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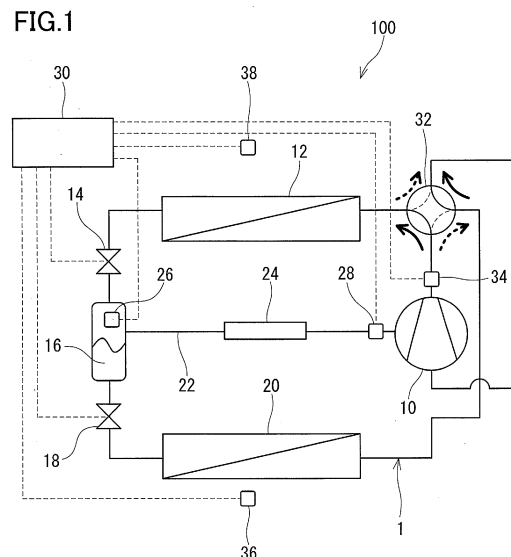
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(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus (100) has: a refrigerant circuit (1) including an upstream-side throttling device (14, 18), a gas-liquid separator (16), and a downstream-side throttling device (18, 14); an injection passage (22); and a controller (30). The injection passage (22) is provided with a heater (24). The controller (30) performs an intermediate pressure control operation for adjusting at least one of an opening degree of the upstream-side throttling device and an opening degree of the downstream-side throttling device so that a temperature difference between a gas-liquid separation temperature detected by an intermediate pressure temperature sensor (26) and an injection temperature detected by a superheat temperature sensor (28) becomes smaller than a predetermined value, and then increasing the opening degree of the downstream-side throttling device until the gas-liquid separation temperature drops by a predetermined value of degrees from the gas-liquid separation temperature that is detected on completion of the adjustment.



Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration cycle apparatus for use in a water heater, a hot-water heater, an air conditioner, or the like.

BACKGROUND ART

[0002] A heating/cooling switchable refrigeration cycle apparatus including a compressor, a four-way valve, an indoor heat exchanger, an indoor-side throttling device, a gas-liquid separator, an outdoor-side throttling device, and an outdoor heat exchanger is conventionally known. For example, Patent Literature 1 discloses a refrigeration cycle apparatus 500 as shown in FIG. 9.

[0003] In this refrigeration cycle apparatus 500, a compressor 501 is connected to an indoor heat exchanger 512 and an outdoor heat exchanger 520 through a four-way valve 532, and the indoor heat exchanger 512 and the outdoor heat exchanger 520 are connected to each other through an indoor-side throttling device 514, a gas-liquid separator 516, and an outdoor-side throttling device 518. An injection passage 522 through which an intermediate pressure gas refrigerant separated in the gas-liquid separator 516 is supplied to the compressor 510 is provided between the gas-liquid separator 516 and the compressor 510. The refrigeration cycle apparatus 500 is further provided with heat exchange temperature sensors 544 and 546 that detect the condensation temperature and the evaporation temperature of a refrigerant and with an intermediate pressure temperature sensor 526 that detects an intermediate pressure temperature that is the temperature of the refrigerant in the gas-liquid separator 516, so as to control the intermediate pressure to be a target value.

[0004] The operation of the refrigeration cycle apparatus 500 configured as described above is described below. In the heating mode, the refrigerant discharged from the compressor 510 passes through the four-way valve 532, exchanges heat in the indoor heat exchanger 512, and is decompressed from a high pressure to an intermediate pressure by the indoor-side throttling device 514. The intermediate pressure refrigerant is separated into a gas refrigerant and a liquid refrigerant in the gas-liquid separator 516, and the intermediate pressure gas refrigerant is supplied to the compressor 510 through the injection passage 522. On the other hand, the intermediate pressure liquid refrigerant is further decompressed by the outdoor-side throttling device 518. The low pressure refrigerant thus decompressed exchanges heat in the outdoor heat exchanger 520, passes through the four-way valve 532, and then is drawn into the compressor 510. In the cooling mode, the refrigerant discharged from the compressor 510 passes through the four-way valve 532, exchanges heat in the outdoor heat exchanger 520, and is decompressed from a high pressure to an

intermediate pressure by the outdoor-side throttling device 518. The intermediate pressure refrigerant is separated into a gas refrigerant and a liquid refrigerant in the gas-liquid separator 516, and the intermediate pressure gas refrigerant is supplied to the compressor 510 through the injection passage 522. On the other hand, the intermediate pressure liquid refrigerant is further decompressed by the indoor-side throttling device 514. The low pressure refrigerant thus decompressed exchanges heat in the indoor heat exchanger 512, passes through the four-way valve 532, and then is drawn into the compressor 510.

[0005] In the refrigeration cycle apparatus 500, the controller 530 determines a target intermediate pressure temperature based on the condensation temperature and evaporation temperature detected by the heat exchange temperature sensors 544 and 546, and the opening degree of the throttling device (the outdoor-side throttling device 516 in the heating mode and the indoor-side throttling device 514 in the cooling mode) located downstream from the gas-liquid separator 516 is adjusted so that the intermediate pressure temperature detected by the intermediate pressure temperature sensor 526 reaches the target intermediate pressure temperature.

CITATION LIST

Patent Literature

[0006] Patent Literature 1: JP 3317170 B

SUMMARY OF INVENTION

Technical Problem

[0007] The refrigeration cycle apparatus 500 shown in FIG. 9 has room for further improvement in efficiency. In view of these circumstances, it is an object of the present disclosure to improve the efficiency of a refrigeration cycle apparatus.

Solution to Problem

[0008] The present disclosure provides a refrigeration cycle apparatus including: a refrigerant circuit in which a refrigerant is circulated so that the refrigerant passes through a compressor, a condenser, an upstream-side throttling device, a gas-liquid separator, a downstream-side throttling device, and an evaporator in this order; an injection passage through which a gas refrigerant separated in the gas-liquid separator is supplied to the compressor; a heater provided in the injection passage; an intermediate pressure temperature sensor that detects a gas-liquid separation temperature that is a temperature of the refrigerant flowing into the injection passage from the refrigerant circuit; a superheat temperature sensor that detects an injection temperature that is a temperature of the refrigerant heated by the heater in the injection

passage; and a controller that performs an intermediate pressure control operation for adjusting at least one of an opening degree of the upstream-side throttling device and an opening degree of the downstream-side throttling device so that a temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than a predetermined value, and then increasing the opening degree of the downstream-side throttling device until the gas-liquid separation temperature drops by a predetermined value of degrees from the gas-liquid separation temperature that is detected on completion of the adjustment.

Advantageous Effects of Invention

[0009] The above-described configuration makes it possible to determine a reference gas-liquid separation temperature using the heater and the superheat temperature sensor, to set, as a target gas-liquid separation temperature, a temperature that is lower by a predetermined value of degrees than this reference temperature, and thereby to cancel out the measurement error caused by the intermediate pressure temperature sensor. As a result, the intermediate pressure can be controlled to have a desired value with high accuracy, and the efficiency of the refrigeration cycle apparatus can be improved.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

FIG. 1 is a configuration diagram of a refrigeration cycle apparatus according to a first embodiment of the present invention.

FIG. 2 is a flow chart illustrating a method for controlling an intermediate pressure control operation in the first embodiment.

FIG. 3 is a graph showing changes in the opening degrees of an upstream-side throttling device and a downstream-side throttling device and changes in the discharge temperature, the injection temperature and the gas-liquid separation temperature in the first embodiment.

FIG. 4 is a diagram showing a heater according to a modification.

FIG. 5 is a configuration diagram of a refrigeration cycle apparatus according to another modification.

FIG. 6 is a configuration diagram of a refrigeration cycle apparatus according to still another modification.

FIG. 7 is a configuration diagram of a refrigeration cycle apparatus according to a second embodiment of the present invention.

FIG. 8 is a flow chart illustrating a method for controlling an intermediate pressure control operation in the second embodiment.

FIG. 9 is a configuration diagram of a conventional

refrigeration cycle apparatus.

DESCRIPTION OF EMBODIMENTS

[0011] In the refrigeration cycle apparatus 500 shown in FIG. 9, the intermediate pressure of the refrigerant supplied from the gas-liquid separator 516 to the compressor 510 through the injection passage 522 is controlled based on the temperatures detected by three temperature sensors 544, 546 and 526. Therefore, variations in the accuracy of the temperature sensors cause a problem. Commonly used temperature sensors have a measurement error of at least $\pm 1.5^{\circ}\text{C}$. In the case where the control is performed using a plurality of temperature sensors, as in the refrigeration cycle apparatus 500 shown in FIG. 9, the measurement error increases as the number of temperature sensors increases (if the error is $\pm 1.5^{\circ}\text{C}$ per sensor, the total measurement error of the three sensors is $\pm 4.5^{\circ}\text{C}$). Therefore, the actually controlled intermediate pressure may deviate from the target value, resulting in a decrease in the efficiency of the refrigeration cycle apparatus.

[0012] A first aspect of the present disclosure provides a refrigeration cycle apparatus including: a refrigerant circuit in which a refrigerant is circulated so that the refrigerant passes through a compressor, a condenser, an upstream-side throttling device, a gas-liquid separator, a downstream-side throttling device, and an evaporator in this order; an injection passage through which a gas refrigerant separated in the gas-liquid separator is supplied to the compressor; a heater provided in the injection passage; an intermediate pressure temperature sensor that detects a gas-liquid separation temperature that is a temperature of the refrigerant flowing into the injection passage from the refrigerant circuit; a superheat temperature sensor that detects an injection temperature that is a temperature of the refrigerant heated by the heater in the injection passage; and a controller that performs an intermediate pressure control operation for adjusting at least one of an opening degree of the upstream-side throttling device and an opening degree of the downstream-side throttling device so that a temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than a predetermined value, and then increasing the opening degree of the downstream-side throttling device until the gas-liquid separation temperature drops by a predetermined value of degrees from the gas-liquid separation temperature that is detected on completion of the adjustment.

[0013] A second aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in the first aspect, further including a post-condensation temperature sensor that detects a condensation-side outlet temperature that is a temperature of the refrigerant flowing out of the condenser, wherein during the intermediate pressure control operation, the controller modifies a gas-liquid separation temperature calculation formula for use

in a steady operation, using the gas-liquid separation temperature and the condensation-side outlet temperature that are detected when the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value.

[0014] According to the second aspect, during the intermediate pressure control operation, the gas-liquid separation temperature calculation formula for use in the steady operation can be modified using the gas-liquid separation temperature and the condensation-side outlet temperature that are detected when the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value.

[0015] A third aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in the second aspect, further including a pre-evaporation temperature sensor that detects an evaporation-side inlet temperature that is a temperature of the refrigerant flowing into the evaporator, wherein the controller also uses the evaporation-side inlet temperature that is detected when the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value, so as to modify the gas-liquid separation temperature calculation formula for use in the steady operation.

[0016] According to the third aspect, during the intermediate pressure control operation, the gas-liquid separation temperature calculation formula for use in the steady operation can be modified using the gas-liquid separation temperature, the condensation-side outlet temperature, and the evaporation-side inlet temperature that are detected when the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value.

[0017] A fourth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in the second or third aspect, wherein the controller performs the steady operation using the gas-liquid separation temperature calculation formula modified during the intermediate pressure control operation.

[0018] According to the fourth aspect, it is possible to increase the accuracy of the intermediate pressure control in the steady operation, taking into consideration the measurement errors of the temperature sensors, etc.

[0019] A fifth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in any one of the first to fourth aspects, wherein the controller performs the intermediate pressure control operation in a starting operation.

[0020] According to the fifth aspect, the refrigeration cycle apparatus can shift from the starting operation to the steady operation while maintaining the optimum conditions.

[0021] A sixth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in any

one of the first to fifth aspects, wherein the controller performs the intermediate pressure control operation during the steady operation.

[0022] According to the sixth aspect, the intermediate pressure control operation is performed even during the steady operation, and thus the intermediate pressure is controlled to have a desired value with higher accuracy.

[0023] A seventh aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in the fifth aspect, further including a discharge temperature sensor that detects a discharge temperature that is a temperature of the refrigerant discharged from the compressor, wherein the controller decreases the opening degree of the downstream-side throttling device until the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value while adjusting the opening degree of the upstream-side throttling device so that the discharge temperature approaches a target discharge temperature, and then increases the opening degree of the downstream-side throttling device.

[0024] According to the seventh aspect, the discharge temperature is controlled using the upstream-side throttling device and the gas-liquid separation temperature is controlled using the downstream-side throttling device, and thereby easy control can be achieved.

[0025] A eighth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in any one of the first to seventh aspects, wherein the refrigerant circuit includes an indoor heat exchanger and an outdoor heat exchanger each serving as the condenser and the evaporator, and includes an indoor-side throttling device and an outdoor-side throttling device each serving as the upstream-side throttling device and the downstream-side throttling device, and the refrigerant circuit is provided with a four-way valve capable of switching a flow direction of the refrigerant.

[0026] According to the eighth aspect, a cooling/heating switchable refrigeration cycle apparatus can be obtained.

[0027] A ninth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in any one of the first to eighth aspects, wherein the heater is an electric heater.

[0028] According to the ninth aspect, it is easy to perform the on-off control of the heater, and therefore the refrigerant flowing in the injection passage can be heated only when the refrigerant flowing in the injection passage needs to be heated.

[0029] A tenth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in any one of the first to eighth aspects, wherein the heater is a heat storage unit that accumulates exhaust heat from the compressor and heats the refrigerant using the accumulated heat.

[0030] According to the tenth aspect, the refrigerant flowing in the injection passage is heated using exhaust heat from the compressor.

[0031] An eleventh aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in any one of the first to eighth aspects, wherein the heater is a heat exchanger including a first heat exchanging portion into which the refrigerant flowing in the injection passage is introduced and a second heat exchanging portion into which the refrigerant flowing in the refrigerant circuit and having a higher temperature than the gas-liquid separation temperature is introduced, and in the heat exchanger, the second heat exchanging portion heats the first heat exchanging portion.

[0032] According to the eleventh aspect, the refrigerant flowing in the injection passage is heated using the heat of the refrigerant flowing in the refrigerant circuit.

[0033] A twelfth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in the eleventh aspect, wherein the refrigerant flowing between the compressor and the condenser is introduced into the second heat exchanging portion.

[0034] According to the twelfth aspect, the refrigerant flowing in the injection passage is heated using the heat of the refrigerant flowing in the refrigerant circuit and having a relatively high temperature.

[0035] A thirteenth aspect of the present disclosure provides a refrigeration cycle apparatus as set forth in the eleventh aspect, wherein the refrigerant flowing between the condenser and the upstream-side throttling device is introduced into the second heat exchanging portion.

[0036] According to the thirteenth aspect, the refrigerant flowing in the injection passage 22 is heated using the heat of the refrigerant flowing in the refrigerant circuit. In addition, since the degree of supercooling of the refrigerant at the outlet of the condenser in the refrigerant circuit is increased, the capacity of the refrigeration cycle apparatus is improved.

[0037] Hereinafter, embodiments of the present invention are described in detail with reference to the drawings. The following description is merely exemplary of the present invention, and the present invention is not limited to this.

(First Embodiment)

[0038] FIG. 1 shows a refrigeration cycle apparatus 100 according to a first embodiment of the present disclosure. This refrigeration cycle apparatus 100 includes a refrigerant circuit 1 in which a refrigerant is circulated and a controller 30.

[0039] The refrigerant circuit 1 includes a compressor 10, a four-way valve 32, an indoor heat exchanger 12, an indoor-side throttling device 14, a gas-liquid separator 16, an outdoor-side throttling device 18, and an outdoor heat exchanger 20. Four ports of the four-way valve 32 are connected to the suction port of the compressor 10, the discharge port thereof, the indoor heat exchanger 12, and the outdoor heat exchanger 20, respectively, by refrigerant pipes. The indoor heat exchanger 12, the in-

door-side throttling device 14, the gas-liquid separator 16, the outdoor-side throttling device 18, and the outdoor heat exchanger 20 are connected in series by refrigerant pipes.

[0040] The four-way valve 32 switches the flow direction of the refrigerant to a first direction indicated by solid arrows in the heating mode, and to a second direction indicated by dashed arrows in the cooling mode. In the first direction, the discharge port of the compressor 10 is connected to the indoor heat exchanger 12, and the suction port of the compressor 10 is connected to the outdoor heat exchanger 20. In the second direction, the discharge port of the compressor 10 is connected to the outdoor heat exchanger 20, and the suction port of the compressor 10 is connected to the indoor heat exchanger 12. Specifically, in the heating mode, the refrigerant circulating in the refrigerant circuit 1 passes through the compressor 10, the indoor heat exchanger 12, the indoor-side throttling device 14, the gas-liquid separator 16, the outdoor-side throttling device 18, and the outdoor heat exchanger 20 in this order. In the cooling mode, the refrigerant passes through the compressor 10, the outdoor heat exchanger 20, the outdoor-side throttling device 18, the gas-liquid separator 16, the indoor-side throttling device 14 and the indoor heat exchanger 12 in this order.

[0041] The indoor heat exchanger 12 serves as a condenser in the heating mode, and as an evaporator in the cooling mode. On the other hand, the outdoor heat exchanger 20 serves as an evaporator in the heating mode, and as a condenser in the cooling mode.

[0042] As the indoor-side throttling device 14 and the outdoor-side throttling device 18, for example, opening-adjustable electric expansion valves are used. The controller 30 sends control signals to the indoor-side throttling device 14 and the outdoor-side throttling device 18 so as to adjust the opening degrees thereof.

[0043] An injection passage 22 through which an intermediate pressure gas refrigerant separated in the gas-liquid separator 16 is supplied to the compressor 10 is provided between the gas-liquid separator 16 and the compressor 10. The injection passage 22 is constituted, for example, by a refrigerant pipe, one end of which is connected to a gas layer side of the gas-liquid separator 16 and the other end of which is connected to an intermediate pressure suction port that opens into a compression chamber of the compressor 10 during a compression process. The injection passage 22 is provided with a heater 24 on the way to the compressor 10, and the intermediate pressure gas refrigerant flowing in the injection passage 22 is heated and then injected into the compressor 10.

[0044] As the heater 24, for example, a heater such as an electric heater can be used. Examples of the electric heater include a resistance heater and an induction heater. The heater 24 does not have to continuously heat the refrigerant flowing in the injection passage 22. For example, under the on-off control of the electric heater, the heater 24 may heat the refrigerant flowing in the injection

passage 22 only in an intermediate pressure control operation described below.

[0045] The refrigeration cycle apparatus 100 is further provided with: a discharge temperature sensor 34 that detects a discharge temperature T_d that is the temperature of the refrigerant discharged from the compressor 10; an outdoor temperature sensor 36 that detects an outdoor temperature T_o ; an indoor temperature sensor 38 that detects an indoor temperature T_i ; an intermediate pressure temperature sensor 26 that detects a gas-liquid separation temperature T_m that is the temperature of the refrigerant flowing into the injection passage 22 from the refrigerant circuit 1; and a superheat temperature sensor 28 that detects an injection temperature T_{inj} that is the temperature of the refrigerant heated by the heater 24 in the injection passage 22. The controller 30 mainly controls the opening degrees of the indoor-side throttling device 14 and the outdoor-side throttling device 18 and the rotational speed of the compressor 10 based on the temperatures detected by these temperature sensors.

[0046] The intermediate pressure temperature sensor 26 may be provided in the gas-liquid separator 16, or may be provided upstream from the heater 24 in the refrigerant pipe that constitutes the injection passage 22. Instead, the intermediate pressure temperature sensor 26 may be provided in a refrigerant pipe that connects the gas-liquid separator 16 and the indoor-side throttling device 14 or in a refrigerant pipe that connects the gas-liquid separator 16 and the outdoor-side throttling device 18. The superheat temperature sensor 28 is provided downstream from the heater 24 in the refrigerant pipe that constitutes the injection passage 22.

[0047] Next, the operation of the refrigeration cycle apparatus 100 is described.

[0048] In the heating mode, the flow direction of the refrigerant is switched to the first direction indicated by solid arrows by the four-way valve 32. In this state, the refrigerant compressed in the compressor 10 is discharged from the compressor 10 and then introduced into the indoor heat exchanger 12. The refrigerant introduced into the indoor heat exchanger 12 transfers its heat to indoor air there and then is introduced into the indoor-side throttling device 14. The refrigerant introduced into the indoor-side throttling device 14 is decompressed by the indoor-side throttling device 14 into an intermediate pressure refrigerant having a pressure between a condensation pressure and an evaporation pressure, and then is introduced into the gas-liquid separator 16. The intermediate pressure refrigerant introduced into the gas-liquid separator 16 is separated into a liquid refrigerant and a gas refrigerant in the gas-liquid separator 16. The intermediate pressure liquid refrigerant is introduced into the outdoor-side throttling device 18, while the intermediate pressure gas refrigerant flows into the injection passage 22. The intermediate pressure liquid refrigerant introduced into the outdoor-side throttling device 18 is decompressed by the outdoor-side throttling device 18, is introduced into the outdoor heat exchanger

20, and absorbs heat from outdoor air there. Then, the liquid refrigerant is returned to the compressor 10. The intermediate pressure gas refrigerant that has flowed into the injection passage 22 is heated in the heater 24, and then is injected into the compressor 10.

[0049] In the cooling mode, the flow direction of the refrigerant is switched to the second direction indicated by dashed arrows by the four-way valve 32. In this state, the refrigerant compressed in the compressor 10 is discharged from the compressor 10 and then introduced into the outdoor heat exchanger 20. The refrigerant introduced into the outdoor heat exchanger 20 transfers its heat to outdoor air there and then is introduced into the outdoor-side throttling device 18. The refrigerant introduced into the outdoor-side throttling device 18 is decompressed by the outdoor-side throttling device 18 into an intermediate pressure refrigerant having a pressure between the condensation pressure and the evaporation pressure, and then is introduced into the gas-liquid separator 16. The intermediate pressure refrigerant introduced into the gas-liquid separator 16 is separated into a liquid refrigerant and a gas refrigerant in the gas-liquid separator 16. The intermediate pressure liquid refrigerant is introduced into the indoor-side throttling device 14, while the intermediate pressure gas refrigerant flows into the injection passage 22. The intermediate pressure liquid refrigerant introduced into the indoor-side throttling device 14 is decompressed by the indoor-side throttling device 14, is introduced into the indoor heat exchanger 12, and absorbs heat from indoor air there. Then, the liquid refrigerant is returned to the compressor 10. The intermediate pressure gas refrigerant that has flowed into the injection passage 22 is heated in the heater 24, and then is injected into the compressor 10.

[0050] In the refrigerant circuit 1, the flow direction of the refrigerant in the heating mode is different from that in the cooling mode. However, in the injection passage 22, the refrigerant flows in the same direction in both modes. Therefore, the same method can be used to control the intermediate pressure in both the heating mode and the cooling mode. Hereinafter, the indoor heat exchanger 12 in the heating mode and the outdoor heat exchanger 20 in the cooling mode are referred to as condensers, the outdoor heat exchanger 20 in the heating mode and the indoor heat exchanger 12 in the cooling mode are referred to as evaporators, the indoor-side throttling device 14 in the heating mode and the outdoor-side throttling device 18 in the cooling mode are referred to as upstream-side throttling devices, and the outdoor-side throttling device 18 in the heating mode and the indoor-side throttling device 14 in the cooling mode are referred to as downstream-side throttling devices. The following description applies to the heating mode and the cooling mode interchangeably.

[0051] In the present embodiment, the controller 30 performs an intermediate pressure control operation in the starting operation. The intermediate pressure control operation is an operation for adjusting at least one of the

opening degree of the upstream-side throttling device and the opening degree of the downstream-side throttling device so that a temperature difference between the gas-liquid separation temperature T_m detected by the intermediate pressure temperature sensor 26 and the injection temperature T_{inj} detected by the superheat temperature sensor 28 becomes smaller than a predetermined value ΔT_i , and then increasing the opening degree of the downstream-side throttling device until the gas-liquid separation temperature T_m drops by a predetermined value of degrees ΔT_m from the gas-liquid separation temperature that is detected on completion of the adjustment. Hereinafter, the intermediate pressure control operation performed by the controller 30 is described in detail with reference to the flow chart of FIG. 2.

[0052] First, the controller 30 decreases the opening degree of the downstream-side throttling device until the temperature difference between the gas-liquid separation temperature T_m and the injection temperature T_{inj} becomes smaller than the predetermined value ΔT_i while adjusting the opening degree of the upstream-side throttling device so that the discharge temperature T_d detected by the discharge temperature sensor 34 approaches a target discharge temperature T_D .

[0053] Specifically, the controller 30 obtains the outdoor temperature T_o detected by the outdoor temperature sensor 36 and obtains the indoor temperature T_i detected by the indoor temperature sensor 38 (Step S1). Next, the controller 30 determines the target discharge temperature T_D based on the detected outdoor temperature T_o and indoor temperature T_i (Step S2). Then, the controller 30 obtains the discharge temperature T_d detected by the discharge temperature sensor 34 (Step S3), and compares a difference between this discharge temperature T_d and the target discharge temperature T_D with a predetermined acceptable value ΔT_d (for example, 1.5°C) (Step S4).

[0054] When the difference between the detected discharge temperature T_d and the target discharge temperature T_D is equal to or larger than the acceptable value ΔT_d (NO in Step S4), the controller 30 adjusts the opening degree of the upstream-side throttling device (Step S5). Specifically, the controller 30 decreases the opening degree of the upstream-side throttling device when the detected discharge temperature T_d is lower than the target discharge temperature T_D , and increases the opening degree of the upstream-side throttling device when the detected discharge temperature T_d is higher than the target discharge temperature T_D . After Step S5, the flow returns to Step S1. Through the repetition of Steps S1 to S5, the actual discharge temperature T_d approaches the target discharge temperature T_D within a certain tolerance. As a result, when the difference between the detected discharge temperature T_d and the target discharge temperature T_D becomes smaller than the acceptable value ΔT_d (YES in Step S4), the flow proceeds to Step S6.

[0055] In Step S6, the controller 30 obtains the gas-

liquid separation temperature T_m of the intermediate pressure refrigerant detected by the intermediate pressure temperature sensor 26 and obtains the injection temperature T_{inj} of the refrigerant that has passed through the heater 24 detected by the superheat temperature sensor 28 (Step S6). Next, the controller 30 determines whether or not the temperature difference between the gas-liquid separation temperature T_m and the injection temperature T_{inj} is smaller than a predetermined value ΔT_i (for example, 3°C) (Step S7).

[0056] The temperature difference between the gas-liquid separation temperature T_m and the injection temperature T_{inj} is the degree of superheat of the gas refrigerant to be injected. Conventionally, since the injection passage 22 is not provided with the heater 24, it cannot be ensured that the intermediate pressure gas refrigerant to be injected is superheated. In contrast, in the present embodiment, since the injection passage 22 is provided with the heater 24, it is ensured that the intermediate pressure gas refrigerant that has passed through the heater 24 is superheated, as long as only the gas refrigerant flows in the injection passage 22.

[0057] In the case of NO in Step S7, that is, in the case where a predetermined degree or higher superheat is obtained, the controller 30 decreases the opening degree of the downstream-side throttling device (Step S8) so as to raise the gas-liquid separation temperature T_m . After Step S8, the flow returns to Step S1. The controller 30 repeats Steps S1 to S8 until YES is determined in Step S7.

[0058] As the opening degree of the downstream-side throttling device is decreased, the pressure difference between the front and rear of the downstream-side throttling device increases, and the intermediate pressure also increases accordingly. The flow rate of the refrigerant to be injected also increases. As the intermediate pressure increases, the dryness of the intermediate pressure refrigerant in the gas-liquid separator 16 decreases. When the opening degree of the downstream-side throttling device is continuously decreased as described above, the dryness of the refrigerant continues to decrease and the flow rate of the refrigerant to be injected continues to increase, and at some point in time, the liquid refrigerant begins to flow into the injection passage 22.

[0059] The liquid refrigerant flowing into the injection passage 22 is heated by the heater 24 and evaporated. Therefore, the injection temperature T_{inj} of the refrigerant that has passed through the heater 24 drops suddenly due to the latent heat of the evaporation. Step S7 is a step for detecting the sudden drop in the injection temperature T_{inj} .

[0060] In the case of YES in Step S7, that is, in the case where the injection temperature T_{inj} drops suddenly and the predetermined degree or higher superheat cannot be obtained for the gas refrigerant that has passed through the heater 24, the controller 30 records the gas-liquid separation temperature T_m detected at that time as T_{m0} (Step S9).

[0061] Since the workload of the compressor 10 for re-compression can be reduced by increasing the intermediate pressure, the power consumption of the compressor 10 can be reduced. However, once the liquid refrigerant begins to flow into the injection passage 22, the amount of liquid refrigerant flowing through the evaporator also decreases, resulting in a decrease in the evaporation capacity and a decrease in the performance of refrigeration cycle. Therefore, in order to achieve high performance in the refrigeration cycle apparatus 100 in which injection is performed, it is necessary to allow only the gas refrigerant to flow in the injection passage 22. So, the controller 30 determines a target gas-liquid separation temperature T_{m1} (Step S10). Specifically, in order to reliably prevent the liquid refrigerant from flowing into the injection passage 22, the controller 30 calculates the target gas-liquid separation temperature T_{m1} by subtracting a predetermined value (for example, 1°C) from the gas-liquid separation temperature T_{m0} at which the predetermined degree or higher superheat cannot be obtained for the gas refrigerant that has passed through the heater 24.

[0062] In the steps following Step S10, the opening degree of the downstream-side throttling device is adjusted again to reduce the intermediate pressure and the gas-liquid separation temperature T_m , so that only the gas refrigerant is allowed to flow in the injection passage 22. Specifically, the controller 30 obtains the intermediate pressure gas-liquid separation temperature T_m detected by the intermediate pressure temperature sensor 26 (Step S11), and compares this temperature T_m with the target gas-liquid separation temperature T_{m1} determined in Step S10 (Step S12). When the detected gas-liquid separation temperature T_m is equal to or higher than the target gas-liquid separation temperature T_{m1} (NO in Step S12), the controller 30 increases the opening degree of the downstream-side throttling device (Step S13) so as to reduce the intermediate pressure. The opening degree of the downstream-side throttling device is further increased, and when the temperature T_m becomes smaller than the target gas-liquid separation temperature T_{m1} (YES in Step S12), the controller 30 shifts to the steady operation in which control is performed to maintain the target discharge temperature and the target gas-liquid separation temperature (Step S14).

[0063] After shifting to the steady operation, the controller 30 obtains the gas-liquid separation temperature T_m detected by the intermediate pressure temperature sensor 26 and the discharge temperature T_d detected by the discharge temperature sensor 34, and adjusts the opening degrees of the upstream-side throttling device and the downstream-side throttling device to prevent these temperatures T_m and T_d from differing significantly from the target values.

[0064] The control of the gas-liquid separation temperature T_m is performed by adjusting the opening degree of the downstream-side throttling device. Specifically, the opening degree of the downstream-side throttling device

is adjusted so that the detected gas-liquid separation temperature T_m falls within a predetermined temperature range ΔT_{ms} from the target gas-liquid separation temperature T_{m1} . When the gas-liquid separation temperature T_m is lower than $T_{m1} - \Delta T_{ms}$, the opening degree of the downstream-side throttling device is decreased to raise the gas-liquid separation temperature T_m and bring T_m close to T_{m1} . Conversely, when the gas-liquid separation temperature T_m is higher than $T_{m1} + \Delta T_{ms}$, the opening of the downstream-side throttling device is increased to lower the gas-liquid separation temperature T_m and bring T_m close to T_{m1} . The amount of this adjustment of the opening degree of the downstream-side throttling device may be fixed during the adjustment, or the amount of the adjustment may be reduced more as the detected value approaches the target value.

[0065] The control of the discharge temperature T_d is performed by adjusting the opening degree of the upstream-side throttling device. Specifically, the opening degree of the upstream-side throttling device is adjusted so that the detected discharge temperature T_d falls within a predetermined temperature range ΔT_{ds} from the target discharge temperature T_{d1} . When the discharge temperature T_d is lower than $T_{d1} - \Delta T_{ds}$, the opening degree of the upstream-side throttling device is decreased to raise the discharge temperature T_d and bring T_d close to T_{d1} . Conversely, when discharge temperature T_d is higher than $T_{d1} + \Delta T_{ds}$, the opening of the upstream-side throttling device is increased to lower the discharge temperature T_d and bring T_d close to T_{d1} . The amount of this adjustment of the opening degree of the upstream-side throttling device may be fixed during the adjustment, or the amount of the adjustment may be reduced more as the detected value approaches the target value.

[0066] As shown in FIG. 1, since the gas-liquid separator 16 is disposed between the upstream-side throttling device and the downstream-side throttling device, the gas-liquid separation temperature T_m is also significantly influenced by the adjustment of the opening degree of the upstream-side throttling device. Specifically, as the opening degree of the upstream-side throttling device is decreased, the differential pressure between the front and rear of the upstream-side throttling device increases, and the intermediate pressure decreases and the gas-liquid separation temperature T_m decreases accordingly. Conversely, as the opening degree of the upstream-side throttling device is increased, the differential pressure between the front and rear of the upstream-side throttling device decreases, and the intermediate pressure increases and the gas-liquid separation temperature T_m increases accordingly. In this way, the adjustment of the opening degree of the upstream-side throttling device has an influence not only on the discharge temperature T_d but also on the gas-liquid separation temperature T_m . This is not just limited to the upstream-side throttling device. When the opening degree of the downstream-side throttling device is adjusted, the amount of the refrigerant flowing into the evaporator is changed and

the suction conditions of the compressor 10 are changed. The adjustment of the opening degree of the downstream-side throttling device has an influence not only on the gas-liquid separation temperature T_m but also on the discharge temperature T_d .

[0067] The adjustment of the opening degree of the upstream-side throttling device and the adjustment of the opening degree of the downstream-side throttling device each have an influence on both the discharge temperature T_d and the gas-liquid separation temperature T_m . However, it is possible to perform easier control by assigning a specific task to each of the upstream-side throttling device and the downstream-side throttling device, for example, by assigning the task of controlling the discharge temperature T_d to the upstream-side throttling device and the task of controlling the gas-liquid separation temperature T_m to the downstream-side throttling device.

[0068] FIG. 3 shows how the opening degrees of the upstream-side throttling device and the downstream-side throttling device change, and how the discharge temperature T_d , the injection temperature T_{inj} , and the gas-liquid separation temperature T_m change, in the intermediate pressure control operation described above. As shown in FIG. 3, in the present embodiment, first, the opening degree of the upstream-side throttling device is gradually decreased to raise the discharge temperature T_d gradually. After that, the opening degree of the downstream-side throttling device is decreased until the injection temperature T_{inj} drops suddenly, and then the opening degree of the downstream-side throttling device is increased.

[0069] In the above-described intermediate pressure control operation, a reference temperature T_{m0} for the gas-liquid separation temperature T_m is determined using the heater 24 and the superheat temperature sensor 28, and a temperature that is lower by a predetermined value of degrees ΔT_m than the reference temperature T_{m0} is set as a target gas-liquid separation temperature T_{m1} , and thereby the measurement error caused by the intermediate pressure temperature sensor 26 can be cancelled out. As a result, the intermediate pressure can be controlled to have a desired value with high accuracy, and the efficiency of the refrigeration cycle apparatus 100 can be improved.

[0070] In the present embodiment, since the intermediate pressure control operation is performed in the starting operation, it is possible to shift the operation from the starting operation to the steady operation while maintaining the optimum conditions.

(Modifications)

[0071] In the embodiment described above, the intermediate pressure control operation is performed in the starting operation. Therefore, both the opening degree of the upstream-side throttling device and the opening degree of the downstream-side throttling device are ad-

justed so that the temperature difference between the gas-liquid separation temperature T_m and the injection temperature T_{inj} becomes smaller than the predetermined value. However, the controller 30 may perform the intermediate pressure control operation during the steady operation. In this case, either one of the opening degree of the upstream-side throttling device and the opening degree of the downstream-side throttling device can be adjusted so that the temperature difference between the gas-liquid separation temperature T_m and the injection temperature T_{inj} becomes smaller than the predetermined value.

[0072] The flow chart given in the case where the intermediate pressure control operation is performed during the steady operation is exactly the same as that of FIG. 2. That is, the controller can proceed to Step S1 when some determination conditions are satisfied during the steady operation. For example, the controller may proceed to Step S1 when the cycle conditions are significantly changed due to a change in the outdoor temperature, or may proceed to Step S1 in response to a change in the user's request. Instead, the controller may proceed to Step S1 based on the elapsed time from the start of the operation.

[0073] In the embodiment described above, an electric heater is used as the heater 24. However, the heater 24 is not limited to a means, such as an electric heater, for applying heat to the refrigerant from outside the refrigerant circuit 1. For example, a part of the refrigerant circuit 1 may constitute the heater 24 in such a manner that a part of a refrigerant pipe constituting the injection passage 22 is brought into direct or indirect contact with a closed casing, a discharge pipe, or the like of the compressor 10 having a higher temperature than the intermediate pressure refrigerant (gas-liquid separation temperature). Modifications of the heater 24 are described in detail below. The modifications shown below are configured in the same manner as in the embodiment described above, unless otherwise described.

[0074] FIG. 4 shows a heater 24A as a modification of the heater 24. The heater 24A is a heat storage unit that accumulates exhaust heat from the compressor 10 and heats the refrigerant flowing in the injection passage 22 by using the accumulated heat. Specifically, the heater 24A has a heat storage material 50 disposed to surround the compressor 10 and a serpentine tube 52 disposed inside the heat storage material 50 in a zigzag pattern. The serpentine tube 52 constitutes a part of the injection passage 22. Therefore, the refrigerant flowing into the injection passage 22 from the gas-liquid separator 16 is heated while flowing in the serpentine tube 52. Then, the refrigerant that has passed through the serpentine tube 52 is injected into the compressor 10. Thereby, the refrigerant flowing in the injection passage 22 can be heated by using exhaust heat from the compressor 10. Since this configuration eliminates the need to provide a separate electric heater to heat the refrigerant flowing in the injection passage 22, the power consumption of the re-

frigeration cycle apparatus can be reduced.

[0075] FIG. 5 shows a refrigeration cycle apparatus 100A including a heater 24B as another modification of the heater 24. The heater 24B is a heat exchanger including a first heat exchanging portion 60 into which the refrigerant flowing in the injection passage 22 is introduced and a second heat exchanging portion 62 which branches from the refrigerant circuit 1 and into which the refrigerant flowing in the refrigerant circuit 1 is introduced. The first heat exchanging portion 60 is also a part of the injection passage 22. The temperature of the refrigerant introduced into the second heat exchanging portion 62 is higher than the gas-liquid separation temperature. The second heat exchanging portion 62 is connected to the refrigerant circuit 1 between the condenser 12 and the upstream-side throttling device 14. Specifically, the second heat exchanging portion 62 has one end connected to the refrigerant circuit 1 between the condenser 12 and the upstream-side throttling device 14 and the other end connected, at a point downstream from the former end, to the refrigerant circuit 1 between the condenser 12 and the upstream-side throttling device 14. Thereby, the refrigerant flowing between the condenser 12 and the upstream-side throttling device 14 is introduced into the second heat exchanging portion 62. The second heat exchanging portion 62 is disposed to heat the first heat exchanging portion 60. Thereby, the refrigerant flowing in the injection passage 22 is heated. As a result, the refrigerant flowing in the injection passage 22 can be heated by using the heat of the refrigerant flowing in the refrigerant circuit 1. Since this configuration eliminates the need to provide a separate electric heater to heat the refrigerant flowing in the injection passage 22, the power consumption of the refrigeration cycle apparatus can be reduced. In addition, since the degree of the supercooling of the refrigerant at the outlet side of the condenser 12 in the refrigerant circuit 1 can be increased, the resulting refrigeration cycle apparatus 100A can improve its cooling capacity.

[0076] The heater 24B is, for example, a double-pipe heat exchanger including an inner pipe and an outer pipe concentric with the inner pipe. In this case, the inside of the inner pipe corresponds to one of the first heat exchanging portion 60 and the second heat exchanging portion 62. The space formed between the inner peripheral surface of the outer pipe and the outer peripheral surface of the inner pipe corresponds to the other one of the first heat exchanging portion 60 and the second heat exchanging portion 62. Instead, for example, the heater 24B may be configured such that a pipe constituting the first heat exchanging portion 60 and a pipe constituting the second heat exchanging portion 62 are disposed in contact with each other. The configuration of the heater 24B is not particularly limited to these configurations as long as the second heat exchanging portion 62 can heat the first heat exchanging portion 60.

[0077] A valve 64 is provided upstream from the second heat exchanging portion 62. The refrigerant circuit 1

is provided with another valve 66 between a position to which one end of the second heat exchanging portion 62 is connected and a position to which the other end of the second heat exchanging portion 62 is connected. The valves 64 and 66 are, for example, opening-adjustable electric valves. The heating of the refrigerant flowing in the injection passage 22 can be controlled by controlling the opening and closing of the valves 64 and 66. For example, the opening and closing of the valves 64 and 66 may be controlled so that the refrigerant flowing in the injection passage 22 is heated only in the intermediate pressure control operation. The valves 64 and 66 may be omitted. The second heat exchanging portion 62 may be configured not to branch from the refrigerant circuit 1. In other words, the second heat exchanging portion 62 may be constituted by a part of the refrigerant circuit 1 between the condenser 12 and the upstream-side throttling device 14.

[0078] FIG. 6 shows a refrigeration cycle apparatus 100B including a heater 24C as another modification of the heater 24. The heater 24C is a heat exchanger including a first heat exchanging portion 70 into which the refrigerant flowing in the injection passage 22 is introduced and a second heat exchanging portion 72 which branches from the refrigerant circuit 1 and into which the refrigerant flowing in the refrigerant circuit 1 is introduced. The first heat exchanging portion 70 is also a part of the injection passage 22. The second heat exchanging portion 72 is connected to the refrigerant circuit 1 between the compressor 10 and the condenser 12. Specifically, the second heat exchanging portion 72 has one end connected to the refrigerant circuit 1 between the compressor 10 and the condenser 12 and the other end connected, at a point downstream from the former end, to the refrigerant circuit 1 between the compressor 10 and the condenser 12. Thereby, the refrigerant flowing between the compressor 10 and the condenser 12 and having a relatively high temperature in the refrigerant flowing in the refrigerant circuit 1 is introduced into the second heat exchanging portion 72. The temperature of the refrigerant introduced into the second heat exchanging portion 72 is higher than the gas-liquid separation temperature. The second heat exchanging portion 72 is disposed to heat the first heat exchanging portion 70. Thereby, the refrigerant flowing in the injection passage 22 is heated. As a result, the refrigerant flowing in the injection passage 22 can be heated by using the heat of the refrigerant having a relatively high temperature in the refrigerant flowing in the refrigerant circuit 1. Since this configuration eliminates the need to provide a separate electric heater to heat the refrigerant flowing in the injection passage 22, the power consumption of the refrigeration cycle apparatus can be reduced.

[0079] The first heat exchanging portion 70 and the second heat exchanging portion 72 may have the same configuration as the first heat exchanging portion 60 and the second heat exchanging portion 62 of the heater 24B. For example, opening-adjustable electric valves may be

provided upstream from the second heat exchanging portion 72 and between the position to which one end of the second heat exchanging portion 72 is connected and the position to which the other end of the second heat exchanging portion 72 is connected in the refrigerant circuit 1. The second heat exchanging portion 72 may be configured not to branch from the refrigerant circuit 1. In other words, the second heat exchanging portion 72 may be constituted by a part of the refrigerant circuit 1 between the compressor 10 and the condenser 12.

(Second Embodiment)

[0080] FIG. 7 shows a refrigeration cycle apparatus 200 according to a second embodiment of the present invention. In the present embodiment, the same components as those in the first embodiment are denoted by the same reference numerals, and the description thereof is omitted.

[0081] In the present embodiment, the refrigerant circuit 1 is provided with an indoor heat exchanger-side temperature sensor 40 between the indoor heat exchanger 12 and the indoor-side throttling device 14, and with an outdoor heat exchanger-side temperature sensor 42 between the outdoor-side throttling device 18 and the outdoor heat exchanger 20. The operation of the refrigeration cycle apparatus 200 of the present embodiment is the same as the operation of the refrigeration cycle apparatus 100 of the first embodiment.

[0082] In the heating mode, the indoor heat exchanger-side temperature sensor 40 detects a condensation-side outlet temperature T_c that is the temperature of the refrigerant flowing out of the indoor heat exchanger (condenser) 12, and the outdoor heat exchanger-side temperature sensor 42 detects an evaporation-side inlet temperature T_e that is the temperature of the refrigerant flowing into the outdoor heat exchanger (evaporator) 20. In the cooling mode, the outdoor heat exchanger-side temperature sensor 42 detects a condensation-side outlet temperature T_c that is the temperature of the refrigerant flowing out of the outdoor heat exchanger (condenser) 20, and the indoor heat exchanger-side temperature sensor 40 detects an evaporation-side inlet temperature T_e that is the temperature of the refrigerant flowing into the indoor heat exchanger (evaporator) 12. Hereinafter, the indoor heat exchanger-side temperature sensor 40 in the heating mode and the outdoor heat exchanger-side temperature sensor 42 in the cooling mode are referred to as post-condensation temperature sensors, and the outdoor heat exchanger-side temperature sensor 42 in the heating mode and the indoor heat exchanger-side temperature sensor 40 in the cooling mode are referred to as pre-evaporation temperature sensors. The following description applies to the heating mode and the cooling mode interchangeably, in the same manner as in the first embodiment.

[0083] The controller 30 performs the intermediate pressure control operation in the almost same manner

as in the first embodiment. During the intermediate pressure control operation, the controller 30 modifies a gas-liquid separation temperature calculation formula for use in a steady operation, using the gas-liquid separation temperature T_m , the condensation-side outlet temperature T_c , and the evaporation-side inlet temperature T_e that are detected when the temperature difference between the gas-liquid separation temperature T_m and the injection temperature T_{inj} becomes smaller than the predetermined value ΔT_i . Hereinafter, the intermediate pressure control operation performed by the controller 30 is described in detail with reference to the flow chart of FIG. 8.

[0084] The flow chart shown in FIG. 8 is given by replacing Step S9 in the flow chart shown in FIG. 2 with Steps S21 to S23, and the other Steps S1 to S8 and S10 to S14 are the same as those in the first embodiment. Therefore, the following description is focused on Steps S21 to S23, which are the steps characteristic of the present embodiment.

[0085] When it is determined in Step S7 that the temperature difference between the gas-liquid separation temperature T_m detected by the intermediate pressure temperature sensor 26 and the injection temperature T_{inj} detected by the superheat temperature sensor 28 is smaller than the predetermined value ΔT_i , the controller 30 obtains the condensation-side outlet temperature T_c detected by the post-condensation temperature sensor and obtains the evaporation-side inlet temperature T_e detected by the pre-evaporation temperature sensor (Step S21). Next, the controller 30 records the gas-liquid separation temperature T_m detected when YES is determined in Step S7 as T_{m0} , and stores the condensation-side outlet temperature T_c and the evaporation-side inlet temperature T_e that are detected in Step S21 as T_{c0} and T_{e0} respectively (Step S22). Then, the controller 30 modifies the gas-liquid separation temperature calculation formula for use in the steady operation, using the stored T_{m0} , T_{c0} and T_{e0} (Step S23).

[0086] As used herein, the gas-liquid separation temperature calculation formula for use in the steady operation is a formula for estimating the gas-liquid separation temperature based on the condensation-side outlet temperature T_c and the evaporation-side inlet temperature T_e or only on the condensation-side outlet temperature T_c , and is represented by, for example, the following formula (1):

$$T_{m2} = \alpha T_c + \beta \dots (1)$$

[0087] In the case where the formula (1) is used, in other words, in the case where the gas-liquid separation temperature is estimated based only on the condensation-side outlet temperature, it is not necessary for the pre-evaporation temperature sensor to detect the evaporation-side inlet temperature T_e in Step S21. That is,

the gas-liquid separation temperature calculation formula can be modified using only T_{m0} and T_{c0} . For the sake of simplicity, the following description is given on the assumption that the formula (1) is used.

[0088] In Step S23, the controller 30 substitutes T_{c0} stored in Step S22 into the formula (1) to calculate an estimated temperature T_{m2} . The controller 30 compares the estimated temperature T_{m2} thus calculated with T_{m0} stored in Step S22, and rewrites the gas-liquid separation temperature calculation formula so that the difference between T_{m2} and T_{m0} is cancelled out as a measurement error caused by the intermediate pressure temperature sensor 26 and the post-condensation temperature sensor. For example, when T_{m0} is larger than T_{m2} , the difference between them ($T_{m0} - T_{m2}$) as a correction value is added to the calculation formula, while when T_{m0} is smaller than T_{m2} , the difference between them ($T_{m2} - T_{m0}$) as a correction value is subtracted from the calculation formula. Instead, the coefficients α and β in the above formula (1) are changed.

[0089] Then, the controller 30 performs Steps S10 to S13 and shifts to the steady operation (Step S14). In the steady operation, the controller 30 uses the gas-liquid separation temperature calculation formula that has been modified during the intermediate pressure control operation to perform the steady operation. Specifically, the controller 30 obtains the gas-liquid separation temperature T_m , the discharge temperature T_d , the condensation-side outlet temperature T_c , and the evaporation-side inlet temperature T_e that are detected by the intermediate pressure temperature sensor 26, the discharge temperature sensor 34, the post-condensation temperature sensor, and the pre-evaporation temperature sensor, respectively, and adjusts the opening degrees of the upstream-side throttling device and the downstream-side throttling device to prevent these detected temperatures from differing significantly from the target values.

[0090] In the first embodiment, the target gas-liquid separation temperature T_{m1} is fixed, but in the present embodiment, the estimated temperature T_{m2} calculated using the gas-liquid separation temperature calculation formula modified in Step S23 is set as the target gas-liquid separation temperature. The control of the discharge temperature T_d and the gas-liquid separation temperature T_m is performed by adjusting the opening degrees of the upstream-side throttling device and the downstream-side throttling device, as in the first embodiment.

[0091] As described above, the calculation formula for estimating the gas-liquid separation temperature T_m based on the other temperatures measured is modified in the intermediate pressure control operation, and the calculation formula thus modified is used in the steady operation. This makes it possible to increase the accuracy of the intermediate pressure control in the steady operation, taking into consideration the measurement errors of the temperature sensors, etc.

(Modifications)

[0092] In the flow chart shown in FIG. 8, Step S21 for detecting the condensation-side outlet temperature T_c and the evaporation-side inlet temperature T_e is performed after Step S7, but this sequence may be changed such that Step S21 is performed between Step S6 and Step S7, a new step for determining a target gas-liquid separation temperature T_{m3} based on the condensation-side outlet temperature T_c and the evaporation-side inlet temperature T_e is performed after Step S21, and in Step S8, the amount of adjustment of the opening degree is increased when the difference between the detected gas-liquid separation temperature T_m and the target gas-liquid separation temperature T_{m3} is large and the amount of adjustment of the opening degree is decreased when the difference between T_m and T_{m3} is small.

[0093] In Step S10, the estimated temperature T_{m2} obtained from the calculation formula that has been modified in Step S23 may be used instead of T_{m0} to determine the target gas-liquid separation temperature T_{m1} .

[0094] The heater 24 in the second embodiment also can be modified in the same manner as in the modifications of the first embodiment.

(Other Embodiments)

[0095] In the embodiments described above, the refrigerant circuit 1 is provided with the four-way valve 32 for switching between the cooling mode and the heating mode, but the refrigeration cycle apparatus of the present invention may be dedicated to the cooling mode or to the heating mode.

INDUSTRIAL APPLICABILITY

[0096] The refrigeration cycle apparatus according to the present invention can be utilized as a heat pump apparatus for a water heater, a hot-water heater, a refrigerator, an air conditioner, or the like.

Claims

1. A refrigeration cycle apparatus comprising:

a refrigerant circuit in which a refrigerant is circulated so that the refrigerant passes through a compressor, a condenser, an upstream-side throttling device, a gas-liquid separator, a downstream-side throttling device, and an evaporator in this order;
 an injection passage through which a gas refrigerant separated in the gas-liquid separator is supplied to the compressor;
 a heater provided in the injection passage;
 an intermediate pressure temperature sensor that detects a gas-liquid separation temperature

- that is a temperature of the refrigerant flowing into the injection passage from the refrigerant circuit;
 a superheat temperature sensor that detects an injection temperature that is a temperature of the refrigerant heated by the heater in the injection passage; and
 a controller that performs an intermediate pressure control operation for adjusting at least one of an opening degree of the upstream-side throttling device and an opening degree of the downstream-side throttling device so that a temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than a predetermined value, and then increasing the opening degree of the downstream-side throttling device until the gas-liquid separation temperature drops by a predetermined value of degrees from the gas-liquid separation temperature that is detected on completion of the adjustment.
2. The refrigeration cycle apparatus according to claim 1, further comprising a post-condensation temperature sensor that detects a condensation-side outlet temperature that is a temperature of the refrigerant flowing out of the condenser, wherein during the intermediate pressure control operation, the controller modifies a gas-liquid separation temperature calculation formula for use in a steady operation, using the gas-liquid separation temperature and the condensation-side outlet temperature that are detected when the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value.
 3. The refrigeration cycle apparatus according to claim 2, further comprising a pre-evaporation temperature sensor that detects an evaporation-side inlet temperature that is a temperature of the refrigerant flowing into the evaporator, wherein the controller also uses the evaporation-side inlet temperature that is detected when the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value, so as to modify the gas-liquid separation temperature calculation formula for use in the steady operation.
 4. The refrigeration cycle apparatus according to claim 2, wherein the controller performs the steady operation using the gas-liquid separation temperature calculation formula modified during the intermediate pressure control operation.
 5. The refrigeration cycle apparatus according to claim 1, wherein the controller performs the intermediate pressure control operation in a starting operation.
 6. The refrigeration cycle apparatus according to claim 1, wherein the controller performs the intermediate pressure control operation during the steady operation.
 7. The refrigeration cycle apparatus according to claim 5, further comprising a discharge temperature sensor that detects a discharge temperature that is a temperature of the refrigerant discharged from the compressor, wherein the controller decreases the opening degree of the downstream-side throttling device until the temperature difference between the gas-liquid separation temperature and the injection temperature becomes smaller than the predetermined value while adjusting the opening degree of the upstream-side throttling device so that the discharge temperature approaches a target discharge temperature, and then increases the opening degree of the downstream-side throttling device.
 8. The refrigeration cycle apparatus according to claim 1, wherein the refrigerant circuit includes an indoor heat exchanger and an outdoor heat exchanger each serving as the condenser and the evaporator, and includes an indoor-side throttling device and an outdoor-side throttling device each serving as the upstream-side throttling device and the downstream-side throttling device, and the refrigerant circuit is provided with a four-way valve capable of switching a flow direction of the refrigerant.
 9. The refrigeration cycle apparatus according to claim 1, wherein the heater is an electric heater.
 10. The refrigeration cycle apparatus according to claim 1, wherein the heater is a heat storage unit that accumulates exhaust heat from the compressor and heats the refrigerant using the accumulated heat.
 11. The refrigeration cycle apparatus according to claim 1, wherein the heater is a heat exchanger including a first heat exchanging portion into which the refrigerant flowing in the injection passage is introduced and a second heat exchanging portion into which the refrigerant flowing in the refrigerant circuit and having a higher temperature than the gas-liquid separation temperature is introduced, and in the heat exchanger, the second heat exchanging portion heats the first heat exchanging portion.
 12. The refrigeration cycle apparatus according to claim 11, wherein the refrigerant flowing between the compressor and the condenser is introduced into the sec-

ond heat exchanging portion.

13. The refrigeration cycle apparatus according to claim 11, wherein the refrigerant flowing between the condenser and the upstream-side throttling device is introduced into the second heat exchanging portion.

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FIG.1

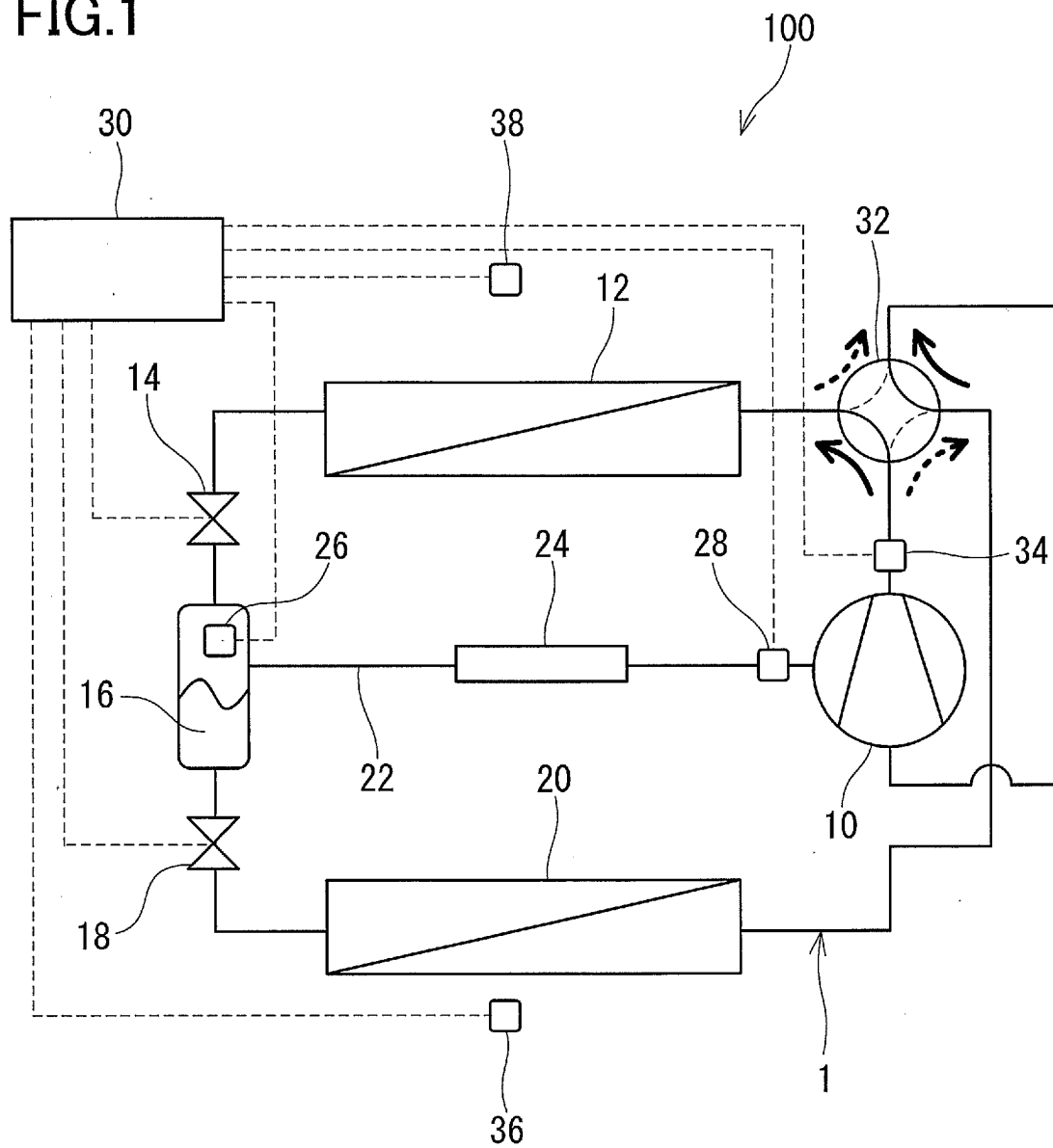


FIG.2

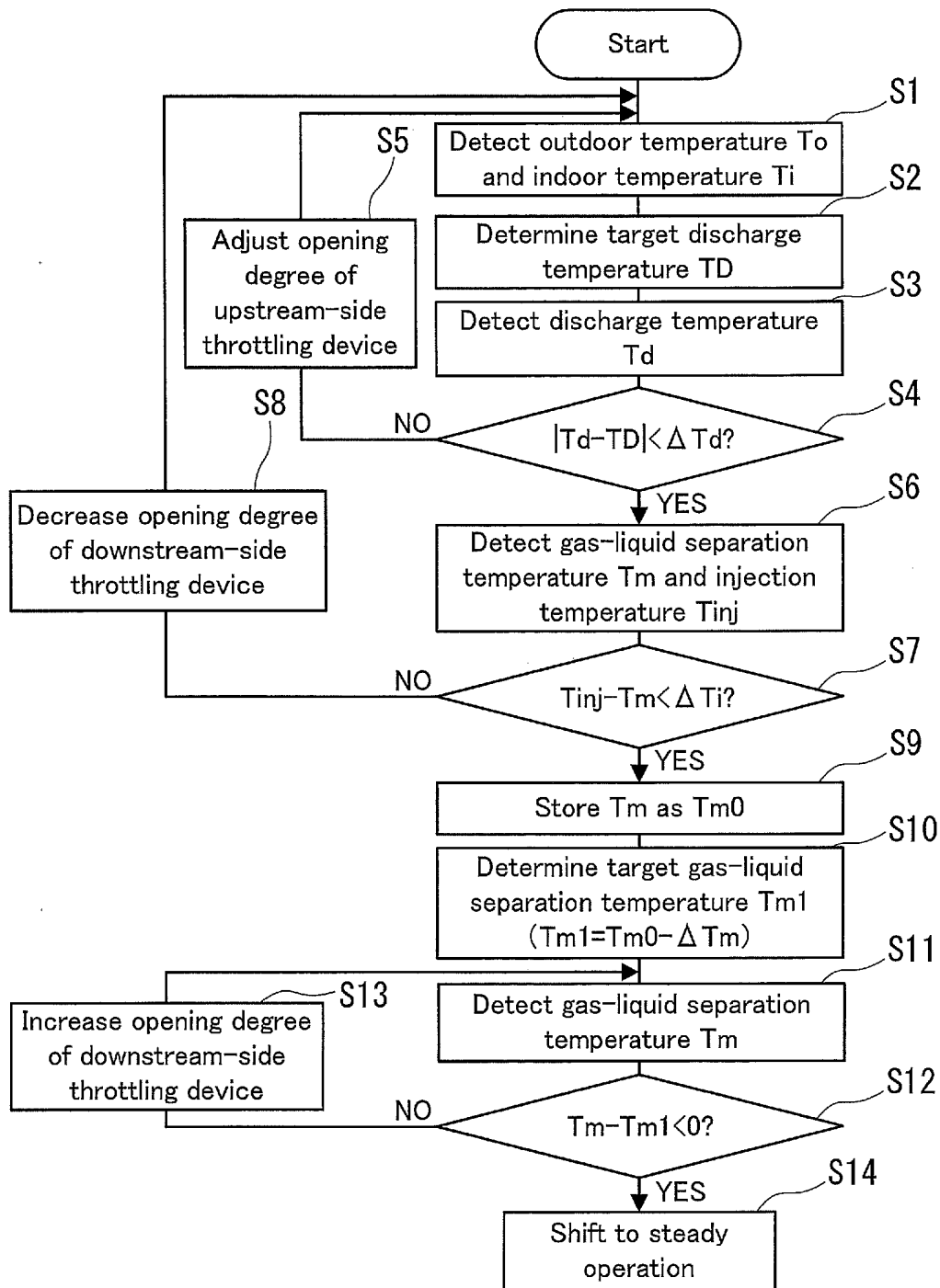


FIG.3

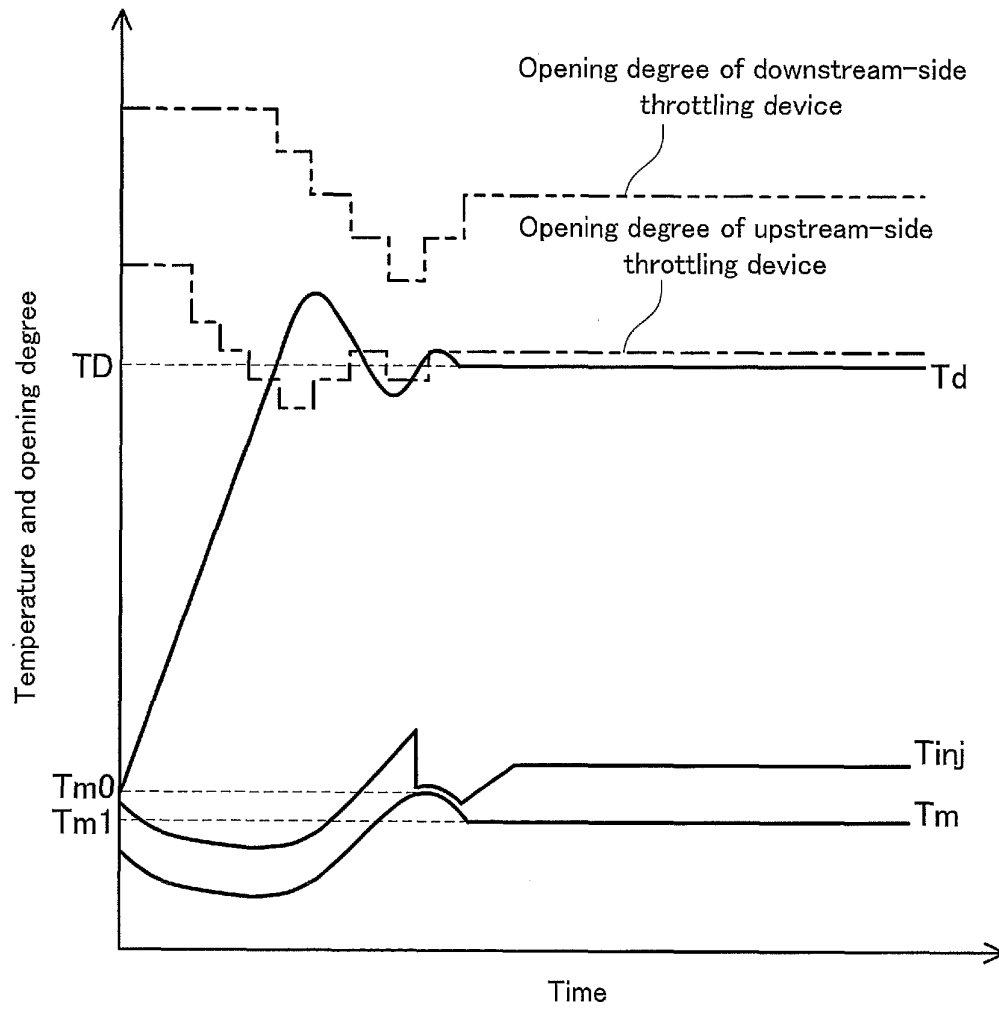


FIG.4

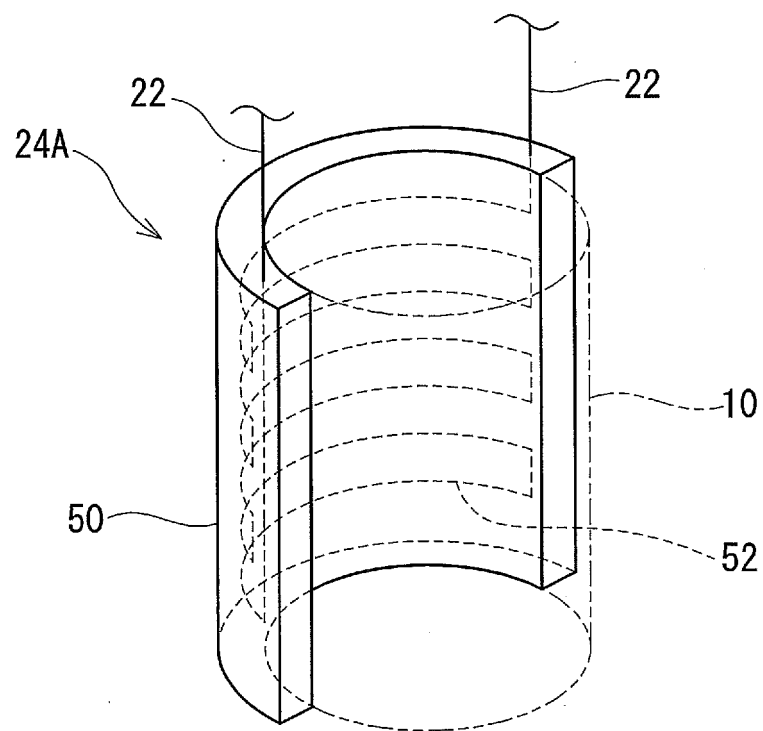


FIG.5

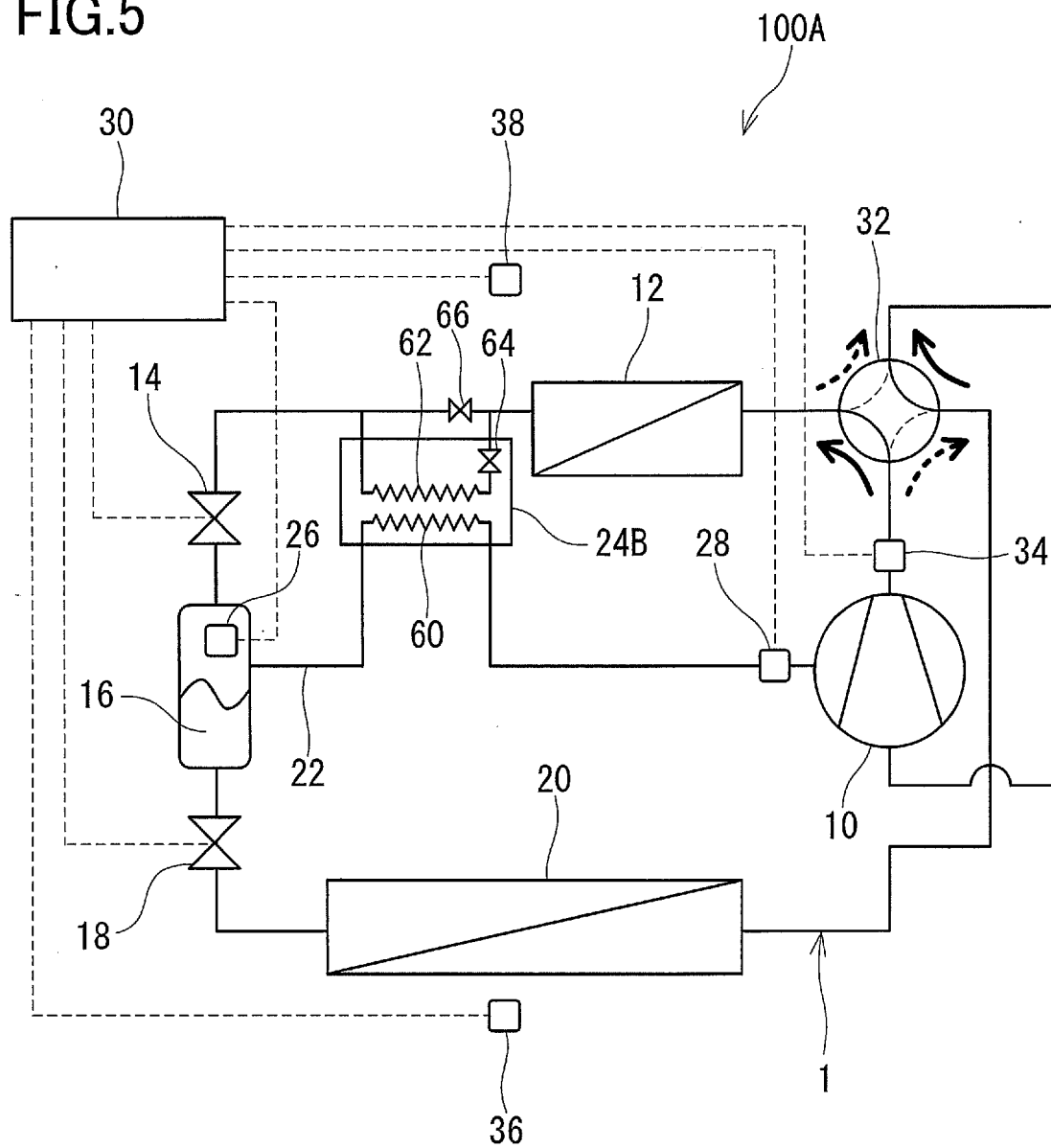


FIG.6

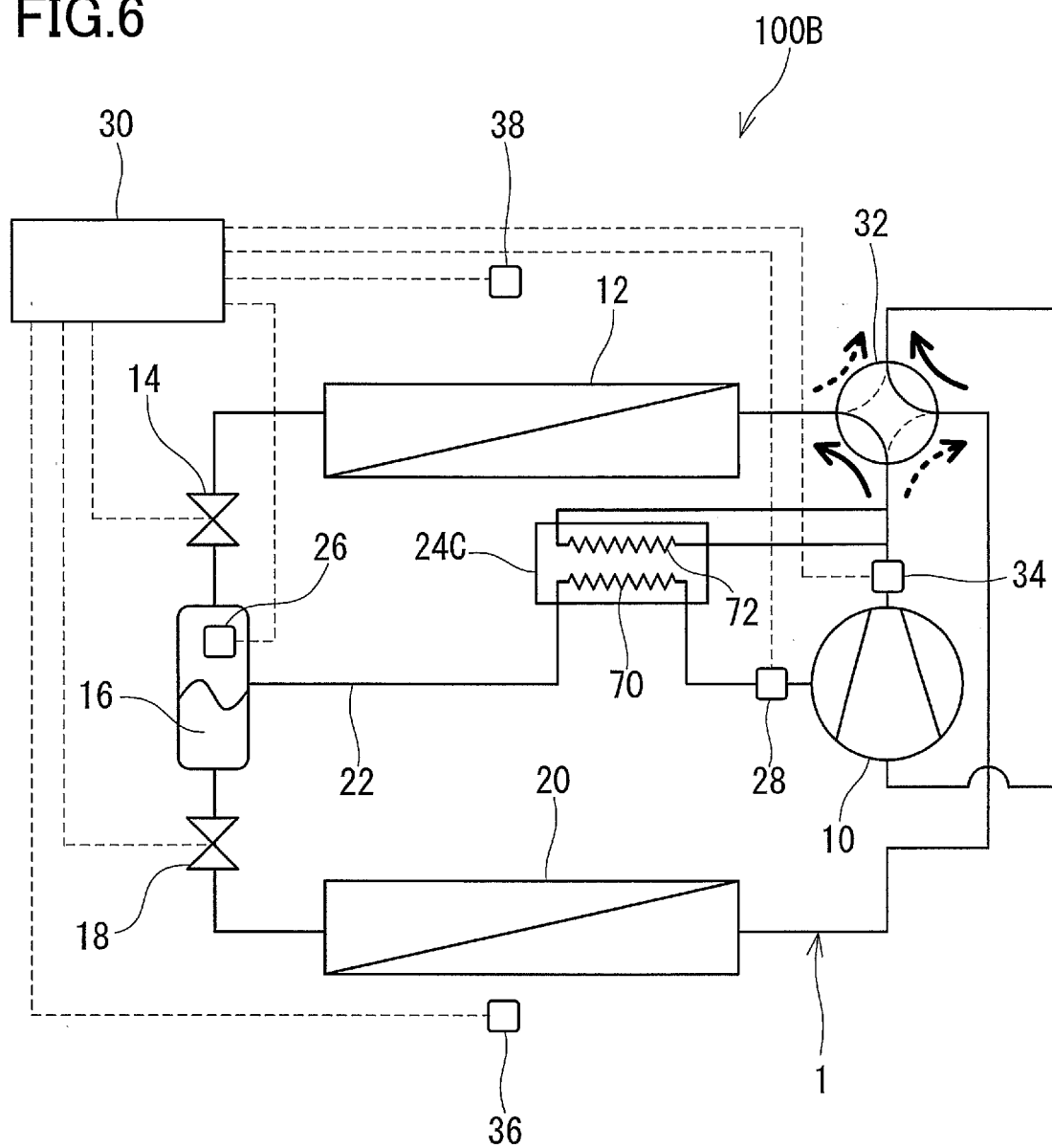


FIG.7

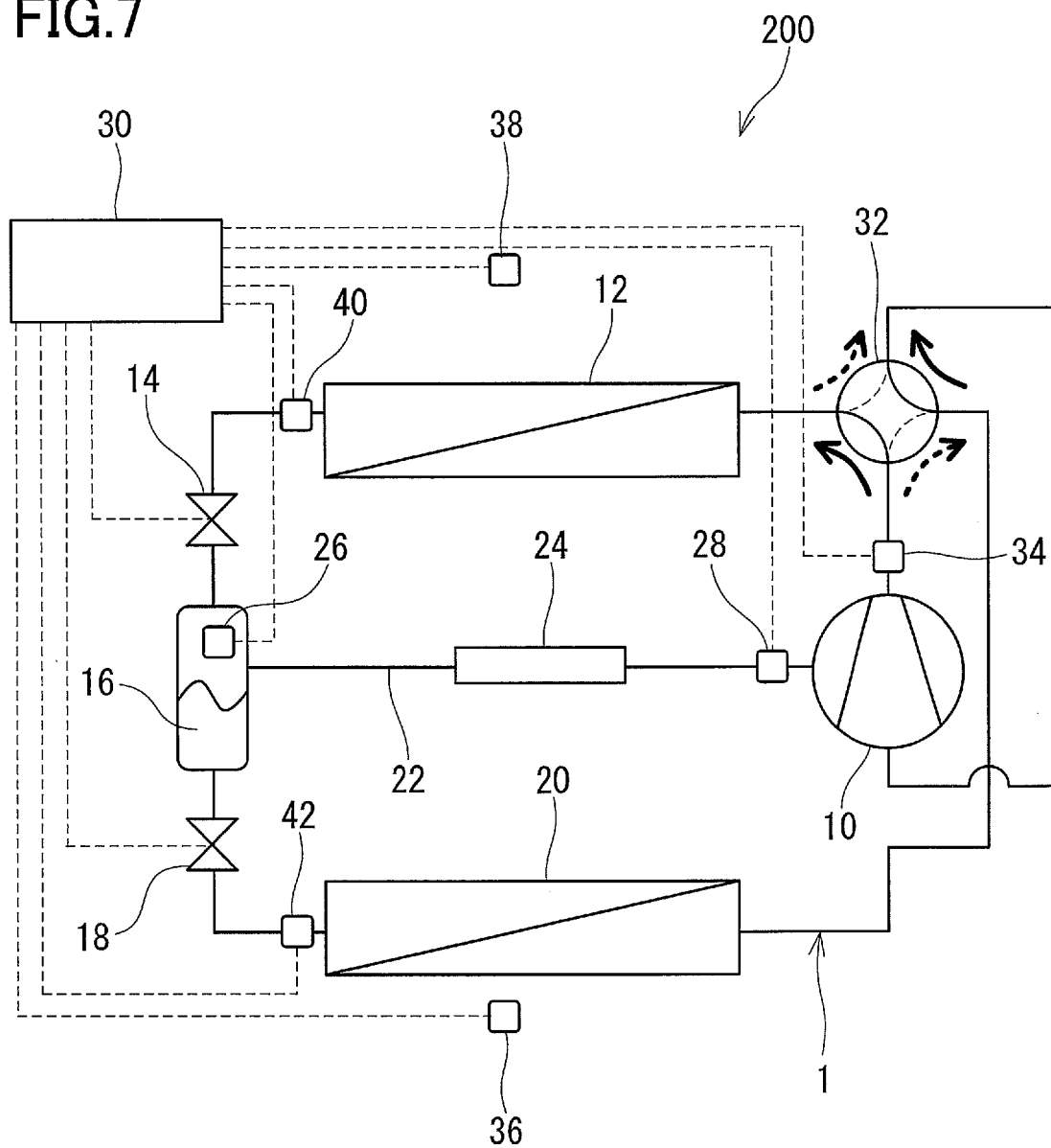


FIG.8

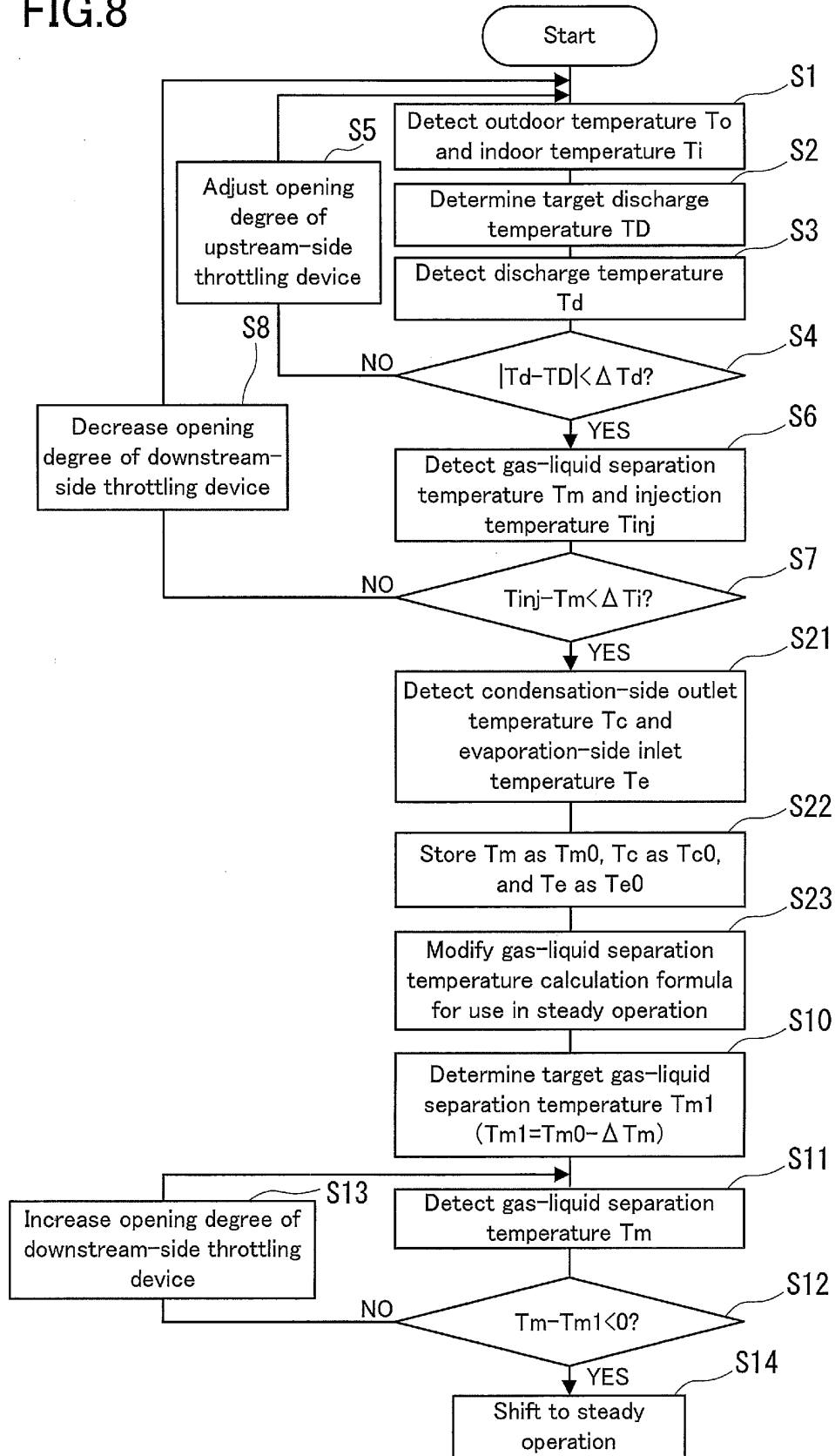
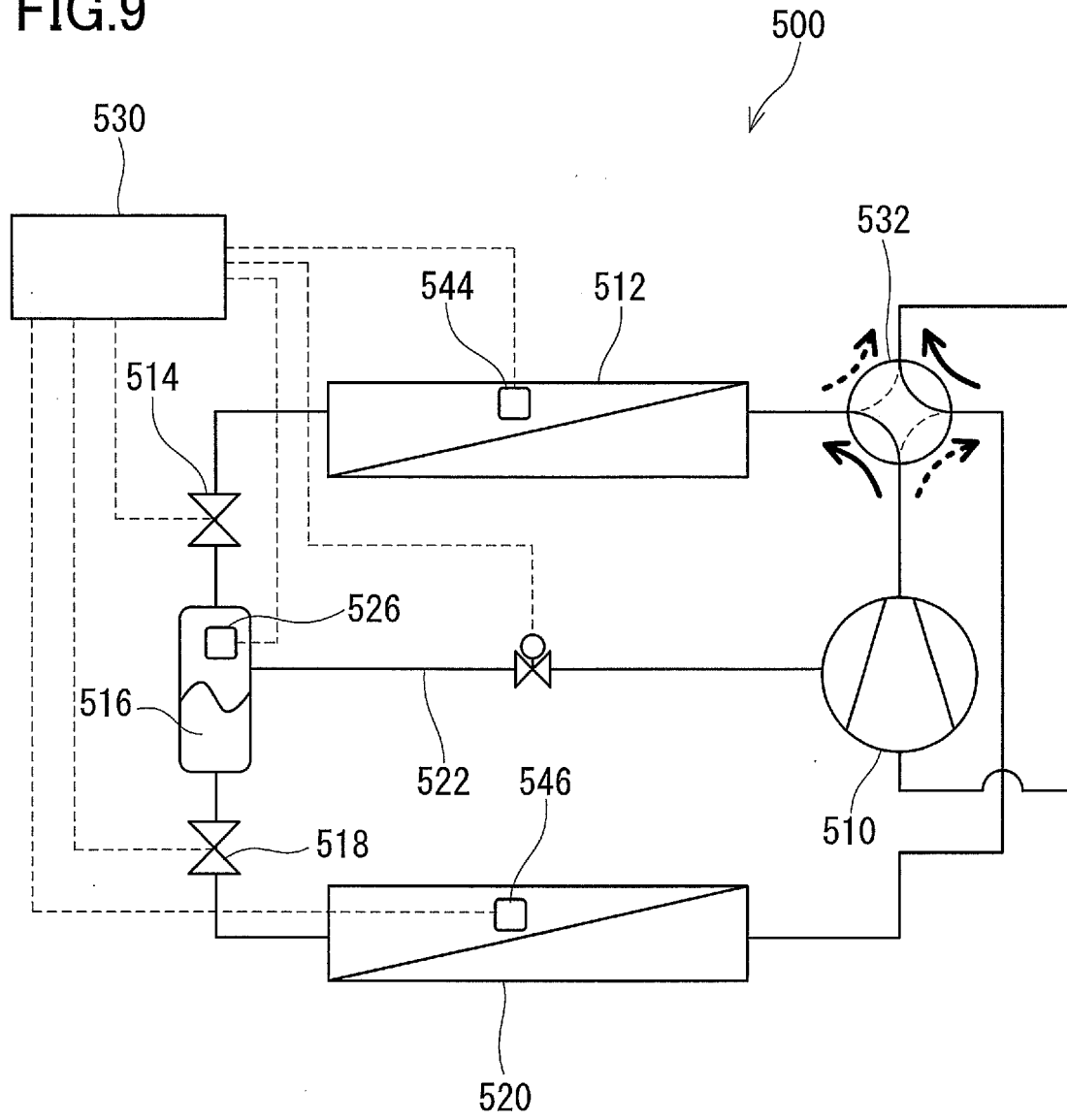


FIG.9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/004313

A. CLASSIFICATION OF SUBJECT MATTER

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

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B1/00, F25B13/00

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 3317170 B2 (Daikin Industries, Ltd.), 26 August 2002 (26.08.2002), entire text; all drawings (Family: none)	1-13
A	JP 5-302767 A (Matsushita Refrigeration Co.), 16 November 1993 (16.11.1993), entire text; all drawings (Family: none)	1-13
A	JP 6-33910 B2 (Mitsubishi Electric Corp.), 02 May 1994 (02.05.1994), entire text; all drawings (Family: none)	1-13

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

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30 July, 2012 (30.07.12)Date of mailing of the international search report
14 August, 2012 (14.08.12)Name and mailing address of the ISA/
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-180427 A (Daikin Industries, Ltd.), 13 August 2009 (13.08.2009), entire text; all drawings (Family: none)	1-13
A	JP 2010-223542 A (Mitsubishi Electric Corp.), 07 October 2010 (07.10.2010), entire text; all drawings (Family: none)	1-13

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3317170 B [0006]