to adjust an amount of the heat medium supplied to the second heat exchanger;

a temperature sensor configured to detect a temperature of the heat medium; and
a controller configured to control the flow rate adjusting device in accordance with an output of the temperature sensor.

2. The air conditioner according to claim 1, wherein

the controller is configured to control the flow rate adjusting device such that the heat medium is supplied to the second heat exchanger when the temperature of the heat medium is lower than a temperature of the refrigerant that is to flow into the second heat exchanger, and the controller is configured to control the flow rate adjusting device such that the heat medium is not supplied to the second heat exchanger when the temperature of the heat medium is higher than the temperature of the refrigerant that is to flow into the second heat exchanger.

3. The air conditioner according to claim 1 or 2, wherein

the second heat exchanger is a double-tube heat exchanger in which an inner tube and an outer tube are arranged, the inner tube is the third flow path through which the refrigerant flows, and the outer tube is the fourth flow path through which the heat medium flows.

4. The air conditioner according to any one of claims 1 to 3, wherein the condenser is configured to exchange heat between the heat medium and the refrigerant.

5. The air conditioner according to any one of claims 1 to 4, wherein the refrigerant is propane.

FIG.1

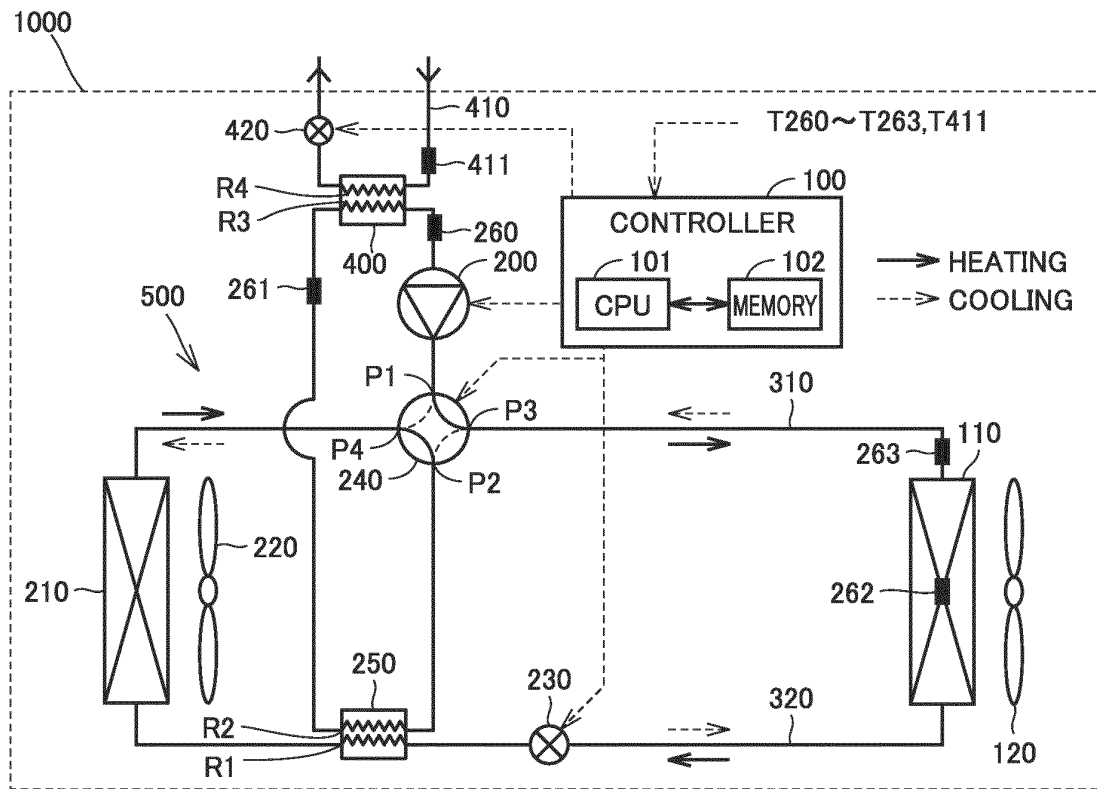


FIG.2

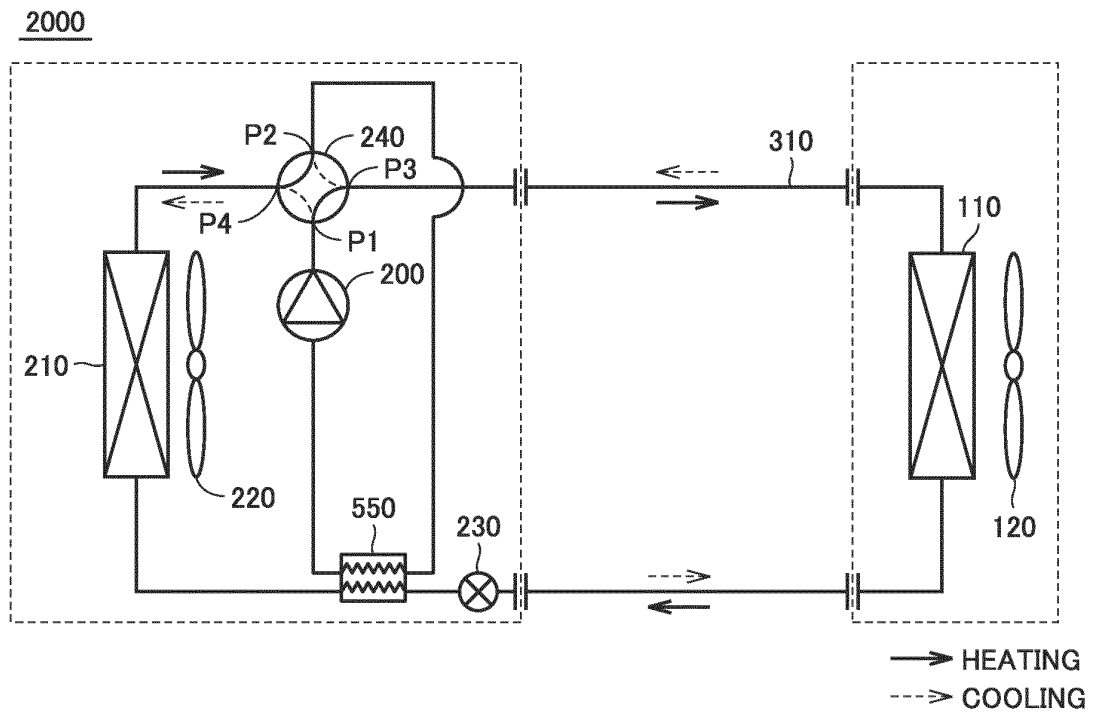


FIG.3 IN THE CASE OF HAVING NO INTERNAL HEAT EXCHANGER

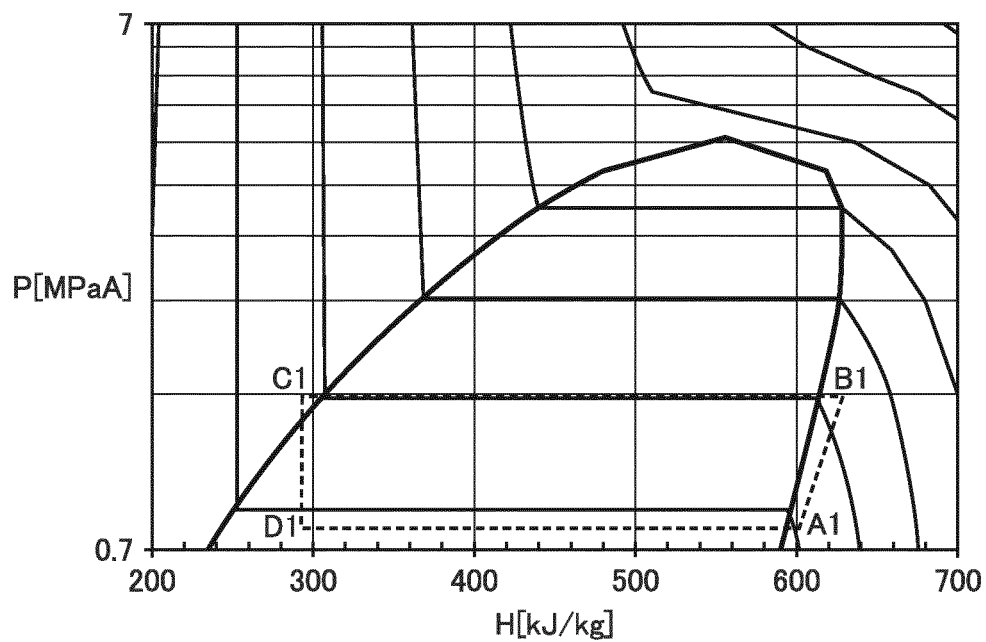


FIG.4 IN THE CASE OF HAVING INTERNAL HEAT EXCHANGER

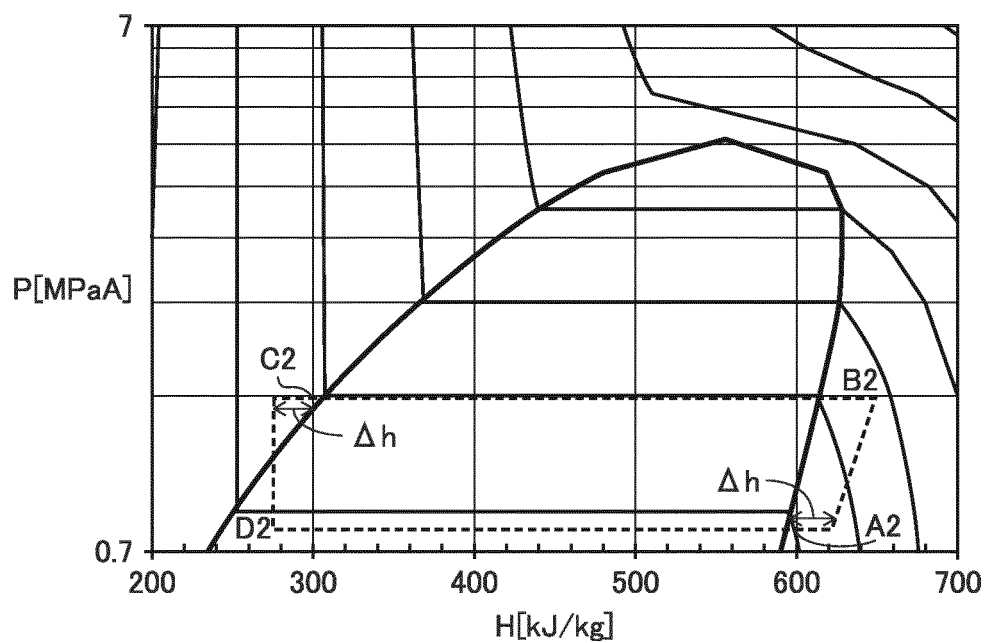


FIG.5

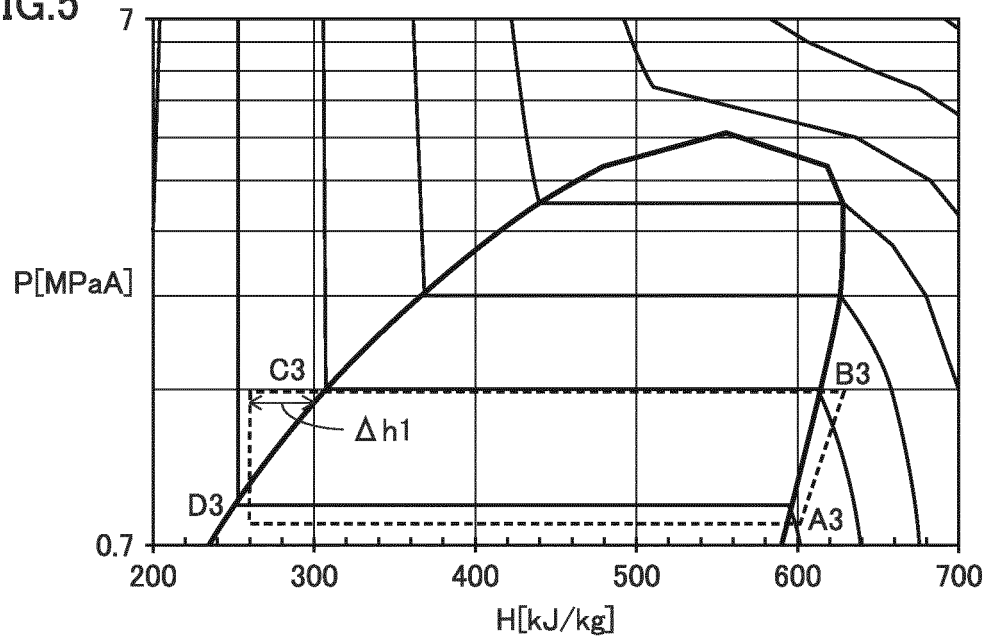


FIG.6

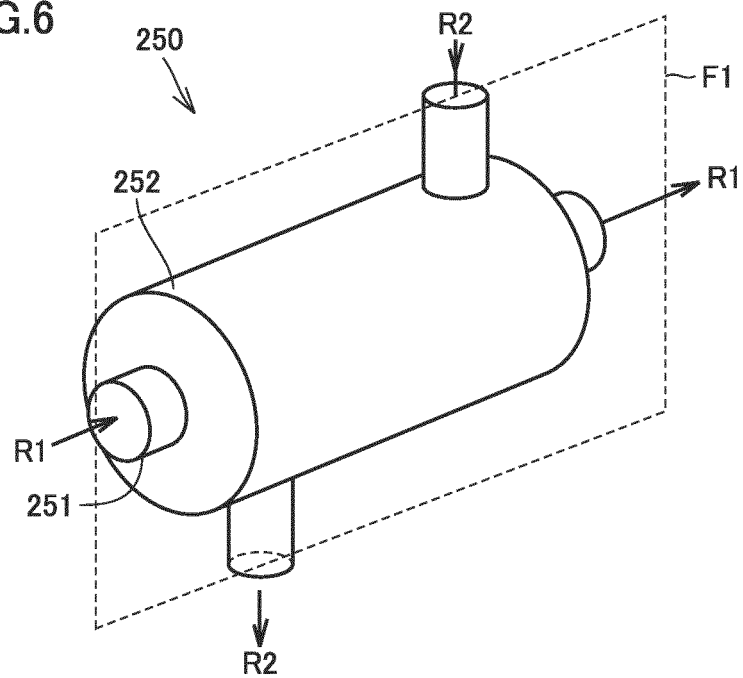


FIG.7

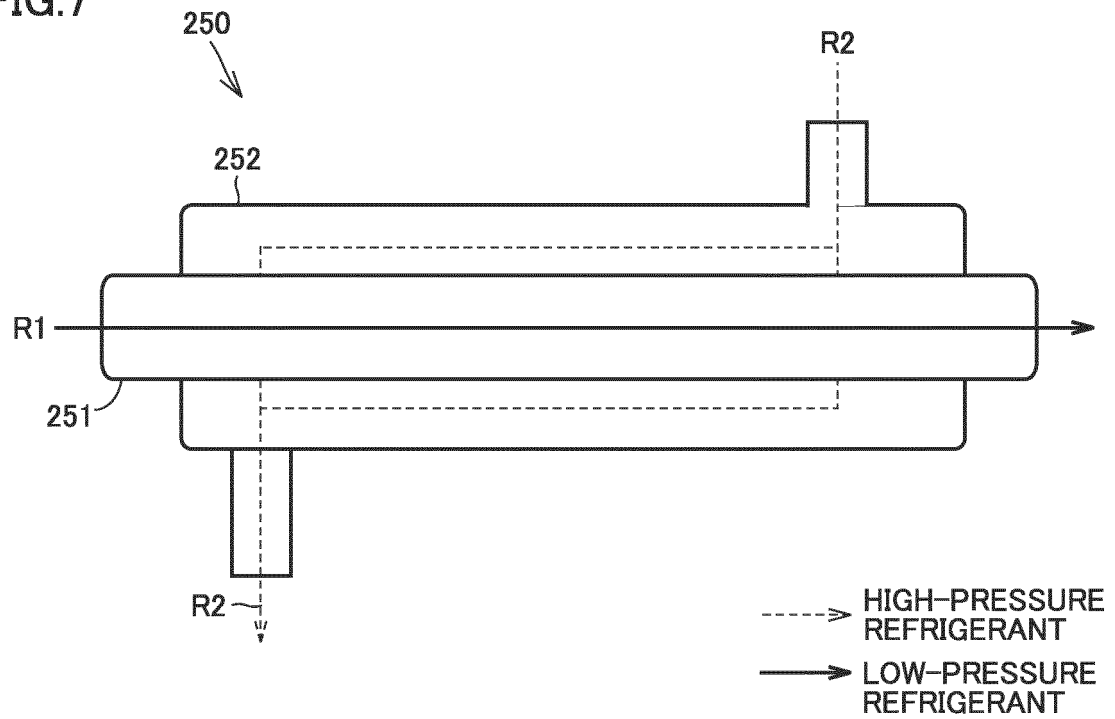


FIG.8

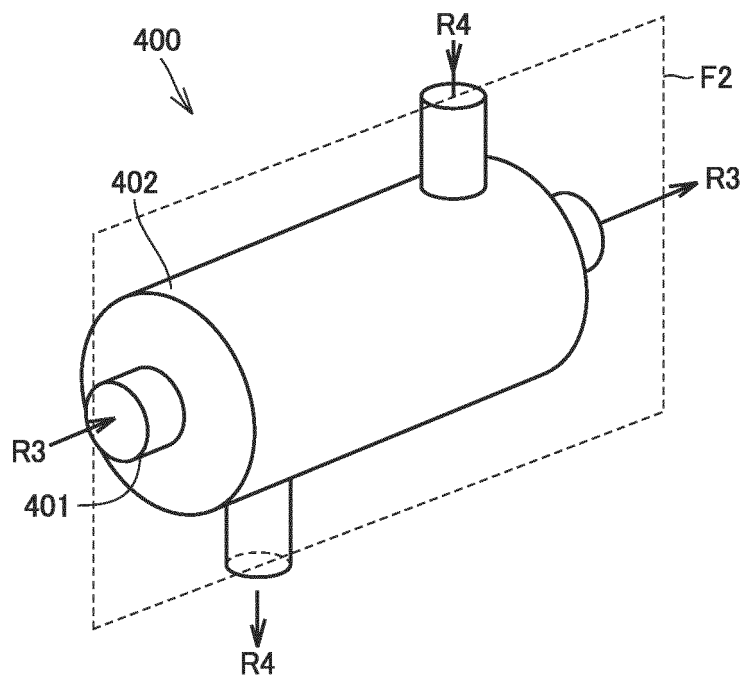


FIG.9

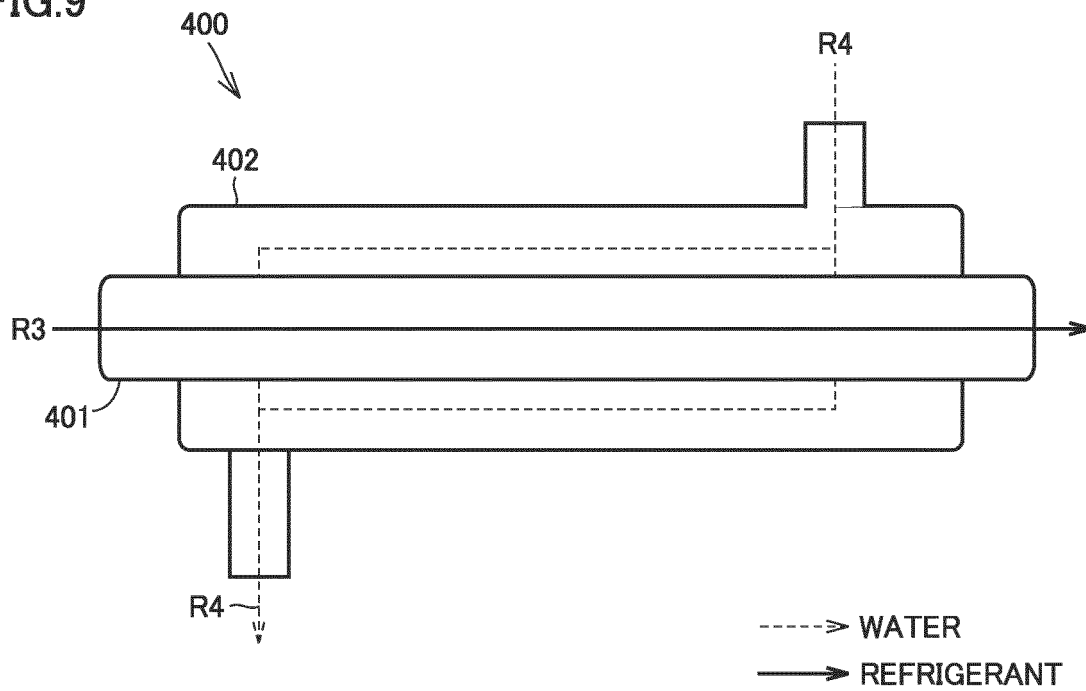


FIG.10

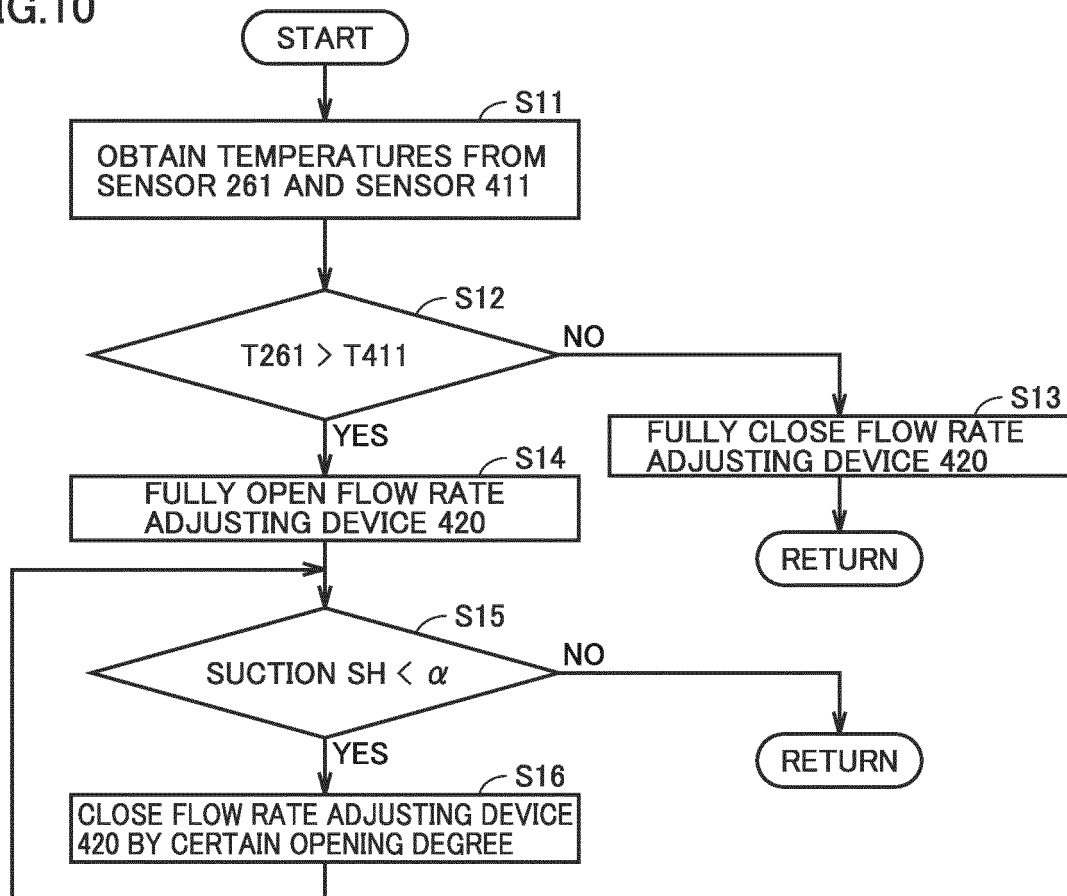


FIG.11

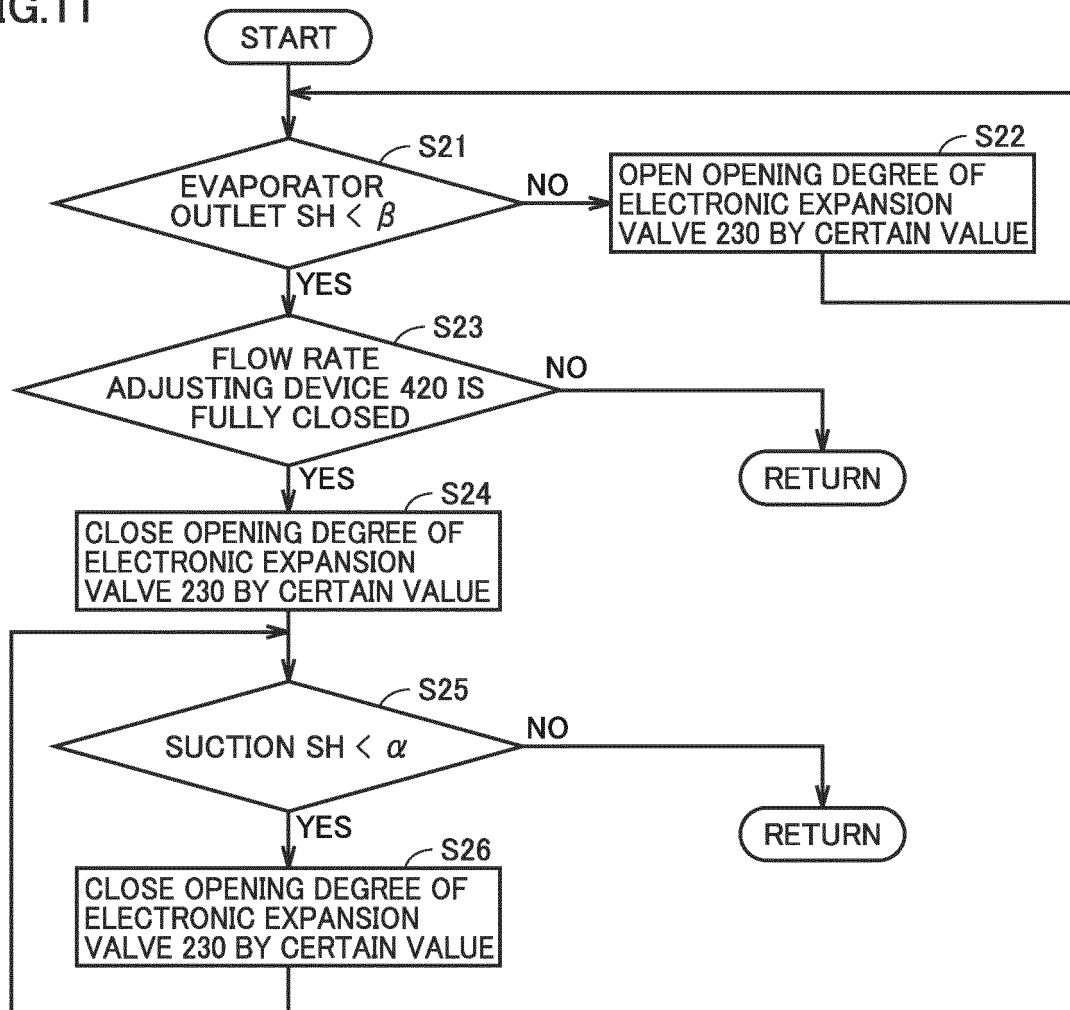


FIG.12

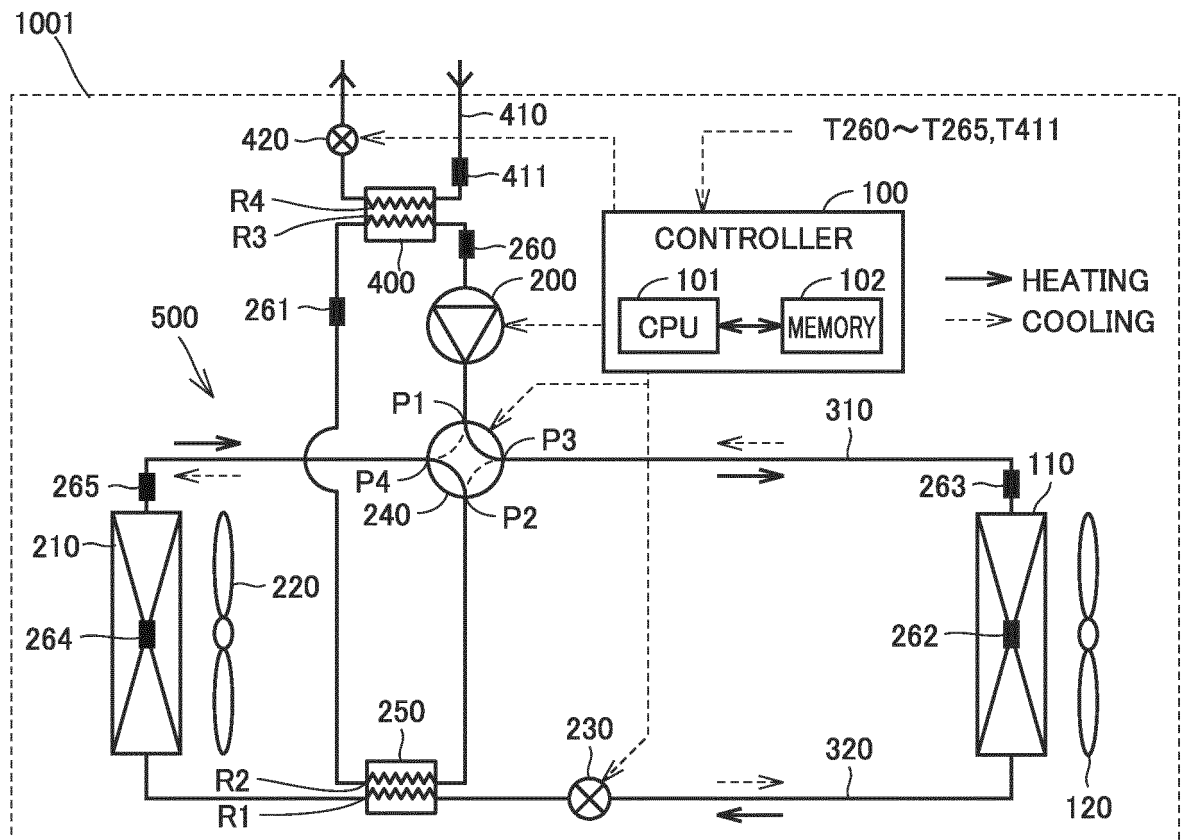


FIG.13

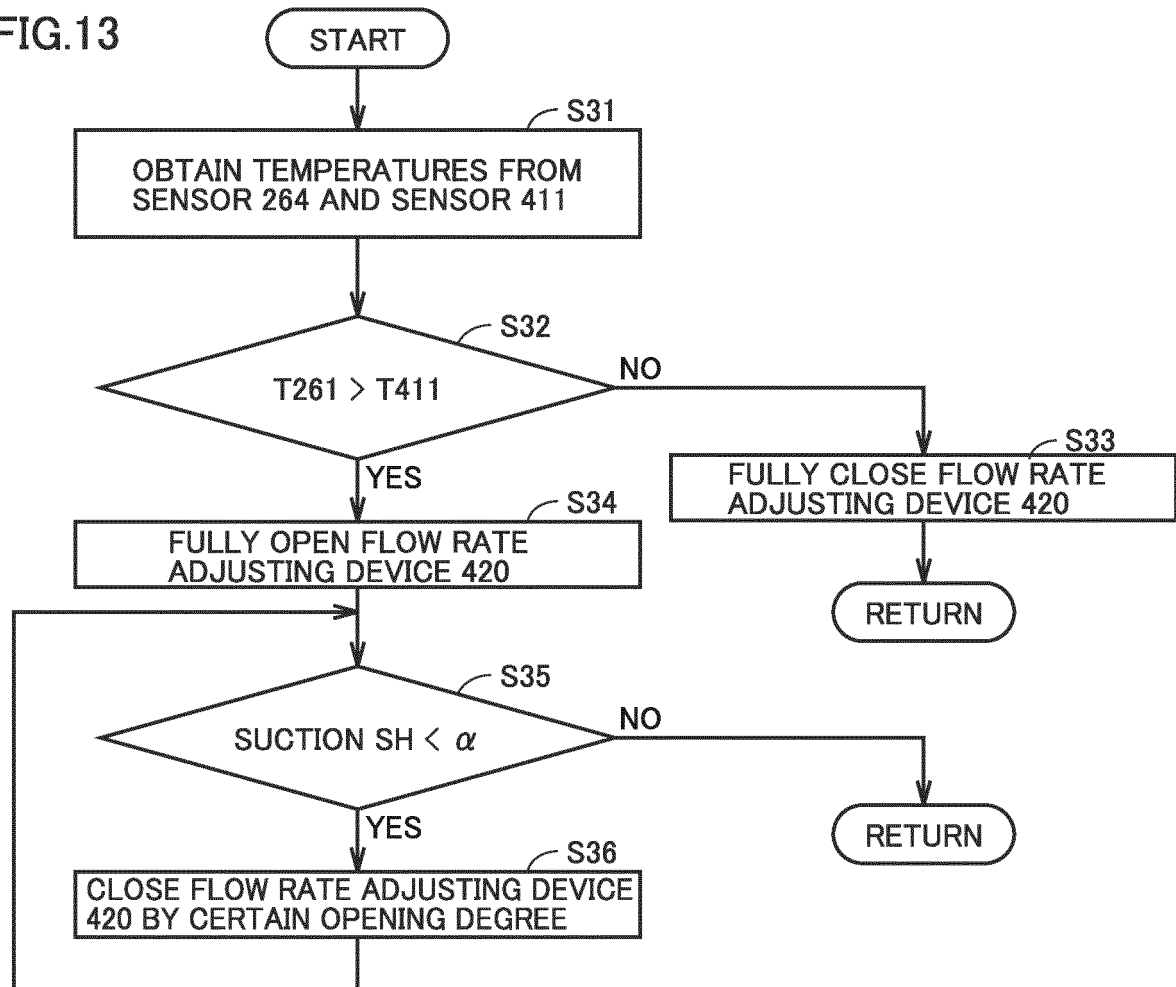
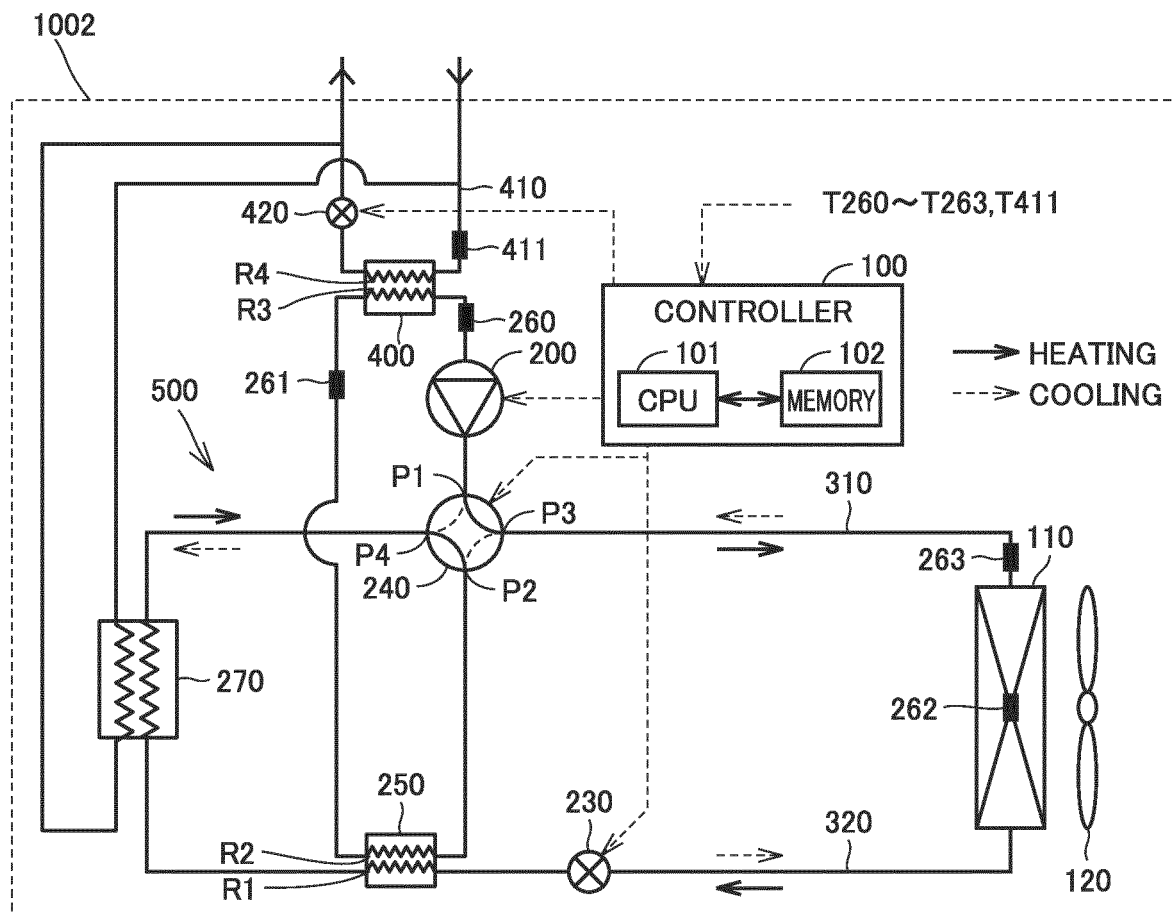


FIG.14



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/033771

5	A. CLASSIFICATION OF SUBJECT MATTER F25B 1/00 (2006.01)i FI: F25B1/00 399Y According to International Patent Classification (IPC) or to both national classification and IPC		
10	B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) F25B1/00 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 1971-2021 Registered utility model specifications of Japan 1996-2021 Published registered utility model applications of Japan 1994-2021 Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
15	C. DOCUMENTS CONSIDERED TO BE RELEVANT		
20	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
25	Y A	JP 2016-125714 A (DAIKIN INDUSTRIES, LTD.) 11 July 2016 (2016-07-11) paragraphs [0037]-[0084], fig. 1	1, 3-5 2
30	Y A	WO 2019/155614 A1 (MITSUBISHI ELECTRIC CORP.) 15 August 2019 (2019-08-15) claim 3, paragraphs [0029], [0030], [0040], [0041], fig. 2	1, 3-5 2
35	Y	JP 2013-249988 A (SAN DEN CORP.) 12 December 2013 (2013-12-12) claim 1, fig. 5	3-5
40	Y	JP 2006-194518 A (DAIKIN INDUSTRIES, LTD.) 27 July 2006 (2006-07-27) claim 3, fig. 16	4-5
45	Y	JP 2009-162403 A (TOSHIBA CARRIER CORP.) 23 July 2009 (2009-07-23) paragraph [0002]	5
50	☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
55	* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "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		
50	Date of the actual completion of the international search 22 October 2021		Date of mailing of the international search report 16 November 2021
55	Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan		Authorized officer Telephone No.

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/JP2021/033771

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	2016-125714	A	11 July 2016	(Family: none)	
WO	2019/155614	A1	15 August 2019	(Family: none)	
JP	2013-249988	A	12 December 2013	(Family: none)	
JP	2006-194518	A	27 July 2006	(Family: none)	
JP	2009-162403	A	23 July 2009	(Family: none)	

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- JP 2009162403 A [0002] [0003]