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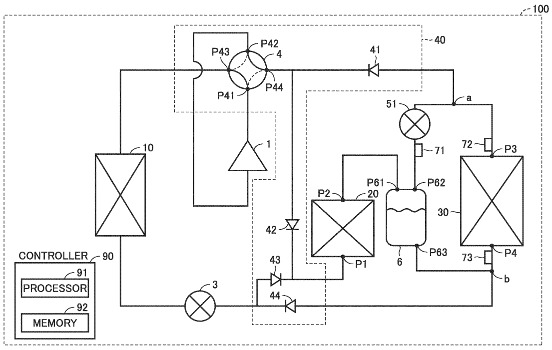
(54) REFRIGERATION CYCLE DEVICE

(57) A refrigeration cycle apparatus (100) includes a compressor (1), a first heat exchanger (10), a second heat exchanger (20), a third heat exchanger (30), an expansion device (3), a gas-liquid separator (6), a first flow rate control device (51), and a switch device (40) configured to switch a route in which refrigerant circulates between a first route and a second route. In the first route, the refrigerant flows in order of the compressor (1), the first heat exchanger (10), the expansion device (3), the second heat exchanger (20), and the gas-liquid separator (6), and then, the refrigerant in liquid state discharged from the gas-liquid separator (6) flows into the third heat exchanger (30). In the second route, the refrigerant flows in order of the compressor (1), the second heat exchanger (20), and the gas-liquid separator (6), and then, the refrigerant in gaseous state discharged from the gas-liquid separator (6) flows through the first flow rate control device (51) into the third heat exchanger (30).

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND ART

[0002] In recent years, the development of a refrigeration cycle apparatus using a zeotropic refrigerant mixture has been pursued partly under the influence of a lowered regulation value of global warming potential (GWP). Japanese Utility Model Publication No. 62-025644 (PTL 1) proposes a refrigeration cycle apparatus using a zeotropic refrigerant mixture described below. Such a refrigeration cycle apparatus includes a compressor, a condenser, a decompressor, a first evaporator, a second evaporator, and a gas-liquid separator, which are connected, and is configured to guide refrigerant in gaseous state separated in the gas-liquid separator to an inlet side of the compressor and guide refrigerant in liquid state separated in the gas-liquid separator to the second evaporator.

CITATION LIST

PATENT LITERATURE

[0003] PTL 1: Japanese Utility Model Publication No. 62-025644

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] The technique described in PTL 1 can improve the efficiency of operating a refrigeration cycle by separating the refrigerant into refrigerant in gaseous state and refrigerant in liquid state by the gas-liquid separator before guiding the refrigerant in liquid state to the second evaporator. PTL 1, however, discloses a technique of exclusively applying the gas-liquid separator to the evaporator. As a result, a system in which a heat exchanger is caused to function not only as an evaporator but also as a condenser fails to efficiently utilize such a technique.

[0005] The present disclosure has been made to solve the above problem. An object of the present disclosure is to provide a refrigeration cycle apparatus that can have operating efficiency improved with the use of a gas-liquid separator when a heat exchanger is caused to function as either an evaporator or a condenser.

SOLUTION TO PROBLEM

[0006] The present disclosure relates to a refrigeration cycle apparatus. The refrigeration cycle apparatus includes a compressor, a first heat exchanger, a second heat exchanger, a third heat exchanger, an expansion device, a gas-liquid separator, a first flow rate control device, and a switch device. The switch device is configured to switch a refrigerant circulation path between a first route corresponding to a first operation mode and a second route corresponding to a second operation mode. In the first route, refrigerant flows in order of the compressor, the first heat exchanger, the expansion device, the second heat exchanger, and the gas-liquid separator, the refrigerant in liquid state discharged from the gas-liquid separator flows into the third heat exchanger, the refrigerant in gaseous state discharged from the gas-liquid separator joins, through the first flow rate control device, the refrigerant discharged from the third heat exchanger at a first junction point, and the refrigerant after joining at the first junction point flows to the compressor. In the second route, the refrigerant flows in order of the compressor, the second heat exchanger, and the gas-liquid separator, the refrigerant in gaseous state discharged from the gas-liquid separator flows through the first flow rate control device into the third heat exchanger, the refrigerant in liquid state discharged from the gas-liquid separator joins the refrigerant discharged from the third heat exchanger at a second junction point, and the refrigerant after joining at the second junction point flows in order of the expansion device, the first heat exchanger, and the compressor.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] The refrigeration cycle apparatus according to the present disclosure can have operating efficiency improved with the use of the gas-liquid separator when the heat exchanger is caused to function as either an evaporator or a condenser.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

Fig. 1 is a refrigerant circuit diagram showing a configuration of a refrigeration cycle apparatus (Embodiment 1).
Fig. 2 shows a refrigerant flow in a first operation mode of the refrigeration cycle apparatus (Embodiment 1).
Fig. 3 shows a refrigerant flow in a second operation mode of the refrigeration cycle apparatus (Embodiment 1).
Fig. 4 is a p-h diagram showing changes in the state of refrigerant in the first operation mode (Embodiment 1).
Fig. 5 is a p-h diagram showing changes in the state of refrigerant in the second operation mode (Embodiment 1).
Fig. 6 is a flowchart for describing control of a controller in the first operation mode (Embodiment 1).
Fig. 7 is a flowchart for describing control of the controller in the second operation mode (Embodiment 1).
Fig. 8 is a refrigerant circuit diagram showing a configuration of a refrigeration cycle apparatus (Embodiment 2).
Fig. 9 is a refrigerant circuit diagram showing a configuration of a refrigeration cycle apparatus (Embodiment 3).
Fig. 10 is a flowchart for describing control of a controller in the second operation mode (Embodiment 3).

DESCRIPTION OF EMBODIMENTS

[0009] Embodiments of the present disclosure will be described below in detail with reference to the drawings. The same or corresponding parts will be designated by the same reference numerals, and description thereof will not be repeated.

Embodiment 1

[0010] Fig. 1 is a refrigerant circuit diagram showing a configuration of a refrigeration cycle apparatus 100 according to Embodiment 1. Refrigeration cycle apparatus 100 includes a refrigerant circuit composed of at least a compressor 1, an expansion device 3, a four-way valve 4, a gas-liquid separator 6, a first heat exchanger 10, a second heat exchanger 20, a third heat exchanger 30, a first flow rate control device 51, and a controller 90.

[0011] First heat exchanger 10 is mounted in an indoor unit. Second heat exchanger 20 and third heat exchanger 30 are mounted in an outdoor unit. A gas-liquid separator 6 is disposed between second heat exchanger 20 and third heat exchanger 30. This configuration is equivalent to a configuration in which a heat exchanger on the outdoor unit side is divided into two heat exchangers, and gas-liquid separator 6 is disposed between one of the heat exchangers and the other heat exchanger.

[0012] Second heat exchanger 20 has a first port P1 and a second port P2. Third heat exchanger 30 has a third port P3 and a fourth port P4.

[0013] Gas-liquid separator 6 includes an inflow port P61, a gas discharge port P62, and a liquid discharge port P63. A first flow rate control device 51, which adjusts a flow rate of the refrigerant, is provided between gas discharge port P62 and third heat exchanger 30. First flow rate control device 51 includes a valve for adjusting a flow rate of the refrigerant. First flow rate control device 51 adjusts a degree of opening of the valve to change a flow rate of the refrigerant.

[0014] The refrigerant discharged from second port P2 of second heat exchanger 20 flows into inflow port P61. Gas discharge port P62 is connected via first flow rate control device 51 to third port P3 of third heat exchanger 30. Gas discharge port P62 discharges the refrigerant in gaseous state from gas-liquid separator 6. Liquid discharge port P63 is connected to fourth port P4 of third heat exchanger 30. Liquid discharge port P63 discharges the refrigerant in liquid state from gas-liquid separator 6.

[0015] Hereinbelow, the refrigerant in gaseous state is referred to as gaseous refrigerant, and the refrigerant in liquid state is referred to as liquid refrigerant. When it is not necessary to refer to whether the state of refrigerant is the gaseous state or the liquid state, the term "refrigerant" is merely used.

[0016] Four-way valve 4 has a first switch port P41, a second switch port P42, a third switch port P43, and a fourth switch port P44. An outlet port of compressor 1 is connected to first switch port P41, and an inlet port of compressor 1 is connected to second switch port P42.

[0017] The refrigerant circuit of refrigeration cycle apparatus 100 is provided with a first check valve 41, a second check valve 42, a third check valve 43, and a fourth check valve 44.

[0018] First check valve 41 is provided between fourth switch port P44 of four-way valve 4 and a point a, shown in Fig. 1, on the refrigerant circuit. Point a corresponds to a first junction point at which the refrigerant discharged from third port P3 of third heat exchanger 30 joins the refrigerant discharged from first flow rate control device 51. First check valve 41 interrupts a flow of the refrigerant from fourth switch port P44 toward first junction point a.

[0019] Second check valve 42 is provided between fourth switch port P44 of four-way valve 4 and first port P1 of second heat exchanger 20. Second check valve 42 interrupts a flow of the refrigerant from expansion device 3 toward fourth switch port P44 of four-way valve 4.

[0020] Third check valve 43 is provided among fourth switch port P44, expansion device 3, and first port P1 of second heat exchanger 20. Third check valve 43 interrupts a flow of the refrigerant from the fourth switch port toward expansion device 3.

[0021] Fourth check valve 44 is provided between expansion device 3 and a point b, shown in Fig. 1, on the refrigerant circuit. Point b corresponds to a second junction point at which the refrigerant discharged from fourth port P4 of third heat exchanger 30 joins the refrigerant discharged from liquid discharge port P63 of gas-liquid separator 6. Fourth check valve 44 interrupts a flow of the refrigerant from expansion device 3 to second junction point b.

[0022] Four-way valve 4 changes between a first state and a second state. In the first state, first switch port P41 communicates with third switch port P43, and second switch port P42 communicates with fourth switch port P44. In the second state, first switch port P41 communicates with fourth switch port P44, and second switch port P42 communicates with third switch port P43.

[0023] Four-way valve 4 changes between the first state and the second state, thus switching the direction in which the refrigerant discharged from compressor 1 flows through a flow path. As four-way valve 4, first check valve 41, second check valve 42, third check valve 43, and fourth check valve 44 function, the order in which the refrigerant circulates is switched between a first order and a second order. Thus, the operation mode of refrigeration cycle apparatus 100 is switched between the first operation mode and the second operation mode.

[0024] In the first operation mode, high-pressure refrigerant flows into first heat exchanger 10. In the second operation mode, low-pressure refrigerant flows into first heat exchanger 10. When first heat exchanger 10 is mounted in the indoor unit, the first operation mode corresponds to a heating operation, and the second operation mode corresponds to a cooling operation. Controller 90 sets four-way valve 4 to the first state in the first operation mode and sets four-way valve 4 to the second state in the second operation mode.

[0025] Four-way valve 4, first check valve 41, second check valve 42, third check valve 43, and fourth check valve 44 constitute switch device 40 that switches the operation mode. Switch device 40 switches the route in which the refrigerant discharged from compressor 1 circulates between a first route corresponding to the first operation mode and a second route corresponding to the second operation mode.

[0026] The refrigerant circuit of refrigeration cycle apparatus 100 is provided with a plurality of temperature sensors including a first temperature sensor 71, a second temperature sensor 72, and a third temperature sensor 73.

[0027] First temperature sensor 71 is provided on the side of gas-liquid separator 6 on which the refrigerant in gaseous state is discharged. More specifically, first temperature sensor 71 is provided between first flow rate control device 51 and the side of gas-liquid separator 6 on which the refrigerant in gaseous state is discharged.

[0028] Second temperature sensor 72 is provided on the third port P3 side of third heat exchanger 30. More specifically, second temperature sensor 72 is provided between first junction point a and the third port P3 side of third heat exchanger 30.

[0029] Third temperature sensor 73 is provided on the fourth port P4 side of third heat exchanger 30. More specifically, third temperature sensor 73 is provided between second junction point b and the fourth port P4 side of third heat exchanger 30.

[0030] Controller 90 includes a processor 91 and a memory 92. Memory 92 includes a Read Only Memory (ROM) and a Random Access Memory (RAM). Processor 91 deploys a program stored in the ROM to the RAM or the like and executes the program. The program stored in the ROM is a program in which a procedure of controller 90 is described.

[0031] Controller 90 controls each device in refrigeration cycle apparatus 100 according to the program stored in memory 92. For example, controller 90 controls compressor 1, expansion device 3, four-way valve 4, and first flow rate control device 51.

[0032] Next, refrigerant flows in the first operation mode and the second operation mode will be described. In the present disclosure, second heat exchanger 20 is located upstream of the refrigerant and third heat exchanger 30 is located downstream of the refrigerant, where compressor 1 is a starting point, in either the first route or the second route, as apparent from the description below.

[0033] The present disclosure will be described by taking a zeotropic refrigerant mixture, such as R466A, as an example of the refrigerant. The zeotropic refrigerant mixture is obtained by mixing two or more types of refrigerant having different boiling points. Thus, the zeotropic refrigerant mixture is characterized by divergence that occurs between saturated gas temperature and saturated liquid temperature under constant pressure. The saturated gas temperature is usually higher than the saturated liquid temperature. Such a temperature difference is referred to as a temperature gradient.

[0034] The presence of temperature gradient may cause an imbalance in the temperature in the heat exchanger, leading to reduced operating efficiency. The present disclosure proposes a configuration that can improve operating performance while reducing a pressure loss when the zeotropic refrigerant mixture is used. In particular, the present disclosure proposes a configuration applicable to either the first operation mode or the second operation mode.

[0035] In refrigeration cycle apparatus 100, the heat exchanger in the outdoor unit is divided into second heat exchanger 20 on the upstream side and third heat exchanger 30 on the downstream side, and gas-liquid separator 6 is disposed in the flow path at some midpoint between second heat exchanger 20 and third heat exchanger 30. In refrigeration cycle apparatus 100, further, liquid refrigerant or gaseous refrigerant is flowed to third heat exchanger 30 on the downstream side according to the operation mode, to thereby improve operating capability. The refrigerant applicable to refrigeration cycle apparatus 100 is not limited to the zeotropic refrigerant mixture.

<Refrigerant Flow in First Operation Mode>

[0036] Fig. 2 shows a refrigerant flow in the first operation mode of refrigeration cycle apparatus 100. The refrigerant flow in the first operation mode will be described with reference to Fig. 2. In the first operation mode, controller 90 controls four-way valve 4 such that the flow path indicated by the solid line in Fig. 2 is formed in four-way valve 4.

[0037] At this time, the refrigerant flows through the refrigerant circuit of refrigeration cycle apparatus 100, as indicated by the arrows, by the action of switch device 40 including four-way valve 4. Specifically, the refrigerant discharged from compressor 1 flows through first switch port P41 and third switch port P43 of four-way valve 4 and then in order of first heat exchanger 10, expansion device 3, second heat exchanger 20, and gas-liquid separator 6. Subsequently, the liquid refrigerant discharged from liquid discharge port P63 of gas-liquid separator 6 flows from fourth port P4 into third heat exchanger 30.

[0038] On the other hand, the gaseous refrigerant discharged from gas discharge port P62 of gas-liquid separator 6 flows through first flow rate control device 51 toward first junction point a shown in Fig. 2. The refrigerant discharged from third port P3 of third heat exchanger 30 also flows into first junction point a. The refrigerant after joining at first junction point a from two directions flows through four-way valve 4 into the inlet port of compressor 1.

[0039] As described above, the first route of the refrigerant in the first operation mode is formed by the route of the refrigerant outlined. In other words, in the first route, the refrigerant flows in order of compressor 1, first heat exchanger 10, expansion device 3, second heat exchanger 20, and gas-liquid separator 6, and then, the refrigerant in liquid state discharged from gas-liquid separator 6 flows into third heat exchanger 30, whereas the refrigerant in gaseous state discharged from gas-liquid separator 6 joins, through first flow rate control device 51, the refrigerant discharged from third heat exchanger 30 at first junction point a. The refrigerant after joining at first junction point a flows to compressor 1.

[0040] Next, a refrigerant flow in the first operation mode will be described in more detail. In the first operation mode, first heat exchanger 10 on the indoor unit side functions as a condenser, and second heat exchanger 20 and third heat exchanger 30 on the outdoor unit side function as an evaporator. High-temperature, high-pressure gaseous refrigerant discharged from compressor 1 flows through four-way valve 4 and then into first heat exchanger 10 on the indoor unit side.

[0041] The gaseous refrigerant that has flowed into first heat exchanger 10 condenses by heat dissipation to the indoor air. As a result, liquefaction of the refrigerant advances in first heat exchanger 10. The refrigerant discharged from first heat exchanger 10 flows into expansion device 3. Expansion device 3 includes a valve for adjusting a degree of expansion of the refrigerant. The refrigerant discharged from first heat exchanger 10 expands in expansion device 3 to turn into two-phase refrigerant that is a mixture of gas and liquid.

[0042] The two-phase refrigerant discharged from expansion device 3 flows through third check valve 43 from first port P1 to second heat exchanger 20 on the outdoor unit side. A flow of the refrigerant from expansion device 3 toward second junction point b is interrupted by fourth check valve 44.

[0043] Since the two-phase refrigerant partly evaporates in second heat exchanger 20, the two-phase refrigerant with an increased dryness fraction is discharged from second port P2 of second heat exchanger 20. The two-phase refrigerant discharged from second port P2 flows from inflow port P61 into gas-liquid separator 6 to be separated into gaseous refrigerant and liquid refrigerant.

[0044] The liquid refrigerant separated in gas-liquid separator 6 is discharged from liquid discharge port P63. The liquid refrigerant discharged from liquid discharge port P63 flows from fourth port P4 into third heat exchanger 30. At this time, the liquid refrigerant discharged from liquid discharge port P63 does not flow through fourth check valve 44 to the expansion device 3 side. This is because the pressure of the liquid refrigerant discharged from liquid discharge port P63 is lower than the pressure of the refrigerant that flows from expansion device 3 toward third check valve 43. The pressure difference therebetween corresponds to the amount of pressure loss between second heat exchanger 20 and third check valve 43.

[0045] Third temperature sensor 73 detects the temperature of the liquid refrigerant that flows from fourth port P4 into third heat exchanger 30. The temperature detected by third temperature sensor 73 is transmitted to controller 90.

[0046] On the other hand, the gaseous refrigerant separated in gas-liquid separator 6 is discharged from gas discharge port P62. The gaseous refrigerant discharged from gas discharge port P62 flows through first flow rate control device 51 toward first junction point a on the downstream side of third heat exchanger 30 without flowing into third heat exchanger 30. Thus, of second heat exchanger 20 and third heat exchanger 30 in the outdoor unit, the liquid refrigerant flows, and the gaseous refrigerant does not flow, into third heat exchanger 30 on the downstream side.

[0047] First temperature sensor 71 detects the temperature of the gaseous refrigerant separated in gas-liquid separator 6. The temperature detected by first temperature sensor 71 is transmitted to controller 90. This temperature is equivalent to the saturated gas temperature of the refrigerant that has flowed into gas-liquid separator 6. Controller 90 estimates the pressure in gas-liquid separator 6 from the temperature detected by first temperature sensor 71.

[0048] In third heat exchanger 30, the liquid refrigerant is subjected to heat exchange with the outside air to be gasified. Thus, since the gaseous refrigerant does not flow into third heat exchanger 30, a temperature gradient does not occur in third heat exchanger 30. Consequently, a temperature imbalance does not occur in third heat exchanger 30. The refrigerant gasified in third heat exchanger 30 is discharged from third port P3.

[0049] Second temperature sensor 72 detects the temperature of the gaseous refrigerant discharged from third port P3. The temperature detected by second temperature sensor 72 is transmitted to controller 90. The temperature detected by second temperature sensor 72 corresponds to the temperature at the outlet of the evaporator in the first operation mode. Controller 90 estimates a degree of superheat (SH) at the outlet of the evaporator based on the temperature detected by first temperature sensor 71 and the temperature detected by second temperature sensor 72.

[0050] The gaseous refrigerant discharged from third port P3 of third heat exchanger 30 joins the gaseous refrigerant discharged from first flow rate control device 51 at first junction point a. The gaseous refrigerant after joining from two directions flows through first check valve 41 and four-way valve 4 into the inlet side of compressor 1. At this time, the gaseous refrigerant does not flow through second check valve 42 to second heat exchanger 20. This is because the pressure of the gaseous refrigerant between first check valve 41 and four-way valve 4 is lower than the pressure of the refrigerant at first port P1 of second heat exchanger 20. The pressure difference therebetween corresponds to the amount of pressure loss between second heat exchanger 20 and first check valve 41.

<Refrigerant Flow in Second Operation Mode>

[0051] Fig. 3 shows a refrigerant flow in the second operation mode of refrigeration cycle apparatus 100. The refrigerant flow in the second operation mode will be described with reference to Fig. 3. In the second operation mode, controller 90 controls four-way valve 4 such that the flow path indicated by the solid line in Fig. 3 is formed in four-way valve 4.

[0052] At this time, the refrigerant flows through the refrigerant circuit of refrigeration cycle apparatus 100, as indicated by the arrows, by the action of switch device 40 including four-way valve 4. Specifically, the refrigerant discharged from compressor 1 flows through first switch port P41 and fourth switch port P44 of four-way valve 4, and then in order of second heat exchanger 20 and gas-liquid separator 6. Subsequently, the gaseous refrigerant discharged from gas discharge port P62 of gas-liquid separator 6 flows through first flow rate control device 51 from third port P3 into third heat exchanger 30.

[0053] On the other hand, the liquid refrigerant discharged from liquid discharge port P63 of gas-liquid separator 6 joins the refrigerant discharged from fourth port P4 of third heat exchanger 30 at second junction point b. The refrigerant after joining at second junction point b flows in order of expansion device 3 and first heat exchanger 10, and then flows through four-way valve 4 into the inlet port of compressor 1.

[0054] As described above, the second route of the refrigerant in the second operation mode is formed by the route of the refrigerant outlined. In other words, in the second route, the refrigerant flows in order of compressor 1, second heat exchanger 20, and gas-liquid separator 6, and the refrigerant in gaseous state discharged from gas-liquid separator 6 flows through first flow rate control device 51 into third heat exchanger 30, whereas the refrigerant in liquid state discharged from gas-liquid separator 6 joins the refrigerant discharged from third heat exchanger 30 at second junction point b, and the refrigerant after joining at second junction point b flows in order of expansion device 3, first heat exchanger 10, and compressor 1.

[0055] Next, a flow of the refrigerant in the second operation mode will be described in more detail. In the second operation mode, first heat exchanger 10 on the indoor unit side functions as an evaporator, and second heat exchanger 20 and third heat exchanger 30 on the outdoor unit side function as a condenser. High-temperature, high-pressure gaseous refrigerant discharged from compressor 1 flows through four-way valve 4, and then flows through second check valve 42 from first port P1 into second heat exchanger 20 on the outdoor unit side. A flow of the refrigerant from four-way valve 4 toward first junction point a is interrupted by first check valve 41.

[0056] The gaseous refrigerant that has flowed into second heat exchanger 20 condenses by heat dissipation to the outside air to turn into two-phase refrigerant that is a mixture of gas and liquid. The two-phase refrigerant discharged from the second port of second heat exchanger 20 flows from inflow port P61 into gas-liquid separator 6 to be separated into gaseous refrigerant and liquid refrigerant.

[0057] The gaseous refrigerant separated in gas-liquid separator 6 is discharged from gas discharge port P62. The gaseous refrigerant discharged from gas discharge port P62 flows through first flow rate control device 51 from third port P3 into third heat exchanger 30. At this time, the gaseous refrigerant discharged from first flow rate control device 51 does not flow through first check valve 41 to the fourth switch port P44 side of four-way valve 4. This is because the pressure of the gaseous refrigerant discharged from first flow rate control device 51 is lower than the pressure of the refrigerant at fourth switch port P44 of four-way valve 4. The pressure difference therebetween is equivalent to the amount of pressure loss between four-way valve 4 and first check valve 41.

[0058] On the other hand, the liquid refrigerant separated in gas-liquid separator 6 is discharged from liquid discharge port P63. The liquid refrigerant discharged from liquid discharge port P63 flows downstream of third heat exchanger 30 without flowing into third heat exchanger 30. Thus, of second heat exchanger 20 and third heat exchanger 30 in the outdoor unit, the gaseous refrigerant flows, and the liquid refrigerant does not flow, into third heat exchanger 30 on the downstream side.

[0059] In third heat exchanger 30, the gaseous refrigerant is subjected to heat exchange with the outside air to be condensed. As a result, the liquefaction of the refrigerant advances in third heat exchanger 30. Thus, since the liquid refrigerant does not flow into third heat exchanger 30, a temperature gradient does not occur in third heat exchanger 30. Consequently, a temperature imbalance does not occur in third heat exchanger 30.

[0060] The liquid refrigerant discharged from fourth port P4 of third heat exchanger 30 joins the liquid refrigerant discharged from liquid discharge port P63 of gas-liquid separator 6 at second junction point b. The liquid refrigerant after joining at second junction point b flows through fourth check valve 44 into expansion device 3. At this time, the liquid refrigerant does not flow through third check valve 43 to second heat exchanger 20. This is because the pressure of the refrigerant at fourth check valve 44 is lower than the pressure of the refrigerant at first port P1 of second heat exchanger 20. The pressure difference therebetween is equivalent to the amount of pressure loss among second heat exchanger 20, first flow rate control device 51, and fourth check valve 44.

[0061] The refrigerant that has flowed into expansion device 3 is expanded by expansion device 3, and then flows into first heat exchanger 10 on the indoor unit side. The refrigerant that has flowed into first heat exchanger 10 evaporates by heat absorption from the indoor air, and then flows through four-way valve 4 into the inlet side of compressor 1.

[0062] Flows of the refrigerant in the first operation mode and the second operation mode are as described above. In refrigeration cycle apparatus 100, first check valve 41 and second check valve 42 constitute a first valve mechanism. Third check valve 43 and fourth check valve 44 constitute a second valve mechanism.

[0063] In the first operation mode where four-way valve 4 is in the first state, the first valve mechanism causes expansion device 3 to communicate with first port P1 of second heat exchanger 20 and interrupts the communication between expansion device 3 and fourth port P4 of third heat exchanger 30.

[0064] In the first operation mode, the first valve mechanism opens a flow of the refrigerant from first junction point a to fourth switch port P44 and interrupts a flow of the refrigerant from expansion device 3 to fourth switch port P44. In the second operation mode, further, the first valve mechanism opens a flow of the refrigerant from fourth switch port P44 to second heat exchanger 20 and interrupts a flow of the refrigerant from fourth switch port P44 to first junction point a.

[0065] The second valve mechanism opens a flow of the refrigerant from expansion device 3 to second heat exchanger 20 and interrupts a flow of the refrigerant from expansion device 3 to second junction point b in the first operation mode, and opens a flow of the refrigerant from second junction point b to expansion device 3 and interrupts a flow of the refrigerant from fourth switch port P44 to expansion device 3 in the second operation mode.

<P-h Diagram in First Operation Mode>

[0066] Fig. 4 is a p-h diagram showing changes in the state of refrigerant in the first operation mode. Fig. 4 will be described with reference to Fig. 2.

[0067] Herein, hout, hout', hg, hl, hin, and hsep in Fig. 4 correspond to Poout, Poout', Pog, Pol, Poin, and Posep in Fig. 2, respectively. For example, the enthalpy at a position Poin of the refrigerant circuit in Fig. 2 corresponds to hin shown in Fig. 4.

[0068] High-temperature, high-pressure gaseous refrigerant discharged from compressor 1 is condensed by first heat exchanger 10. Subsequently, the refrigerant is separated into two phases, that is, gaseous refrigerant and liquid refrigerant, in expansion device 3, and then flows into second heat exchanger 20. The enthalpy of the refrigerant at this time is hin. The two-phase refrigerant with a higher dryness fraction is discharged from second heat exchanger 20. The discharged two-phase refrigerant flows into gas-liquid separator 6. The enthalpy of the refrigerant at this time is hsep.

[0069] The two-phase refrigerant that has flowed into gas-liquid separator 6 is separated into gaseous refrigerant and liquid refrigerant in gas-liquid separator 6. The gaseous refrigerant discharged from gas-liquid separator 6 flows toward first flow rate control device 51. The enthalpy of the gaseous refrigerant at this time is hg. On the other hand, the gaseous refrigerant discharged from gas-liquid separator 6 flows toward third heat exchanger 30. The enthalpy of the liquid refrigerant at this time is hl.

[0070] Here, X = Y + Z holds, where X[kg/hr] is an amount of the refrigerant that flows into gas-liquid separator 6, Y[kg/hr] is an amount of the gaseous refrigerant discharged from gas-liquid separator 6, and Z[kg/hr] is an amount of the liquid refrigerant discharged from gas-liquid separator 6. At this time, evaporation capacity is expressed by Equation (1) below.

$$Qeva = (hsep - hin)X + (hout' - hl)Z \quad \ldots (1)$$

[0071] Here, a flow rate X depends on the rotation speed of compressor 1, the density of the refrigerant suctioned into compressor 1, and the like. A flow rate Y and a flow rate Z depend on the degree of opening of first flow rate control device 51 attached to the gaseous refrigerant outlet side of gas-liquid separator 6. An enthalpy hsep of the refrigerant that flows into gas-liquid separator 6 can be adjusted by the size, air volume, and the like of second heat exchanger 20 that functions as an evaporator. Thus, evaporation capacity can be improved by adjusting the degree of opening of first flow rate control device 51 while taking into account changes in the composition of the refrigerant.

[0072] The liquid refrigerant that has flowed into third heat exchanger 30 is subjected to heat exchange with the outside air to be gasified. Consequently, the enthalpy of the refrigerant discharged from third heat exchanger 30 is hout'. The gaseous refrigerant discharged from third heat exchanger 30 joins the gaseous refrigerant discharged from first flow rate control device 51 at junction point a. The enthalpy of the gaseous refrigerant at this time is hout. Subsequently, the gaseous refrigerant flows through four-way valve 4 back to compressor 1.

[0073] In the first operation mode, only the liquid refrigerant is flowed to third heat exchanger 30 with the use of gas-liquid separator 6. Thus, the flow rate of the refrigerant that flows to third heat exchanger 30 can be reduced compared with the case where the total amount of two-phase refrigerant including gaseous refrigerant and liquid refrigerant is flowed to third heat exchanger 30 (Z = X - Y). As a result, a pressure loss can be reduced compared with the case where the total amount of two-phase refrigerant is flowed to third heat exchanger 30.

[0074] In addition, since only the liquid refrigerant having a higher density than that of the gaseous refrigerant is flowed to third heat exchanger 30, the dryness fraction at the inlet of third heat exchanger 30 is almost zero. Thus, the flow rate of the refrigerant that flows through third heat exchanger 30 can be reduced compared with the case where two-phase refrigerant is flowed. As a result, a pressure loss can be reduced also in terms of flow rate.

[0075] Considered here is a case where a plurality of flow paths are provided in third heat exchanger 30 on the downstream side. In this case, when the two-phase zeotropic refrigerant mixture composed of gaseous refrigerant and liquid refrigerant is flowed to third heat exchanger 30, the gaseous refrigerant flows through a flow path at a relatively high position, and the liquid refrigerant flows through a flow path at a relatively low position. This is because there is a density difference between the gaseous refrigerant and the liquid refrigerant. Then, an imbalance occurs in the refrigerant temperature due to the temperature gradient of the zeotropic refrigerant mixture. In the present embodiment, however, only the liquid refrigerant having an almost zero dryness fraction is flowed to third heat exchanger 30. Such liquid refrigerant is insusceptible to gravity or a flow imbalance. Thus, the flow rate of the refrigerant in each flow path can be made uniform as only the liquid refrigerant is flowed to third heat exchanger 30. As a result, the present embodiment can reduce an imbalance in the refrigerant temperature due to a temperature gradient.

[0076] The present embodiment can control the amount of the liquid refrigerant that flows through third heat exchanger 30 by adjusting the degree of opening of first flow rate control device 51. For example, as the degree of opening of first flow rate control device 51 is increased with the rotation speed of compressor 1 and the degree of opening of expansion device 3 being kept constant, the amount of the gaseous refrigerant that is bypassed to the outlet side of third heat exchanger 30 that functions as an evaporator increases, and the amount of liquid refrigerant that flows through third heat exchanger 30 decreases.

[0077] It is expected that as the amount of the liquid refrigerant that flows through third heat exchanger 30 decreases, the refrigerant will entirely evaporate within third heat exchanger 30 to be gasified. In this case, the degree of superheat at the outlet of third heat exchanger 30 increases. Contrastingly, as the degree of opening of first flow rate control device 51 is reduced, the amount of the liquid refrigerant that flows into third heat exchanger 30 increases, so that the liquid refrigerant will not entirely gasify within third heat exchanger 30. As a result, the degree of superheat decreases. Thus, the degree of superheat at the outlet portion of third heat exchanger 30 can be controlled to an optimum value by adjusting the degree of opening of first flow rate control device 51 to increase or decrease the amount of gaseous refrigerant to be bypassed.

[0078] The degree of superheat at the outlet portion of third heat exchanger 30 can be estimated based on the temperature detected by first temperature sensor 71 and the temperature detected by second temperature sensor 72. It is difficult to estimate a saturation temperature from the temperature of the refrigerant in two-phase state because the zeotropic refrigerant mixture has a temperature gradient, but the degree of superheat can be estimated more accurately based on the temperature of the gaseous refrigerant brought to a single-phase state by gas-liquid separator 6.

<P-h Diagram in Second Operation Mode>

[0079] Fig. 5 is a p-h diagram showing changes in the state of refrigerant in the second operation mode. Fig. 5 will be described with reference to Fig. 3.

[0080] Herein, hout, hout', hg, hl, hin, and hsep in Fig. 5 correspond to Poout, Poout', Pog, Pol, Poin, and Posep in Fig. 3, respectively.

[0081] High-temperature, high-pressure gaseous refrigerant discharged from compressor 1 flows into second heat exchanger 20. The enthalpy of the refrigerant at this time is hin. The refrigerant that has flowed into second heat exchanger

20 condenses to turn into two-phase refrigerant, and is then discharged. The two-phase refrigerant discharged from second heat exchanger 20 flows into gas-liquid separator 6. The enthalpy of the refrigerant at this time is hsep.

[0082] The two-phase refrigerant that has flowed into gas-liquid separator 6 is separated into gaseous refrigerant and liquid refrigerant in gas-liquid separator 6. The gaseous refrigerant discharged from gas-liquid separator 6 flows through first flow rate control device 51 toward third heat exchanger 30. The enthalpy of the gaseous refrigerant upstream of first flow rate control device 51 is hg. On the other hand, the liquid refrigerant discharged from gas-liquid separator 6 flows downstream of third heat exchanger 30. The enthalpy of the liquid refrigerant at this time is hl.

[0083] Herein, X = Y + Z holds as in the case of the first operation mode, where X[kg/hr] is an amount of refrigerant that flows into gas-liquid separator 6, Y[kg/hr] is an amount of gaseous refrigerant discharged from gas-liquid separator 6, and Z[kg/hr] is an amount of liquid refrigerant discharged from gas-liquid separator 6. At this time, condensation capacity is expressed by Equation (2) below.

$$Qcond = (hin - hsep)X + (hg - hout')Y \ldots \quad (2)$$

[0084] The gaseous refrigerant that has flowed into third heat exchanger 30 is subjected to heat exchange with the outside air to be condensed. As a result, the enthalpy of the refrigerant discharged from third heat exchanger 30 is hout'. The refrigerant discharged from third heat exchanger 30 joins the liquid refrigerant discharged from gas-liquid separator 6 at second junction point b. The enthalpy of the refrigerant at this time is hout. Subsequently, the refrigerant expands in expansion device 3, flows into first heat exchanger 10, evaporates, and then flows through four-way valve 4 back to compressor 1.

[0085] In the second operation mode, only the gaseous refrigerant is flowed to third heat exchanger 30 with the use of gas-liquid separator 6. Thus, the flow rate of the refrigerant that flows to third heat exchanger 30 can be reduced compared with the case where the total amount of the two-phase refrigerant including gaseous refrigerant and liquid refrigerant is flowed to third heat exchanger 30. As a result, a pressure loss can be reduced compared with the case where the total amount of the two-phase refrigerant is flowed to third heat exchanger 30.

[0086] In the second operation mode, when the zeotropic refrigerant mixture flows into second heat exchanger 20 on the outdoor unit side, refrigerant having a higher boiling point is condensed preferentially in second heat exchanger 20 over refrigerant having a lower boiling point. Thus, the gaseous refrigerant in gas-liquid separator 6 is mostly refrigerant containing low-boiling components, and the liquid refrigerant in gas-liquid separator 6 is mostly refrigerant having a high boiling point. In the second operation mode, since only the gaseous refrigerant separated in gas-liquid separator 6 is flowed to third heat exchanger 30, it is refrigerant containing low-boiling components that is condensed in third heat exchanger 30.

[0087] Thus, in the second operation mode, the use of gas-liquid separator 6 allows refrigerant containing more low-boiling components to flow to third heat exchanger 30 on the downstream side, of second heat exchanger 20 and third heat exchanger 30. Herein, if the theoretical coefficient of performance of the refrigerant containing low-boiling components is higher than that of the refrigerant containing high-boiling components, the efficiency of the refrigeration cycle can be improved.

[0088] Also in the second operation mode, the amount of the refrigerant that flows to third heat exchanger 30 can be adjusted by adjusting the degree of opening of first flow rate control device 51 while taking into account changes in the composition of the refrigerant, as in the first operation mode. For example, when the degree of opening of first flow rate control device 51 is increased with the rotation speed of compressor 1 and the degree of opening of expansion device 3 being kept constant, the amount of gaseous refrigerant that flows into third heat exchanger 30 increases.

[0089] An increase in the amount of the gaseous refrigerant that flows to third heat exchanger 30 leads to a higher liquid level in gas-liquid separator 6. As a result, the degree of supercool (SC) at the outlet portion of third heat exchanger 30 decreases. On the other hand, reducing the degree of opening of first flow rate control device 51 increases the degree of supercool. Thus, the degree of supercool at the outlet portion of third heat exchanger 30 can be controlled to an optimum value by adjusting the degree of opening of first flow rate control device 51 to increase or reduce the amount of the gaseous refrigerant that flows to third heat exchanger 30.

[0090] The degree of supercool at the outlet portion of third heat exchanger 30 can be estimated based on the temperature detected by first temperature sensor 71 and the temperature detected by third temperature sensor 73.

<Control of Controller in First Operation Mode>

[0091] Fig. 6 is a flowchart for describing control of controller 90 in the first operation mode. First, controller 90 changes the rotation speed of compressor 1 (step S1). The rotation speed of compressor 1 is determined according to, for example, a difference between the indoor temperature and the temperature set with a remote control for the indoor unit. Controller 90 changes the rotation speed of compressor 1 to an appropriate value.

[0092] Controller 90 then adjusts the degree of opening of expansion device 3 (step S2).

[0093] Controller 90 then calculates the degree of supercool (SC) at the outlet of first heat exchanger 10 that functions as a condenser (step S3). The degree of supercool at the outlet of first heat exchanger 10 can be calculated from, for example, the temperature at the outlet of first heat exchanger 10 and the pressure of first heat exchanger 10. Thus, a sensor that detects temperature and a sensor that detects pressure can be disposed in the refrigerant circuit as appropriate.

[0094] Controller 90 then determines whether the degree of supercool at the outlet of first heat exchanger 10 that functions as a condenser is within a target range (step S4). When determining that the degree of supercool at the outlet of first heat exchanger 10 is not within the target range, controller 90 adjusts the degree of opening of expansion device 3 again in step S2.

[0095] Thus, controller 90 repeatedly adjusts the degree of opening of expansion device 3 in step S2 until the degree of supercool at the outlet of first heat exchanger 10 falls within the target range that is set for every rotation speed of compressor 1. Herein, the target range is a target value ± a target error.

[0096] When the degree of supercool at the outlet of first heat exchanger 10 is within the target range in step S4, controller 90 adjusts the degree of opening of first flow rate control device 51 (step S5).

[0097] Controller 90 then calculates the degree of superheat (SH) at the outlet of third heat exchanger 30 that functions as an evaporator (step S6). At this time, controller 90 calculates the degree of superheat at the outlet portion of third heat exchanger 30 based on the temperature detected by first temperature sensor 71 and the temperature detected by second temperature sensor 72.

[0098] Controller 90 then determines whether the degree of superheat at the outlet of third heat exchanger 30 that functions as an evaporator is within the target range (step S7). When determining that the degree of superheat at the outlet of third heat exchanger 30 is not within the target value, controller 90 adjusts the degree of opening of first flow rate control device 51 again in step S5.

[0099] Thus, controller 90 repeatedly adjusts the degree of opening of first flow rate control device 51 in step S5 until the degree of superheat at the outlet of third heat exchanger 30 falls within the target range that is set for every rotation speed of compressor 1. When determining that the degree of superheat at the outlet of third heat exchanger 30 is within the target range, controller 90 ends the process.

[0100] When the rotation speed of compressor 1 is within a prescribed rotation speed range, controller 90 may set the degree of opening of first flow rate control device 51 to zero to block the flow path, thereby allowing the gaseous refrigerant to flow to third heat exchanger 30. In this case, controller 90 checks whether the rotation speed of compressor 1 is within the prescribed rotation speed range every time the rotation speed of compressor 1 changes.

[0101] As described above with reference to the flowchart shown in Fig. 6, in the first operation mode, controller 90 calculates the degree of superheat of third heat exchanger 30 based on a detected value of first temperature sensor 71 and a detected value of second temperature sensor 72 and adjusts the degree of opening of first flow rate control device 51, thereby controlling the degree of superheat of third heat exchanger 30.

<Control of Controller in Second Operation Mode>

[0102] Fig. 7 is a flowchart for describing control of controller 90 in the second operation mode. First, controller 90 changes the rotation speed of compressor 1 as in the process of step S1 (step S11).

[0103] When changing the rotation speed of compressor 1, controller 90 adjusts the degree of opening of expansion device 3 such that the discharge temperature of compressor 1 is within the target range (step S12). The discharge temperature of compressor 1 can be specified based on, for example, a detected value of the temperature sensor provided at the discharge portion of compressor 1. Controller 90 then determines whether the discharge temperature of compressor 1 is within the target range (step S13). When determining that the discharge temperature of compressor 1 is not within the target range, controller 90 adjusts the degree of opening of expansion device 3 again in step S12.

[0104] When determining that the discharge temperature of compressor 1 is within the target range in step S 13, controller 90 adjusts the degree of opening of first flow rate control device 51 (step S14).

[0105] Controller 90 then calculates the degree of supercool at the outlet of third heat exchanger 30 that functions as a condenser (step S15). At this time, controller 90 calculates the degree of supercool at the outlet portion of third heat exchanger 30 based on the temperature detected by first temperature sensor 71 and the temperature detected by third temperature sensor 73.

[0106] Controller 90 then determines whether the degree of supercool at the outlet of third heat exchanger 30 that functions as a condenser is within the target range that is set for every rotation speed of compressor 1 (step S16). When determining that the degree of supercool at the outlet of third heat exchanger 30 is not within the target range, controller 90 adjusts the degree of opening of first flow rate control device 51 again in step S 14.

[0107] Thus, controller 90 repeatedly adjusts the degree of opening of first flow rate control device 51 in step S14 until the degree of supercool at the outlet of third heat exchanger 30 falls within the target range that is set for every rotation speed of compressor 1. When determining that the degree of supercool at the outlet of third heat exchanger 30 is within the target range, controller 90 ends the process.

[0108] As described above with reference to the flowchart shown in Fig. 7, in the second operation mode, controller 90 calculates the degree of supercool of third heat exchanger 30 based on the detected value of first temperature sensor 71 and the detected value of third temperature sensor 73 and adjusts the degree of opening of first flow rate control device 51, thereby controlling the degree of supercool of third heat exchanger 30.

[0109] As described above, refrigeration cycle apparatus 100 according to Embodiment 1 has operation capability improved by flowing liquid refrigerant or gaseous refrigerant to third heat exchanger 30 on the downstream side according to its operation mode. Refrigeration cycle apparatus 100 can thus have improved efficiency of operating a refrigeration cycle in either the first operation mode or the second operation mode. In other words, refrigeration cycle apparatus 100 can have operating efficiency improved with the use of gas-liquid separator 6 when second heat exchanger 20 and third heat exchanger 30 on the outdoor unit side are caused to function as either an evaporator or a condenser. In particular, the effect of improving the efficiency of operating a refrigeration cycle can be improved when a zeotropic refrigerant mixture is used.

Embodiment 2

[0110] Next, Embodiment 2 will be described with reference to Fig. 8. Fig. 8 is a refrigerant circuit diagram showing a configuration of a refrigeration cycle apparatus 110 according to Embodiment 2. Refrigeration cycle apparatus 110 according to Embodiment 2 is different from refrigeration cycle apparatus 100 according to Embodiment 1 in the configuration of the switch device. Refrigeration cycle apparatus 110 according to Embodiment 2 includes a switch device 400 composed of a first three-way valve 45 and a second three-way valve 46.

[0111] First three-way valve 45 is provided among fourth switch port P44, second heat exchanger 20, and first junction point a. First three-way valve 45 switches a target to be connected to fourth switch port P44 between second heat exchanger 20 and first junction point a.

[0112] Second three-way valve 46 is provided among expansion device 3, second heat exchanger 20, and second junction point b. Second three-way valve 46 switches a target to be connected to expansion device 3 between second heat exchanger 20 and second junction point b.

[0113] Controller 90 controls four-way valve 4, first three-way valve 45, and second three-way valve 46 such that the flow path indicated by the solid line in Fig. 8 is formed in the first operation mode. As a result, the refrigerant circulates through the refrigerant circuit in the same order as the order shown in Fig. 2. In the second operation mode, controller 90 controls four-way valve 4 as shown in Fig. 3 and also switches the manner of connection of first three-way valve 45 and second three-way valve 46 to the manner indicated by the broken line in Fig. 8. Thus, the refrigerant circulates through the refrigerant circuit in the same order as the order shown in Fig. 3.

[0114] First three-way valve 45 functions similarly to first check valve 41 and second check valve 42 of refrigeration cycle apparatus 100 according to Embodiment 1. Second three-way valve 46 functions similarly to third check valve 43 and fourth check valve 44 of refrigeration cycle apparatus 100 according of Embodiment 1. In Embodiment 2, thus, the first valve mechanism includes first three-way valve 45, and the second valve mechanism includes second three-way valve 46.

[0115] The first valve mechanism according to Embodiment 1 includes first check valve 41 and second check valve 42. On the other hand, the first valve mechanism according to Embodiment 2 includes first three-way valve 45. The second valve mechanism according to Embodiment 1 includes third check valve 43 and fourth check valve 44. On the other hand, the second valve mechanism according to Embodiment 2 includes second three-way valve 46. Embodiment 2 can thus reduce the number of components compared with Embodiment 1.

Embodiment 3

[0116] Fig. 9 is a refrigerant circuit diagram showing a configuration of a refrigeration cycle apparatus 120 according to Embodiment 3. Compared with refrigeration cycle apparatus 100 according to Embodiment 1, refrigeration cycle apparatus 120 according to Embodiment 3 further includes a second flow rate control device 52 and a fourth temperature sensor 74.

[0117] Second flow rate control device 52 is provided between second junction point b and the side of gas-liquid separator 6 on which the refrigerant in liquid state is discharged. Fourth temperature sensor 74 is provided between second flow rate control device 52 and the side of gas-liquid separator 6 on which liquid refrigerant is discharged.

[0118] Thus, as the mechanism that can adjust the flow rate is provided also in the portion to which liquid refrigerant is discharged from gas-liquid separator 6, controller 90 can more finely adjust the amount of gaseous refrigerant and the amount of liquid refrigerant discharged from gas-liquid separator 6.

[0119] In addition, since the detection target of first temperature sensor 71 is a temperature of gaseous refrigerant, the temperature gradient of the zeotropic refrigerant mixture needs to be taken into account when the saturation temperature of liquid refrigerant is calculated using a detected value of first temperature sensor 71. In refrigeration cycle apparatus 120 according to Embodiment 3, however, the saturation temperature of the liquid refrigerant can be directly detected with fourth temperature sensor 74. This allows controller 90 to more accurately calculate a degree of supercool based on a detected value of third temperature sensor 73 and a detected value of fourth temperature sensor 74.

[0120] Fig. 10 is a flowchart for describing control of controller 90 in the second operation mode according to Embodiment 3. The flowchart shown in Fig. 10 is different from the flowchart shown in Fig. 7 only in that step S24 is provided in place of step S14.

[0121] The processes of steps S21 to S23 in Fig. 10 are the same as the processes of steps S11 to S13 in Fig. 7, description of which will not be repeated.

[0122] In step S24, controller 90 adjusts the degrees of opening of first flow rate control device 51 and second flow rate control device 52.

[0123] Controller 90 then calculates the degree of supercool at the outlet of third heat exchanger 30 that functions as a condenser (step S25). At this time, controller 90 calculates the degree of supercool at the outlet portion of third heat exchanger 30 based on the temperature detected by third temperature sensor 73 and the temperature detected by fourth temperature sensor 74. Thus, controller 90 can more accurately calculate a degree of supercool than when calculating the degree of supercool at the outlet portion of third heat exchanger 30 based on the temperature detected by first temperature sensor 71 and the temperature detected by third temperature sensor 73.

[0124] Controller 90 then determines whether the degree of supercool at the outlet of third heat exchanger 30 that functions as a condenser is within the target range that is set for every rotation speed of compressor 1 (step S26). When determining that the degree of supercool at the outlet of third heat exchanger 30 is not within the target range, controller 90 adjusts the degrees of opening of first flow rate control device 51 and second flow rate control device 52 again in step S24.

[0125] Thus, controller 90 repeatedly adjusts the degrees of opening of first flow rate control device 51 and second flow rate control device 52 in step S24 until the degree of supercool at the outlet of third heat exchanger 30 falls within the target range that is set for every rotation speed of compressor 1. When determining that the degree of supercool at the outlet of third heat exchanger 30 is within the target range, controller 90 ends the process.

[0126] In Embodiment 3, the first valve mechanism includes first check valve 41 and second check valve 42, and the second valve mechanism includes third check valve 43 and fourth check valve 44. However, the first valve mechanism may include first three-way valve 45, and the second valve mechanism may include second three-way valve 46.

Summary

[0127] The present embodiments will be summarized as follows.

[0128] (1) The present disclosure relates to a refrigeration cycle apparatus. A refrigeration cycle apparatus (100) includes a compressor (1), a first heat exchanger (10), a second heat exchanger (20), a third heat exchanger (30), an expansion device (3), a gas-liquid separator (6), a first flow rate control device (51), and a switch device (40) configured to switch a refrigerant circulation path between a first route corresponding to a first operation mode and a second route corresponding to a second operation mode. In the first route, refrigerant flows in order of the compressor (1), the first heat exchanger (10), the expansion device (3), the second heat exchanger (20), and the gas-liquid separator (6), and then, the refrigerant in liquid state discharged from the gas-liquid separator (6) flows into the third heat exchanger (30), and the refrigerant in gaseous state discharged from the gas-liquid separator (6) joins, through the first flow rate control device (51), the refrigerant discharged from the third heat exchanger (30) at a first junction point (a). The refrigerant after joining at the first junction point (a) flows to the compressor (1). In the second route, the refrigerant flows in order of the compressor (1), the second heat exchanger (20), and the gas-liquid separator (6), the refrigerant in gaseous state discharged from the gas-liquid separator (6) flows through the first flow rate control device (51) into the third heat exchanger (30), the refrigerant in liquid state discharged from the gas-liquid separator (6) joins the refrigerant discharged from the third heat exchanger (30) at a second junction point (b), and the refrigerant after joining at the second junction point (b) flows in order of the expansion device (3), the first heat exchanger (10), and the compressor (1).

[0129] With such a configuration, the efficiency of operating a refrigeration cycle can be improved in either the first operation mode or the second operation mode. In other words, the operating efficiency can be improved with the gas-liquid separator when the heat exchanger is caused to function as either an evaporator or a condenser. In particular, the efficiency of operating a refrigeration cycle can be improved when a zeotropic refrigerant mixture is used.

[0130] (2) The switch device (40) includes a four-way valve (4), a first valve mechanism (41, 42), and a second valve mechanism (43, 44). The four-way valve (4) has a first switch port (P41), a second switch port (P42), a third switch port (P43), and a fourth switch port (P44), an outlet port of the compressor (1) is connected to the first switch port (P41), and an inlet port of the compressor (1) is connected to the second switch port (P42). The four-way valve (4) is configured to, in the first operation mode, cause the first switch port (P41) to communicate with the third switch port (P43) and cause the second switch port (P42) to communicate with the fourth switch port (P44), and in the second operation mode, cause the first switch port (P41) to communicate with the fourth switch port (P44) and cause the second switch port (P42) to communicate with the third switch port (P43). The first valve mechanism (41, 42) is configured to, in the first operation mode, open a flow of the refrigerant from the first junction point (a) to the fourth switch port (P44) and interrupt a flow of the refrigerant from the expansion device (3) to the fourth switch port (P44), and in the second operation mode, open a flow of the refrigerant from the fourth switch port (P44) to the second heat exchanger (20) and interrupt a flow of the refrigerant from the fourth switch port (P44) to the first junction point (a). The second valve mechanism (43, 44) is configured to, in the first operation mode, open a flow of the refrigerant from the expansion device (3) to the second heat exchanger (20) and interrupt a flow of the refrigerant from the expansion device (3) to the second junction point (b), and in the second operation mode, open a flow of the refrigerant from the second junction point (b) to the expansion device (3) and interrupt a flow of the refrigerant from the fourth switch port (P44) to the expansion device (3).

[0131] (3) The first valve mechanism (41, 42) includes a first check valve (41) provided between the fourth switch port (P44) and the first junction point (a) and configured to interrupt a flow of the refrigerant from the fourth switch port (P44) toward a first junction point (a), and a second check valve (42) provided among the expansion device (3), the fourth switch port (P44), and the second heat exchanger (20) and configured to interrupt a flow of the refrigerant from the expansion device (3) to the fourth switch port (P44). The second valve mechanism (43, 44) includes a third check valve (43) provided among the fourth switch port (P44), the expansion device (3), and the second heat exchanger (20) and configured to interrupt a flow of the refrigerant from the fourth switch port (P44) to the expansion device (3), and a fourth check valve (44) provided between the expansion device and the second junction point (b) and configured to interrupt a flow of the refrigerant from the expansion device (3) to the second junction point (b).

[0132] (4) The first valve mechanism may include a first three-way valve (45). The second valve mechanism may include a second three-way valve (46). The first three-way valve (45) is provided among the fourth switch port (P44), the second heat exchanger (20), and the first junction point (a) and is configured to switch a target to be connected to the fourth switch port (P44) between the second heat exchanger (20) and the first junction point (a). The second three-way valve (46) is provided among the expansion device (3), the second heat exchanger (20), and the second junction point (b) and is configured to switch a target to be connected to the expansion device (3) between the second heat exchanger (20) and the second junction point (b).

[0133] (5) The refrigeration cycle apparatus further includes a first temperature sensor (71) provided between the first flow rate control device (51) and a side (P62) of the gas-liquid separator (6) on which the refrigerant in gaseous state is discharged, a second temperature sensor (72) provided between the third heat exchanger (30) and the first junction point (a), and a controller (90) configured to control the first flow rate control device (51). The controller (90) is configured to, in the first operation mode, calculate a degree of superheat of the third heat exchanger (30) based on a detected value of the first temperature sensor (71) and a detected value of the second temperature sensor (72) (step S6) and adjust a degree of opening of the first flow rate control device (51) to control the degree of superheat of the third heat exchanger (30) (step S5 to step S7).

[0134] (6) The refrigeration cycle apparatus may further include a third temperature sensor (73) provided between the third heat exchanger (30) and the second junction point (b). The controller (90) is configured to, in the second operation mode, calculate a degree of supercool of the third heat exchanger (30) based on a detected value of the first temperature sensor (71) and a detected value of the third temperature sensor (73) (step S15), and adjust the degree of opening of the first flow rate control device (51) to control the degree of supercool of the third heat exchanger (30) (step S14 to step S16).

[0135] (7) The refrigeration cycle apparatus may further include a second flow rate control device (52) provided between the second junction point (b) and a side (P63) of the gas-liquid separator (6) on which the refrigerant in liquid state is discharged, a third temperature sensor (73) provided between the third heat exchanger (30) and the second junction point (b), and a fourth temperature sensor (74) provided between the second flow rate control device (52) and a side (P63) of the gas-liquid separator (6) on which the refrigerant in liquid state is discharged. The controller (90) is configured to, in the second operation mode, calculate a degree of supercool of the third heat exchanger (30) based on a detected value of the third temperature sensor (73) and a detected value of the fourth temperature sensor (74) (step S25), and adjust degrees of opening of the first flow rate control device (51) and the second flow rate control device (52) to control the degree of supercool of the third heat exchanger (30) (step S24 to step S26).

[0136] It should be understood that the embodiments disclosed herein have been presented for the purpose of illustration and non-restrictive in every respect. It is therefore intended that the scope of the present disclosure is defined by claims, not only by the embodiments described above, and encompasses all modifications and variations equivalent in meaning and scope to the claims.

REFERENCE SIGNS LIST

[0137] 1 compressor; 3 expansion device; 4 four-way valve; 6 gas-liquid separator; 10 first heat exchanger; 20 second heat exchanger; 30 third heat exchanger; 40 switch device; 41 first check valve; 42 second check valve; 43 third check valve; 44 fourth check valve; 45 first three-way valve; 46 second three-way valve; 51 first flow rate control device; 52 second flow rate control device; 71 first temperature sensor; 72 second temperature sensor; 73 third temperature sensor; 74 fourth temperature sensor; 90 controller; 91 processor; 92 memory; 100, 110, 120 refrigeration cycle apparatus; 400 switch device; P1 first port; P2 second port; P3 third port; P4 fourth port; P41 first switch port; P42 second switch port; P43 third switch port; P44 fourth switch port; P61 inflow port; P62 gas discharge port; P63 liquid discharge port.

Claims

1. A refrigeration cycle apparatus comprising:

a compressor;
a first heat exchanger;
a second heat exchanger;
a third heat exchanger;
an expansion device;
a gas-liquid separator;
a first flow rate control device; and
a switch device configured to switch a refrigerant circulation path between a first route corresponding to a first operation mode and a second route corresponding to a second operation mode, wherein
in the first route,

refrigerant flows in order of the compressor, the first heat exchanger, the expansion device, the second heat exchanger, and the gas-liquid separator,
the refrigerant in liquid state discharged from the gas-liquid separator flows into the third heat exchanger,
the refrigerant in gaseous state discharged from the gas-liquid separator joins, through the first flow rate control device, the refrigerant discharged from the third heat exchanger at a first junction point, and
the refrigerant after joining at the first junction point flows to the compressor, and

in the second route,

the refrigerant flows in order of the compressor, the second heat exchanger, and the gas-liquid separator,
the refrigerant in gaseous state discharged from the gas-liquid separator flows through the first flow rate control device into the third heat exchanger,
the refrigerant in liquid state discharged from the gas-liquid separator joins the refrigerant discharged from the third heat exchanger at a second junction point, and
the refrigerant after joining at the second junction point flows in order of the expansion device, the first heat exchanger, and the compressor.

2. The refrigeration cycle apparatus according to claim 1, wherein

the switch device comprises

a four-way valve,
a first valve mechanism, and
a second valve mechanism,

the four-way valve has a first switch port, a second switch port, a third switch port, and a fourth switch port, an outlet port of the compressor is connected to the first switch port, and an inlet port of the compressor is connected to the second switch port,
the four-way valve is configured to

in the first operation mode, cause the first switch port to communicate with the third switch port and cause the second switch port to communicate with the fourth switch port, and
in the second operation mode, cause the first switch port to communicate with the fourth switch port and cause the second switch port to communicate with the third switch port,

the first valve mechanism is configured to

in the first operation mode, open a flow of the refrigerant from the first junction point to the fourth switch port and interrupt a flow of the refrigerant from the expansion device to the fourth switch port, and
in the second operation mode, open a flow of the refrigerant from the fourth switch port to the second heat exchanger and interrupt a flow of the refrigerant from the fourth switch port to the first junction point, and

the second valve mechanism is configured to

in the first operation mode, open a flow of the refrigerant from the expansion device to the second heat exchanger and interrupt a flow of the refrigerant from the expansion device to the second junction point, and
in the second operation mode, open a flow of the refrigerant from the second junction point to the expansion device and interrupt a flow of the refrigerant from the fourth switch port to the expansion device.

3. The refrigeration cycle apparatus according to claim 2, wherein

the first valve mechanism comprises

a first check valve provided between the fourth switch port and the first junction point and configured to interrupt a flow of the refrigerant from the fourth switch port toward the first junction point, and
a second check valve provided among the expansion device, the fourth switch port, and the second heat exchanger and configured to interrupt the flow of the refrigerant from the expansion device to the fourth switch port, and

the second valve mechanism comprises

a third check valve provided among the fourth switch port, the expansion device, and the second heat exchanger and configured to interrupt the flow of the refrigerant from the fourth switch port to the expansion device, and
a fourth check valve provided between the expansion device and the second junction point and configured to interrupt the flow of the refrigerant from the expansion device to the second junction point.

4. The refrigeration cycle apparatus according to claim 2, wherein

the first valve mechanism comprises a first three-way valve,
the second valve mechanism comprises a second three-way valve,
the first three-way valve is provided among the fourth switch port, the second heat exchanger, and the first junction point and is configured to switch a target to be connected to the fourth switch port between the second heat exchanger and the first junction point, and
the second three-way valve is provided among the expansion device, the second heat exchanger, and the second junction point and is configured to switch a target to be connected to the expansion device between the second heat exchanger and the second junction point.

5. The refrigeration cycle apparatus according to any one of claims 1 to 4, further comprising:

a first temperature sensor provided between the first flow rate control device and a side of the gas-liquid separator on which the refrigerant in gaseous state is discharged;
a second temperature sensor provided between the third heat exchanger and the first junction point; and
a controller configured to control the first flow rate control device,
wherein the controller is configured to, in the first operation mode,

calculate a degree of superheat of the third heat exchanger based on a detected value of the first temperature sensor and a detected value of the second temperature sensor, and
adjust a degree of opening of the first flow rate control device to control the degree of superheat of the third heat exchanger.

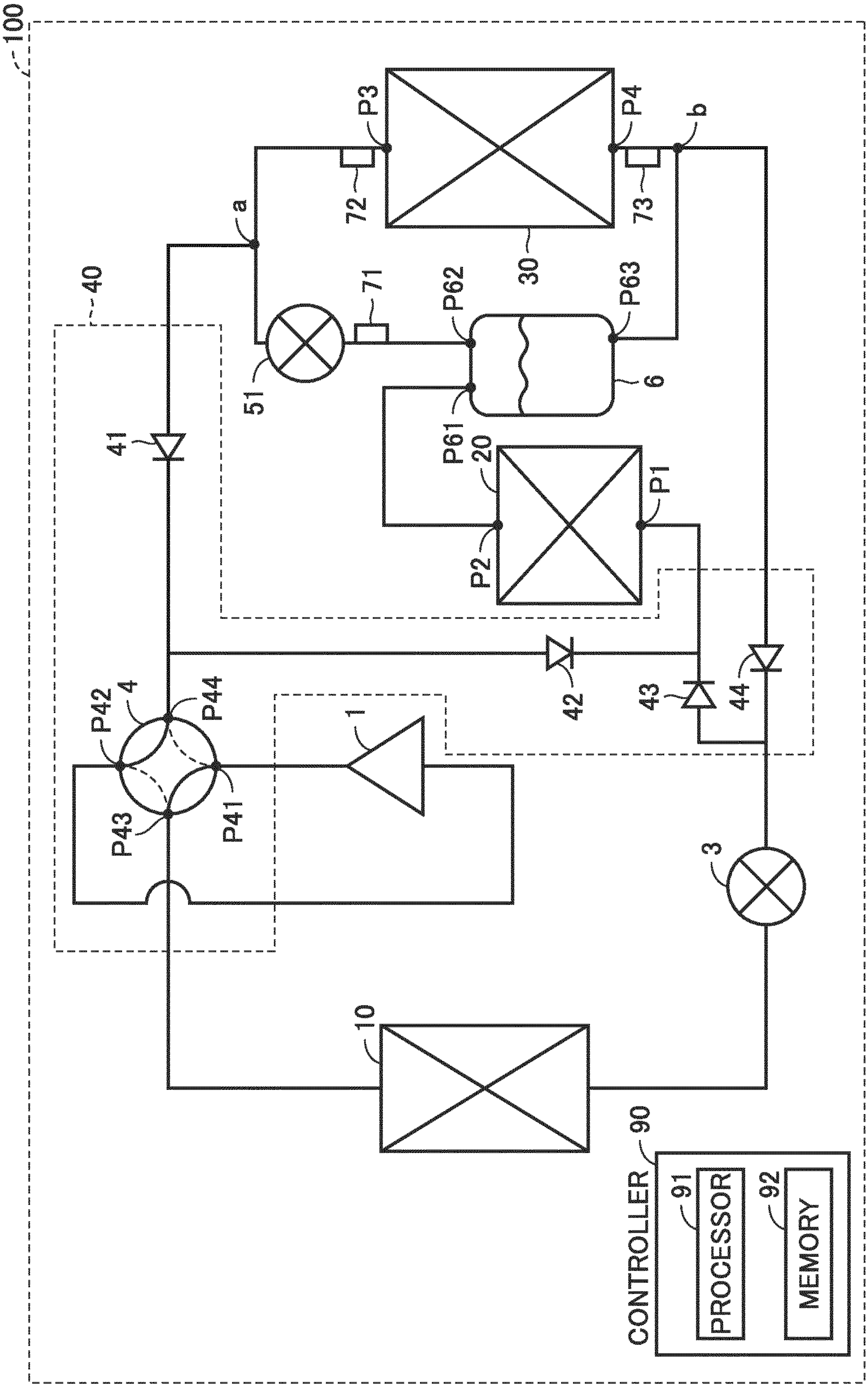
6. The refrigeration cycle apparatus according to claim 5, further comprising a third temperature sensor provided between the third heat exchanger and the second junction point, wherein the controller is configured to, in the second operation mode,

calculate a degree of supercool of the third heat exchanger based on a detected value of the first temperature sensor and a detected value of the third temperature sensor, and
adjust the degree of opening of the first flow rate control device to control the degree of supercool of the third heat exchanger.

7. The refrigeration cycle apparatus according to claim 5, further comprising:

a second flow rate control device provided between the second junction point and a side of the gas-liquid separator on which the refrigerant in liquid state is discharged;
a third temperature sensor provided between the third heat exchanger and the second junction point; and
a fourth temperature sensor provided between the second flow rate control device and a side of the gas-liquid separator on which the refrigerant in liquid state is discharged,
wherein the controller is configured to, in the second operation mode,

calculate a degree of supercool of the third heat exchanger based on a detected value of the third temperature sensor and a detected value of the fourth temperature sensor, and
adjust degrees of opening of the first flow rate control device and the second flow rate control device to control the degree of supercool of the third heat exchanger.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a
b
P3
P4
72
73
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P62
P63
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6
P61
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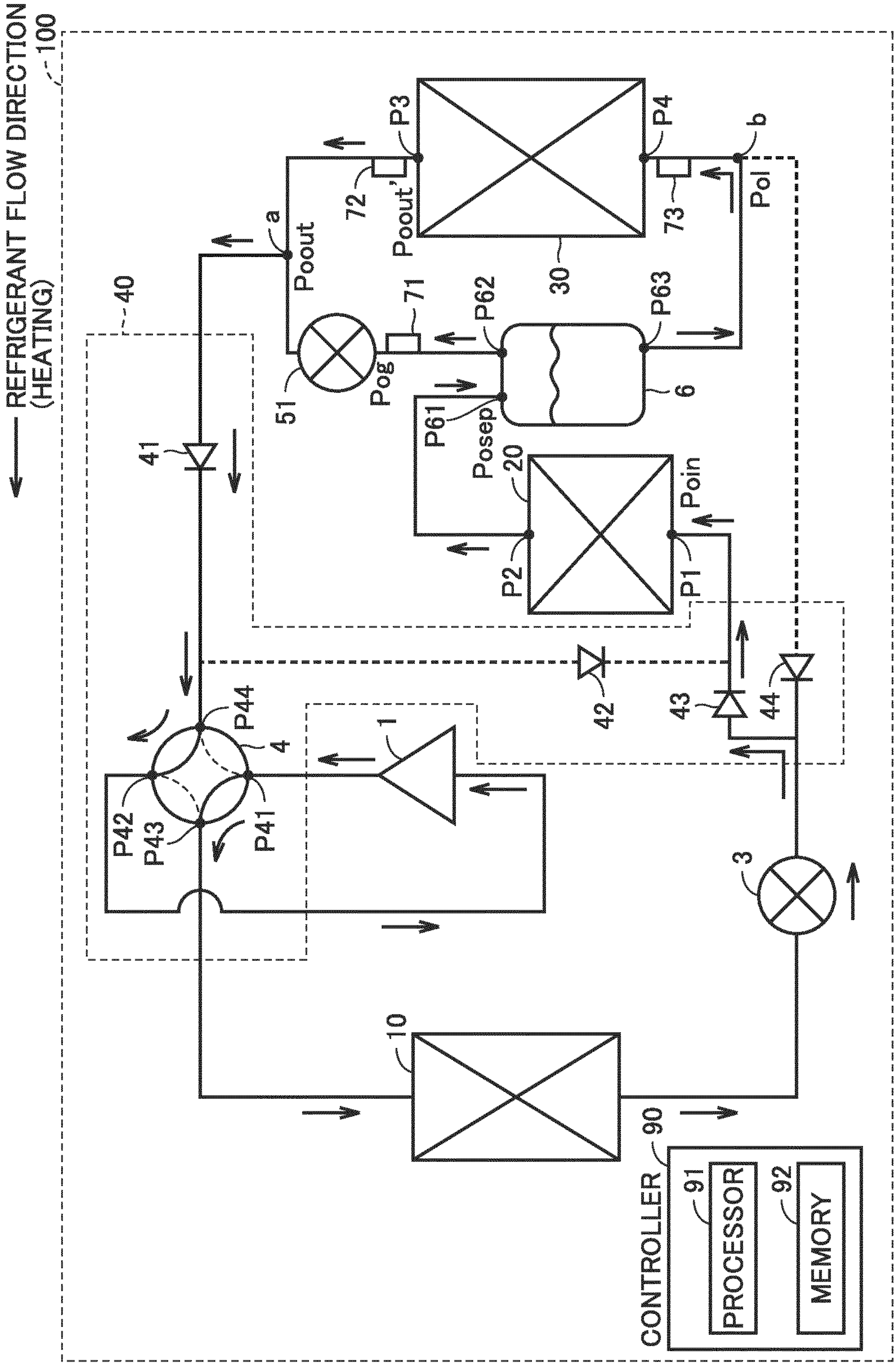
P1
P2
42
43
44
P42
4
P44
1
P43
P41
3
10
90
CONTROLLER
91
PROCESSOR
92
MEMORY

FIG.1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(HEATING)
100
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41
42
43
44
1
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4
P41
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20
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6
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71
72
73
a
b
P1
P2
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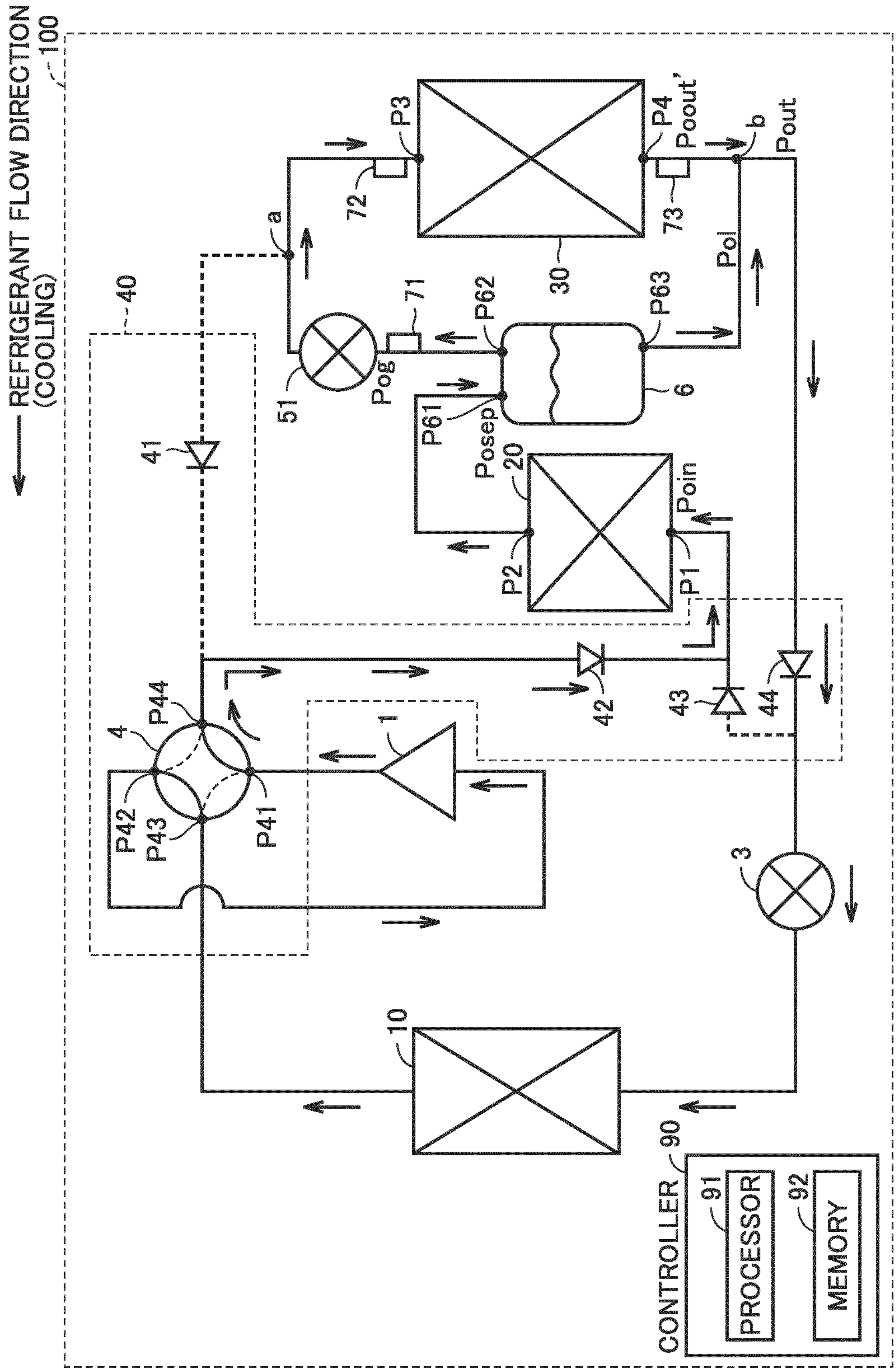
Poout'
Pol
90
CONTROLLER
91
PROCESSOR
92
MEMORY

FIG.2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CONTROLLER
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PROCESSOR
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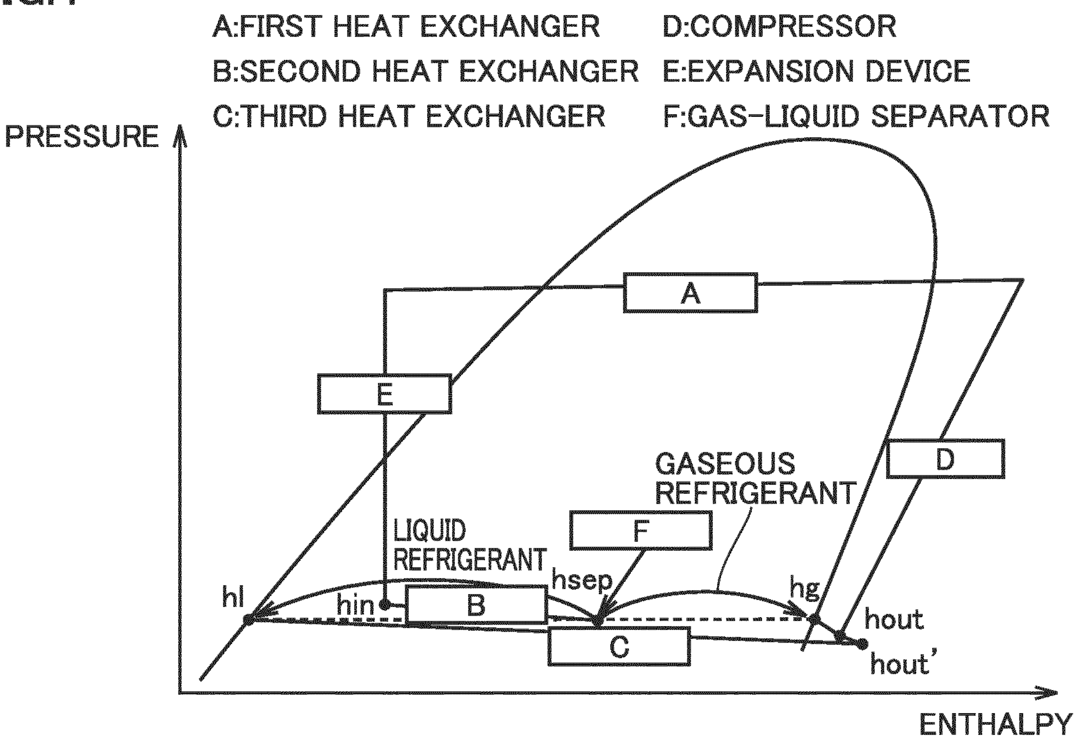
MEMORY

FIG.3

FIG.4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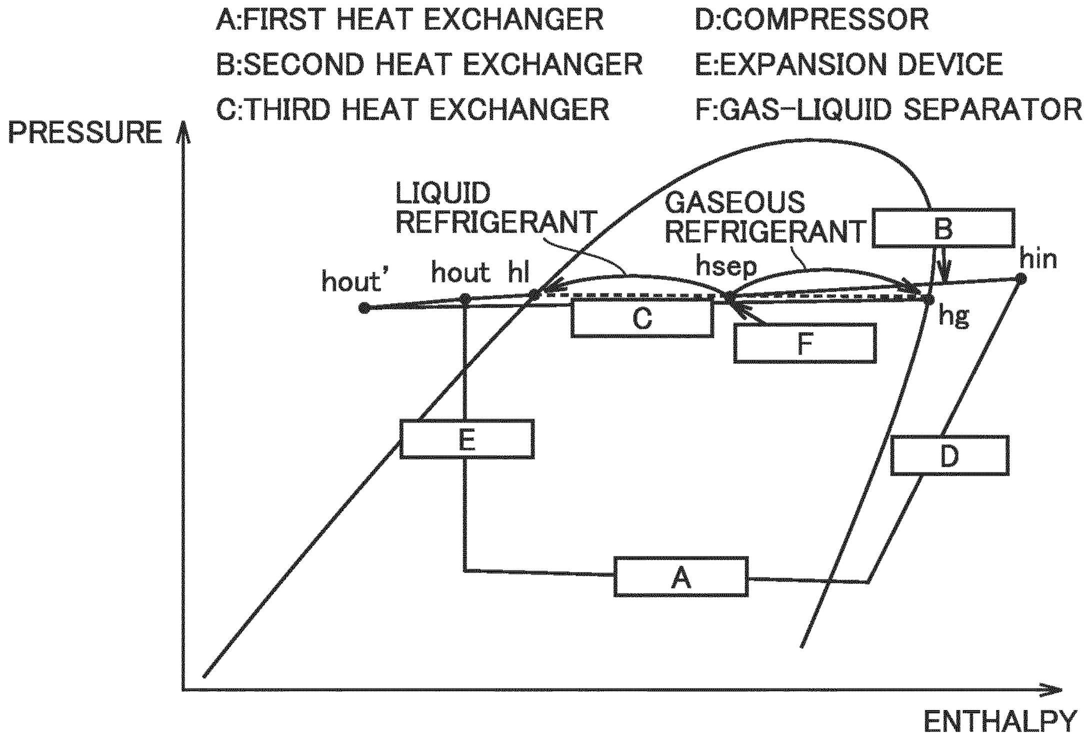
B:SECOND HEAT EXCHANGER
C:THIRD HEAT EXCHANGER
D:COMPRESSOR
E:EXPANSION DEVICE
F:GAS-LIQUID SEPARATOR
PRESSURE
A
E
D
GASEOUS
REFRIGERANT
F
LIQUID
REFRIGERANT
hsep
hg
hl
hin
B
hout
C
hout'
ENTHALPY

FIG.5


A:FIRST HEAT EXCHANGER
B:SECOND HEAT EXCHANGER
C:THIRD HEAT EXCHANGER
D:COMPRESSOR
E:EXPANSION DEVICE
F:GAS-LIQUID SEPARATOR
PRESSURE
LIQUID REFRIGERANT
GASEOUS REFRIGERANT
hout'
hout
hl
hsep
hin
hg
A
B
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D
E
F
ENTHALPY

FIG.6

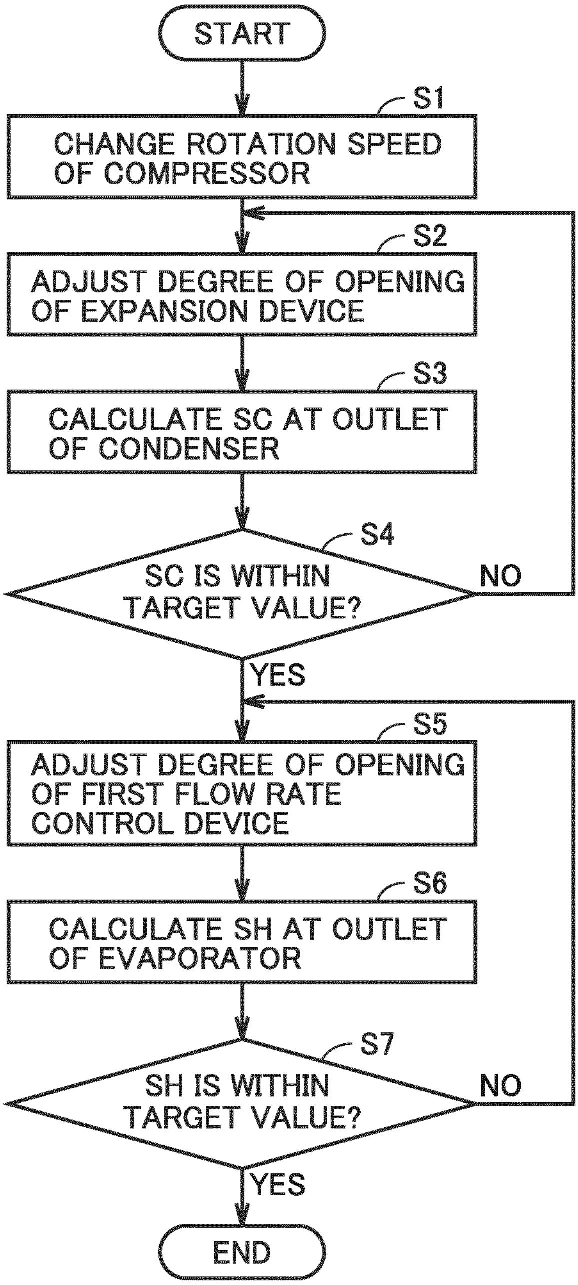
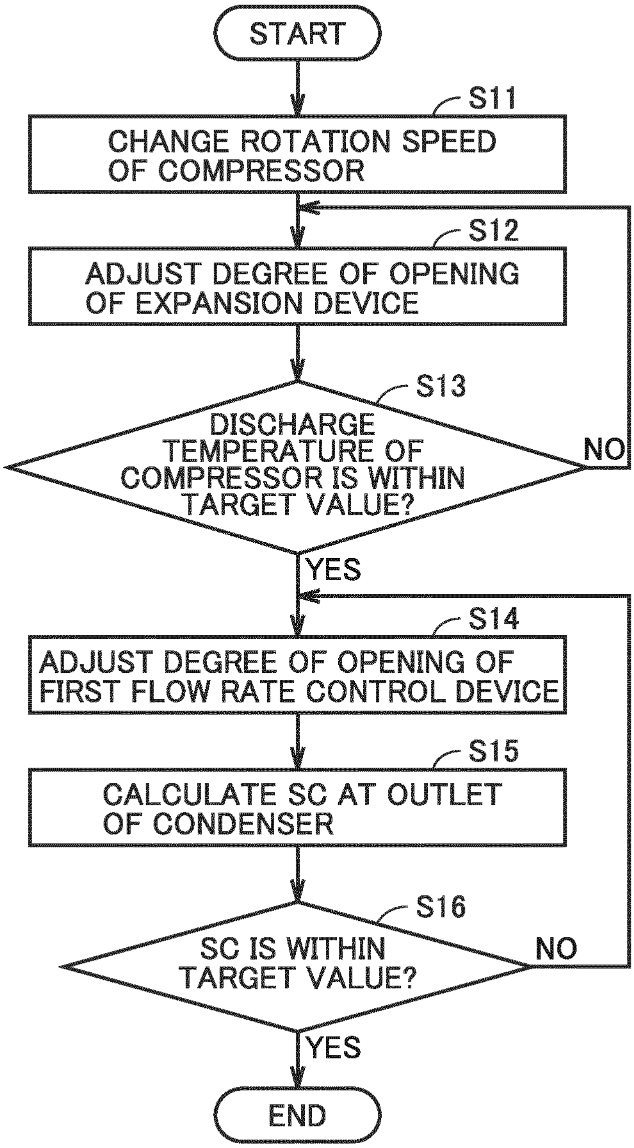
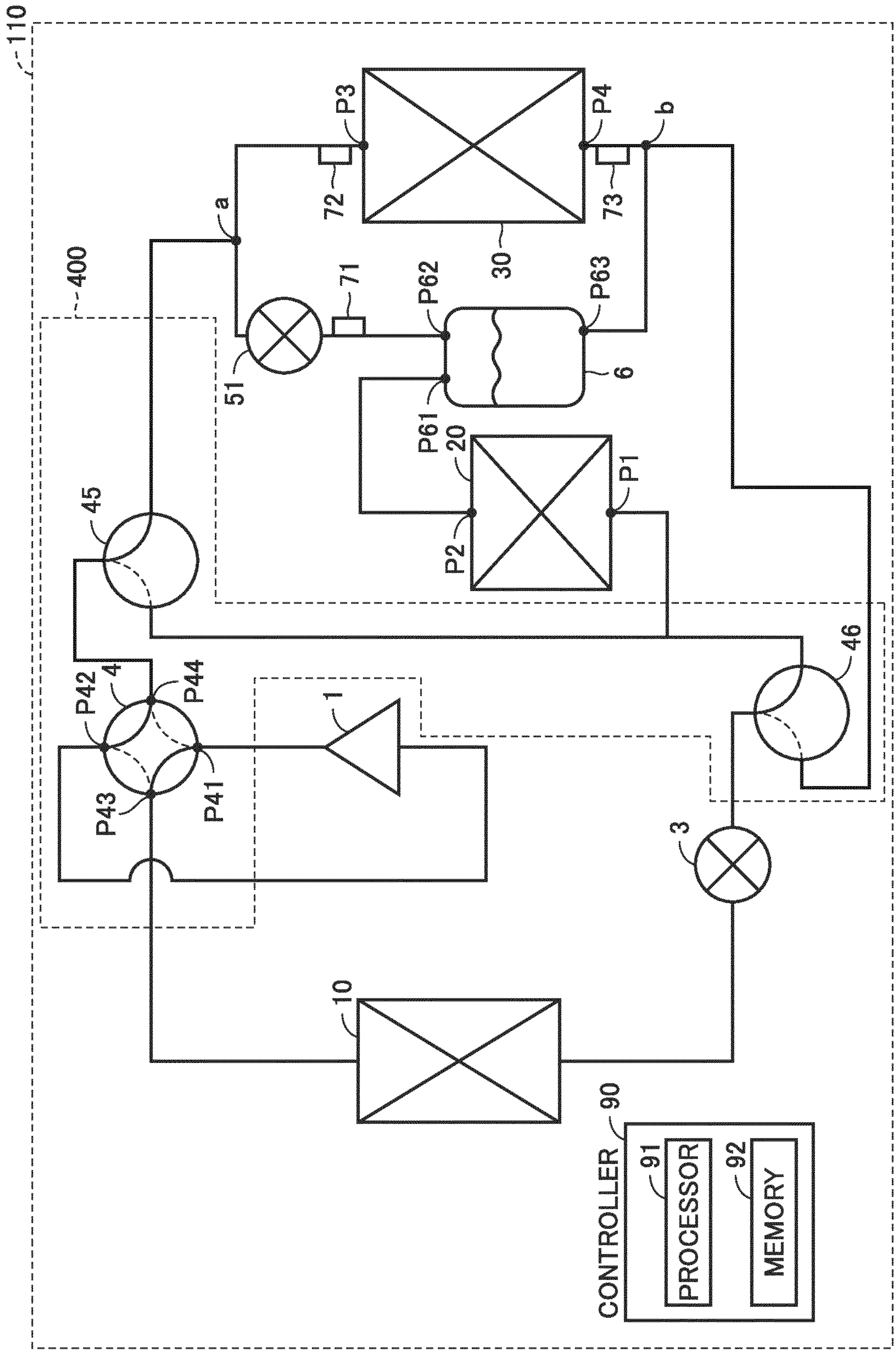

START
S1
CHANGE ROTATION SPEED OF COMPRESSOR
S2
ADJUST DEGREE OF OPENING OF EXPANSION DEVICE
S3
CALCULATE SC AT OUTLET OF CONDENSER
S4
SC IS WITHIN TARGET VALUE?
NO
YES
S5
ADJUST DEGREE OF OPENING OF FIRST FLOW RATE CONTROL DEVICE
S6
CALCULATE SH AT OUTLET OF EVAPORATOR
S7
SH IS WITHIN TARGET VALUE?
NO
YES
END

FIG.7


START
S11
CHANGE ROTATION SPEED OF COMPRESSOR
S12
ADJUST DEGREE OF OPENING OF EXPANSION DEVICE
S13
DISCHARGE TEMPERATURE OF COMPRESSOR IS WITHIN TARGET VALUE?
NO
YES
S14
ADJUST DEGREE OF OPENING OF FIRST FLOW RATE CONTROL DEVICE
S15
CALCULATE SC AT OUTLET OF CONDENSER
S16
SC IS WITHIN TARGET VALUE?
NO
YES
END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CONTROLLER
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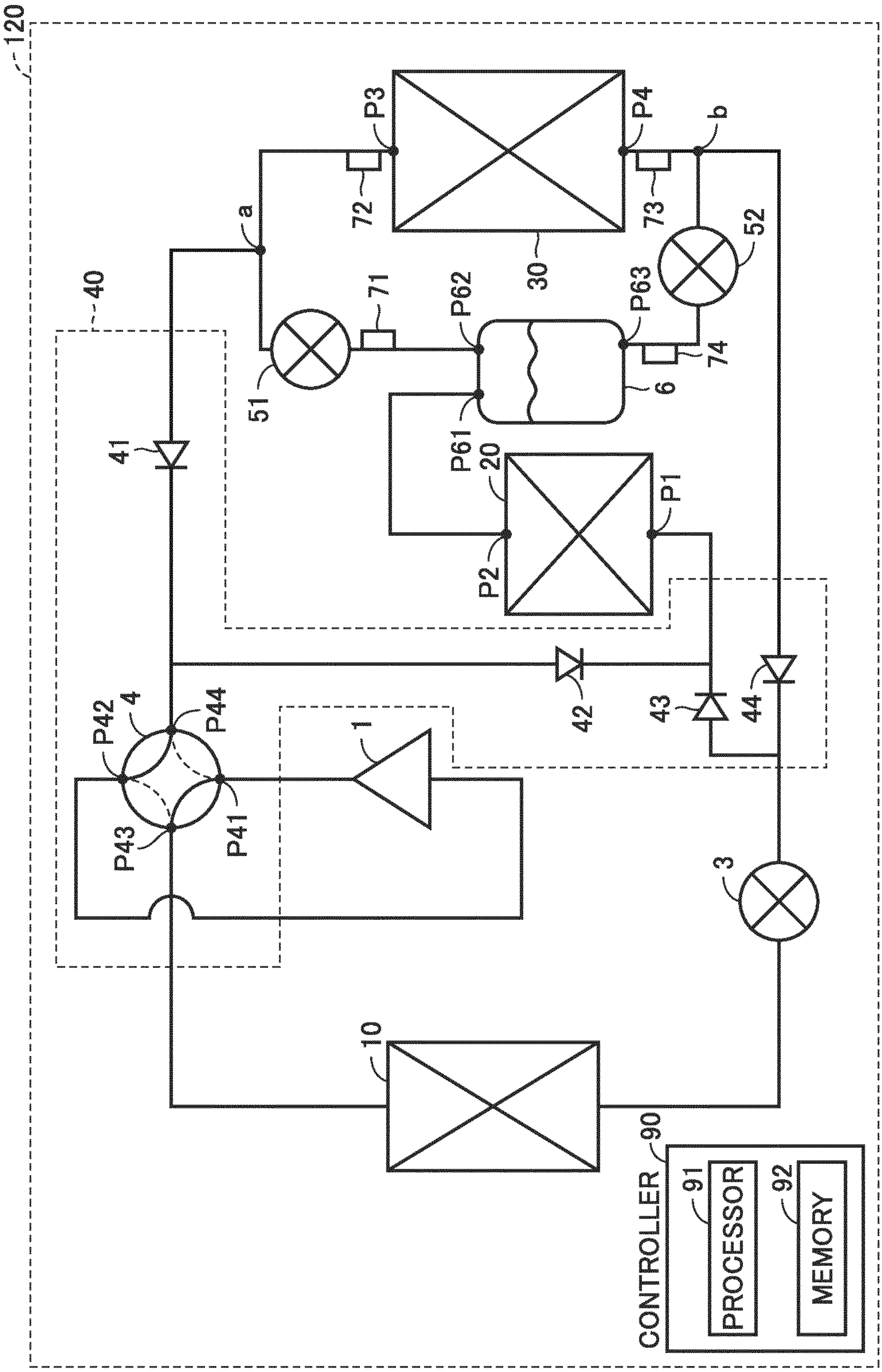
PROCESSOR
92
MEMORY

FIG.8

FIG.9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P41
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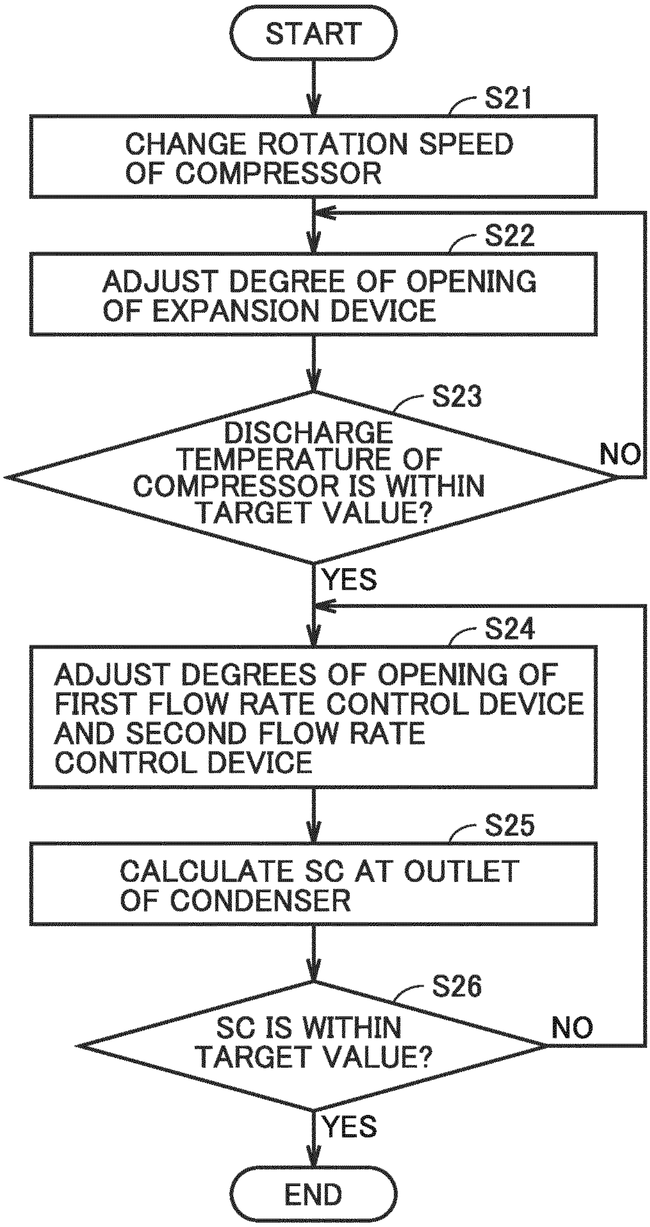
CONTROLLER
91
PROCESSOR
92
MEMORY

FIG.10


START
S21
CHANGE ROTATION SPEED OF COMPRESSOR
S22
ADJUST DEGREE OF OPENING OF EXPANSION DEVICE
S23
DISCHARGE TEMPERATURE OF COMPRESSOR IS WITHIN TARGET VALUE?
NO
YES
S24
ADJUST DEGREES OF OPENING OF FIRST FLOW RATE CONTROL DEVICE AND SECOND FLOW RATE CONTROL DEVICE
S25
CALCULATE SC AT OUTLET OF CONDENSER
S26
SC IS WITHIN TARGET VALUE?
NO
YES
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/012114

A. CLASSIFICATION OF SUBJECT MATTER
F25B 13/00(2006.01)i
FI: F25B13/00 Q
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)
F25B13/00

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)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	WO 2021/024443 A1 (MITSUBISHI ELECTRIC CORP) 11 February 2021 (2021-02-11) paragraphs [0072]-[0081], fig. 15-16	1 2-7
Y	JP 2005-300067 A (DENSO CORP) 27 October 2005 (2005-10-27) claim 1, paragraph [0011]	1
A	JP 2019-158308 A (MITSUBISHI ELECTRIC CORP) 19 September 2019 (2019-09-19) paragraphs [0016]-[0043]	1-7

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

* Special categories of cited documents:
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- "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
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- "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
07 April 2021 (07.04.2021)	27 April 2021 (27.04.2021)

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)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/012114

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
WO 2021/024443 A1	11 Feb. 2021	(Family: none)	
JP 2005-300067 A	27 Oct. 2005	(Family: none)	
JP 2019-158308 A	19 Sep. 2019	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

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Patent documents cited in the description

- JP 62025644 U **[0002] [0003]**