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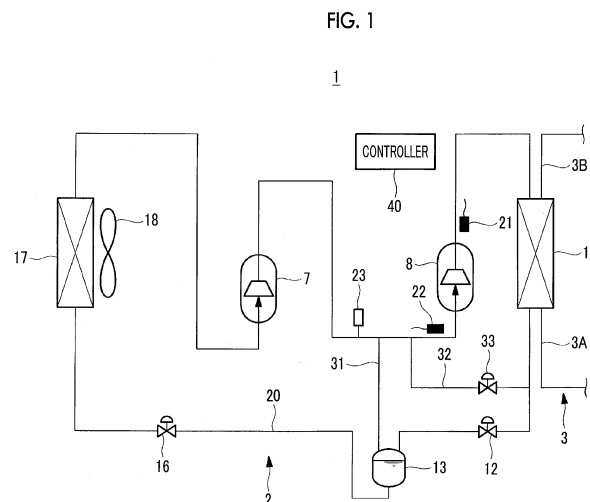
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(54) **REFRIGERATION CYCLE DEVICE AND REFRIGERATION CYCLE DEVICE CONTROL METHOD**

(57) The purpose of the present invention is to reduce the temperature of a refrigerant sucked in by a high-stage compressor and prevent the high-stage compressor from sucking in a liquid medium. This refrigeration cycle device has a compression unit having a low-stage compressor (7) and a high-stage compressor (8), a condenser (11), a first expansion valve (12), and an evaporator (17). The refrigeration cycle device is equipped with: a liquid bypass circuit (32) which branches off from a pipe connecting the condenser (11) and the first expansion valve (12), and joins into a pipe connecting the low-stage compressor (7) and the high-stage compressor (8); a third expansion valve (33) which is provided to the liquid bypass circuit (32) and adjusts the amount of the refrigerant flowing through the liquid bypass circuit (32); and a controller (40) which controls the third expansion valve (33) and increases the amount of the refrigerant flowing through the liquid bypass circuit (32) when the discharge temperature of the high-stage compressor (8) is higher than a predetermined value, and which controls the third expansion valve (33) and adjusts the amount of the refrigerant flowing through the liquid bypass circuit (32) on the basis of the suction superheat degree of the high-stage compressor (8).



Description

Technical Field

[0001] The present invention relates to a refrigeration cycle device and a refrigeration cycle device control method.

Background Art

[0002] As a heat pump system using a refrigeration cycle in which a refrigerant circulates, there is a heat pump system aimed at enabling hot water to be discharged even in a low outside air temperature environment.

[0003] In the heat pump system, the lower the outside air temperature, the lower the refrigerant temperature and pressure at an inlet of an evaporator of a refrigerant become, and a suction pressure at an inlet of a compressor is also lowered. As a result, when the discharge pressure of the compressor is raised to a predetermined value, the lower the outside air temperature, the higher the temperature of the refrigerant which is discharged from the compressor rises. Further, the higher the hot water temperature, the higher the discharge pressure of the compressor is set, and therefore, the temperature of the refrigerant which is discharged from the compressor rises.

Citation List

Patent Literature

[0004] [PTL 1] Japanese Unexamined Patent Application Publication No. 2007-155143

Summary of Invention

Technical Problem

[0005] If the temperature of the refrigerant which is discharged from the compressor rises under the above-mentioned conditions or the like, there is a concern that deterioration of lubricating oil, damage to a valve, burnout of a bearing, or the like may occur. For this reason, in a case where the outside air temperature is low, there is a case where the refrigerant cooled in a condenser (a refrigerant/water heat exchanger) is supplied to a suction pipe of a compressor by being bypassed without passing through an evaporator. In this way, the temperature of the refrigerant which is sucked into the compressor is lowered, and thus the temperature of the refrigerant which is discharged from the compressor can be lowered.

[0006] However, the refrigerant which is supplied to the suction pipe of the compressor is a supercooled liquid medium, and if the amount of the supplied liquid medium is large, the refrigerant at the inlet of the compressor enters a gas-liquid two-phase state. As a result, the com-

pressor compresses liquid, and therefore, there is a concern that the compressor may be broken. Therefore, a method of supplying the supercooled liquid medium to the suction pipe of the compressor cannot be constantly performed, and thus the temperature rise of the compressor can be merely prevented intermittently.

[0007] The above-mentioned PTL 1 discloses a technique in which a liquid refrigerant is supplied between a low-stage compression mechanism and a high-stage compression mechanism to lower the temperature of the refrigerant which is sucked into the high-stage compressor. In this way, the discharge refrigerant temperature of the high-stage compression mechanism is lowered. However, if the amount of the liquid refrigerant which is supplied to the high-stage compression mechanism is large, the refrigerant at the inlet of the high-stage compression mechanism enters a gas-liquid two-phase state. Therefore, an appropriate amount of liquid medium needs to be supplied to the high-stage compressor.

[0008] The above-described problem exists also in an air conditioner or the like which is a refrigeration cycle device other than a heat pump system.

[0009] The present invention has been made in view of such circumstances and has an object to provide a refrigeration cycle device and a refrigeration cycle device control method, in which it is possible to lower the temperature of a refrigerant which is sucked into a high-stage compressor and to prevent the high-stage compressor from sucking in a liquid medium.

Solution to Problem

[0010] According to a first aspect of the present invention, there is provided a refrigeration cycle device having a refrigerant cycle in which a compression section having a low-stage compressor and a high-stage compressor, a condenser, an expansion section, and an evaporator are connected with one another by piping and a refrigerant is circulated, the refrigeration cycle device including: a bypass pipe which branches off from a pipe connecting the condenser and the expansion section with each other and joins a pipe connecting the low-stage compressor and the high-stage compressor with each other; a flow rate adjustment section which is provided in the bypass pipe and adjusts the amount of a refrigerant flowing through the bypass pipe; and a controller which controls the flow rate adjustment section to increase the amount of the refrigerant flowing through the bypass pipe, when a discharge temperature of the high-stage compressor is higher than a predetermined value, and controls the flow rate adjustment section to adjust the amount of the refrigerant flowing through the bypass pipe, based on a suction superheat degree of the high-stage compressor.

[0011] According to this configuration, the refrigerant sent out from the condenser is branched through the bypass pipe before it is supplied to the expansion section, and is supplied between the low-stage compressor and the high-stage compressor. The flow rate adjustment

section adjusts the flow rate of the refrigerant while starting or stopping the flow of the refrigerant in the bypass pipe.

[0012] When the discharge temperature of the high-stage compressor is higher than a predetermined value, the flow rate adjustment section is controlled to increase the amount of the refrigerant flowing through the bypass pipe, so that the temperature of the refrigerant which is sucked into the high-stage compressor is lowered. Further, the flow rate adjustment section is controlled to adjust the amount of the refrigerant flowing through the bypass pipe, based on the suction superheat degree of the high-stage compressor. Therefore, control can be performed such that the refrigerant which is sucked into the high-stage compressor becomes superheated gas, and the compressor can be prevented from sucking a liquid refrigerant. Further, the degree of superheat of the refrigerant which is sucked into the high-stage compressor can be made to be constant, and therefore, the compressor can be prevented from becoming higher in temperature and being broken.

[0013] In the first aspect of the present invention, the controller may control the flow rate adjustment section to reduce the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is equal to or lower than a predetermined value.

[0014] According to this configuration, when the suction superheat degree of the high-stage compressor is equal to or lower than a predetermined value, the flow rate adjustment section is controlled to reduce the amount of the refrigerant flowing through the bypass pipe, and therefore, a decrease in the degree of superheat of the refrigerant which is sucked into the high-stage compressor can be suppressed.

[0015] In the first aspect of the present invention, the controller may control the flow rate adjustment section to increase the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is higher than the predetermined value.

[0016] According to this configuration, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is higher than the predetermined value, the flow rate adjustment section is controlled to increase the amount of the refrigerant flowing through the bypass pipe, and therefore, an increase in the degree of superheat of the refrigerant which is sucked into the high-stage compressor can be suppressed.

[0017] In the first aspect of the present invention, the controller may cause the flow rate adjustment section to maintain the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is higher than a predeter-

mined value and the discharge temperature of the high-stage compressor is equal to or lower than the predetermined value.

[0018] According to this configuration, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is equal to or lower than the predetermined value, even if, for example, the flow rate adjustment section is not controlled, the amount of the refrigerant flowing through the bypass pipe is maintained, and thus a decrease and an increase in the degree of superheat of the refrigerant which is sucked into the high-stage compressor can be suppressed to maintain the degree of superheat to be constant.

[0019] In the first aspect of the present invention, the controller may increase a discharge pressure of the refrigerant which is discharged from the low-stage compressor by controlling a rotational frequency of the low-stage compressor or the high-stage compressor, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor or a discharge pressure of the high-stage compressor is higher than a predetermined value.

[0020] According to this configuration, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor or a discharge pressure of the high-stage compressor is higher than a predetermined value, a discharge pressure of the refrigerant which is discharged from the low-stage compressor is increased by controlling a rotational frequency of the low-stage compressor or the high-stage compressor, and therefore, the suction pressure of the high-stage compressor also increases, and thus the difference between the suction pressure and the discharge pressure of the high-stage compressor can be reduced. As a result, it is possible to lower the discharge temperature of the high-stage compressor.

[0021] In order to increase the discharge pressure of the refrigerant which is discharged from the low-stage compressor, the rotational frequency of the high-stage compressor is decreased or the rotational frequency of the low-stage compressor is increased.

[0022] In the first aspect of the present invention, the flow rate adjustment section may be an expansion valve, and the controller may control the rotational frequency of the low-stage compressor or the high-stage compressor when a degree of opening of the expansion valve has reached a maximum opening degree, when the discharge temperature of the high-stage compressor or the discharge pressure of the high-stage compressor is higher than a predetermined value.

[0023] According to this configuration, even in a case where the discharge temperature of the high-stage compressor or the discharge pressure of the high-stage compressor is higher than a predetermined value and the degree of opening of the expansion valve cannot be in-

creased, so that an increase in the degree of superheat cannot be suppressed, the discharge temperature of the high-stage compressor can be reliably lowered by controlling the rotational frequency of the low-stage compressor or the high-stage compressor.

[0024] According to a second aspect of the present invention, there is provided a method of controlling a refrigeration cycle device having a refrigerant cycle in which a compression section having a low-stage compressor and a high-stage compressor, a condenser, an expansion section, and an evaporator are connected by piping and a refrigerant is circulated, the refrigeration cycle device including a bypass pipe which branches off from a pipe connecting the condenser and the expansion section and joins a pipe connecting the low-stage compressor and the high-stage compressor, and a flow rate adjustment section which is provided in the bypass pipe and adjusts the amount of a refrigerant flowing through the bypass pipe, the method including: a step of increasing the amount of the refrigerant flowing through the bypass pipe by controlling the flow rate adjustment section when a discharge temperature of the high-stage compressor is higher than a predetermined value; and a step of adjusting the amount of the refrigerant flowing through the bypass pipe by controlling the flow rate adjustment section, based on a suction superheat degree of the high-stage compressor.

Advantageous Effects of Invention

[0025] According to the present invention, it is possible to lower the temperature of the refrigerant which is sucked into the high-stage compressor and to prevent the high-stage compressor from sucking in a liquid medium.

Brief Description of Drawings

[0026]

Fig. 1 is a configuration diagram showing a heat pump water heater according to a first embodiment of the present invention.

Fig. 2 is a configuration diagram showing a heat pump water heater according to a modification example of the first embodiment of the present invention.

Fig. 3 is a flowchart showing an operation of the heat pump water heater according to the first embodiment of the present invention.

Fig. 4 is a flowchart showing an operation of a heat pump water heater according to a second embodiment of the present invention.

Fig. 5 is a Mollier chart of a heat pump of the heat pump water heater according to the second embodiment of the present invention.

Description of Embodiments

[First Embodiment]

[0027] Hereinafter, a heat pump water heater 1 according to a first embodiment of the present invention will be described with reference to the drawings.

[0028] The heat pump water heater 1 according to this embodiment is provided with a heat pump system (hereinafter simply referred to as a heat pump) 2, and a water circulation line 3 connected to a hot water storage tank unit (not shown), as shown in Fig. 1. In the following, a case where a refrigeration cycle device is the heat pump 2 will be described. However, the refrigeration cycle device according to the present invention is not limited to this example. For example, the refrigeration cycle device according to the present invention can also be applied to an air conditioner or the like having a refrigerant cycle.

[0029] The water circulation line 3 on the hot water storage tank unit side is provided with a water supply-side line 3A connected to a water-side flow path of a condenser (a refrigerant/water heat exchanger) 11 in the heat pump 2, and a hot water extraction-side line 3B for extracting hot water produced in the condenser 11, and the water supply-side line 3A is provided with a water pump and a flow rate control valve.

[0030] The heat pump 2 is configured with a closed cycle refrigerant circuit in which a compression section having a low-stage compressor 7 and a high-stage compressor 8, the condenser 11 dissipating the heat of a refrigerant gas, a first expansion valve 12 reducing the pressure of a refrigerant to an intermediate pressure, an intermediate pressure receiver 13 having a gas-liquid separation function, a second expansion valve 16 reducing the pressure of an intermediate pressure refrigerant such that the intermediate pressure refrigerant becomes a low-temperature and low-pressure gas-liquid two-phase refrigerant, and an evaporator (an air heat exchanger) 17 performing heat exchange between the refrigerant and the outside air which is blown from a blower 18 are connected in this order through a refrigerant pipe.

[0031] The condenser 11 of the heat pump 2 is a refrigerant/water heat exchanger, in which heat exchange between water and the refrigerant gas is performed by circulating a high-temperature and high-pressure refrigerant gas discharged from the compression section in a refrigerant-side flow path on one side and circulating water in a water-side flow path on the other side through the water circulation line 3. Then, the condenser 11 is configured so as to produce hot water by heating the water with the high-temperature and high-pressure refrigerant gas.

[0032] Further, the refrigerant circuit is provided with a gas injection circuit 31 which supplies an intermediate pressure refrigerant gas separated in the intermediate pressure receiver 13 having a gas-liquid separation function to the high-stage compressor 8. The gas injection circuit 31 may be provided with an electromagnetic valve

and a check valve so as to be able to open and close the gas injection circuit 31 as necessary. Due to the economizer effect by gas injection, the heating capacity and the coefficient of performance (COP) by the heat pump 2 is improved, and thus the hot water supply capacity can be increased.

[0033] The refrigerant circuit is provided with a liquid bypass circuit 32 which supplies the refrigerant cooled by heat exchange with water in the condenser 11 to the high-stage compressor 8. A third expansion valve 33 is provided in the liquid bypass circuit 32.

[0034] In the heat pump water heater 1, if the heat pump 2 is operated, the high-temperature and high-pressure refrigerant gas compressed in two stages in the compression section is introduced into the condenser 11, where the high-temperature and high-pressure refrigerant gas is subjected to heat exchange with water which flows from the water supply-side line 3A of the water circulation line 3 to the water-side flow path. The water is heated and increased in temperature by heat dissipation from the high-temperature and high-pressure refrigerant gas and then returned to a hot water storage tank (not shown) through the hot water extraction-side line 3B, and the heat exchange between the refrigerant and the water is continuously performed in the condenser 11 until the amount of hot water stored in the hot water storage tank reaches a predetermined amount. If the amount of stored hot water reaches the predetermined amount, the hot water storage operation is ended.

[0035] The refrigerant cooled by heat exchange with water in the condenser 11 is reduced in pressure by the first expansion valve 12 and reaches the intermediate pressure receiver 13 where the refrigerant is subjected to gas-liquid separation. The intermediate pressure gas refrigerant separated in the intermediate pressure receiver 13 is supplied to the high-stage compressor 8 by the gas injection circuit 31, sucked into the high-stage compressor 8, and recompressed. Due to the economizer effect by the gas injection, the heating capacity and the coefficient of performance (COP) is improved, and thus the hot water supply capacity can be increased.

[0036] On the other hand, a liquid refrigerant separated in the intermediate pressure receiver 13 is reduced in pressure by the second expansion valve 16, becomes a low-temperature and low-pressure gas-liquid two-phase refrigerant, and flows into the evaporator (an air heat exchanger) 17. The refrigerant flowing into the evaporator 17 is subjected to heat exchange with the outside air which is blown by the blower, absorbs heat from the outside air, and is evaporated and gasified.

[0037] The refrigerant gasified in the evaporator 17 is sucked into the compression section and recompressed. Hereinafter, the same operation is repeated, whereby the production of hot water is performed.

[0038] A first temperature sensor 21 is provided in a discharge pipe of the high-stage compressor 8. The temperature of the refrigerant discharged from the high-stage compressor 8 (the discharge temperature of the high-

stage compressor 8) is measured by the first temperature sensor 21.

[0039] A second temperature sensor 22 is provided in a portion after joining the liquid bypass circuit 32, of a suction pipe of the high-stage compressor 8. The temperature of the refrigerant which is sucked into the high-stage compressor 8 is measured by the second temperature sensor 22. Further, a pressure sensor 23 is provided in the suction pipe of the high-stage compressor 8. The pressure in the suction pipe of the high-stage compressor 8 is measured by the pressure sensor 23.

[0040] A controller 40 calculates the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8, based on the temperature and pressure of the refrigerant measured by the second temperature sensor 22 and the pressure sensor 23.

[0041] Further, the controller 40 adjusts the degree of opening of the third expansion valve 33 according to the calculated degree of superheat of the refrigerant and the discharge temperature of the high-stage compressor 8.

[0042] Specifically, in a case where the discharge temperature of the high-stage compressor 8 is equal to or lower than a predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is maintained. In contrast, in a case where the discharge temperature of the high-stage compressor 8 becomes higher than the predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is set to a predetermined initial value.

[0043] Further, in a case where the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8 is equal to or lower than a predetermined second threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is reduced. In contrast, in a case where the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8 becomes higher than the predetermined second threshold value, the degree of opening of the third expansion valve 33 is maintained or increased according to the discharge temperature of the high-stage compressor 8.

[0044] In a case where the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8 becomes higher than the predetermined second threshold value, when the discharge temperature of the high-stage compressor 8 is equal to or lower than the predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is maintained, and when the discharge temperature of the high-stage compressor 8 becomes higher than the predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is in-

creased.

[0045] Further, in the embodiment described above, a case where the pressure sensor 23 provided in the suction pipe of the high-stage compressor 8 is used to calculate the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8 has been described. However, as shown in Fig. 2, third temperature sensors 24A, 24B, and 24C which are provided in pipes connected to the intermediate pressure receiver 13 may be used.

[0046] As the temperature sensor, any one of the third temperature sensor 24A which is provided in a refrigerant pipe 20 connecting the intermediate pressure receiver 13 and the evaporator (an air heat exchanger) 17, the third temperature sensor 24B which is provided in the gas injection circuit 31 connecting the intermediate pressure receiver 13 and the suction pipe of the high-stage compressor 8, and the third temperature sensor 24C which is provided in a pipe connecting the condenser 11 and the intermediate pressure receiver 13 is used.

[0047] The third temperature sensor 24A can measure the temperature of the refrigerant that is a saturated liquid which is supplied from the intermediate pressure receiver 13 to the evaporator 17, the third temperature sensor 24B can measure the temperature of the refrigerant that is a saturated gas which is supplied from the intermediate pressure receiver 13 to the suction pipe of the high-stage compressor 8, and the third temperature sensor 24C can measure the temperature of the gas-liquid two-phase refrigerant which is supplied to the intermediate pressure receiver 13.

[0048] The controller 40 calculates the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8, based on the difference between the temperatures of the refrigerant measured by at least one of the third temperature sensors 24A, 24B, and 24C and the first temperature sensor 21. In a case where the third temperature sensors 24A, 24B, and 24C are provided instead of the pressure sensor 23, as compared with a case where the pressure sensor 23 is provided in the suction pipe of the high-stage compressor 8, a configuration can be simplified and the cost can also be reduced.

[0049] Hereinafter, control of the third expansion valve 33 in the heat pump system according to this embodiment will be described with reference to Fig. 3.

[0050] First, in a state where the third expansion valve 33 is closed, the discharge temperature (hereinafter also referred to as a "first temperature") of the high-stage compressor 8 is detected (step S1), and whether or not the first temperature is higher than a predetermined first threshold value is determined (step S2).

[0051] In a case where the first temperature is equal to or lower than the first threshold value, a state where the third expansion valve 33 is closed is continued.

[0052] On the other hand, in a case where the first temperature becomes higher than the first threshold value, a third expansion valve opening degree initial value set-

ting command is sent to the third expansion valve 33 (step S3), and a state is created where the degree of opening of the third expansion valve 33 is opened to a predetermined initial value. In this way, the refrigerant cooled in the condenser 11 is supplied to the high-stage compressor 8 through the liquid bypass circuit 32.

[0053] Further, a high-stage compressor suction superheat degree (hereinafter also referred to as a "first degree of superheat") is calculated (step S4), and whether or not the first degree of superheat is higher than a predetermined second threshold value is determined (step S5). In a case where the first degree of superheat is equal to or lower than the second threshold value, since it is a state where the suction superheat degree of the high-stage compressor 8 is low, a third expansion valve opening degree reduction command is sent to the third expansion valve 33 (step S6), and the degree of opening of the third expansion valve 33 is reduced. Thereafter, the detection of the first degree of superheat is continued (step S4), and the adjustment of the degree of opening of the third expansion valve 33 is continuously performed.

[0054] On the other hand, in a case where the first degree of superheat becomes higher than the second threshold value, the discharge temperature (the first temperature) of the high-stage compressor 8 is detected (step S7), and whether or not the first temperature is higher than the predetermined first threshold value is determined (step S8).

[0055] In a case where the first degree of superheat is higher than the second threshold value and the first temperature is equal to or lower than the first threshold value, the current degree of opening of the third expansion valve 33 is continued. Thereafter, the detection of the first degree of superheat is continued (step S4), and the adjustment of the degree of opening of the third expansion valve 33 is continuously performed.

[0056] On the other hand, in a case where the first temperature becomes higher than the first threshold value, a third expansion valve opening degree increase command is sent to the third expansion valve 33 (step S9), and a state is created where the degree of opening of the third expansion valve 33 is further opened. In this way, a greater amount of refrigerant cooled in the condenser 11 is supplied to the high-stage compressor 8 through the liquid bypass circuit 32. Thereafter, the detection of the first degree of superheat is continued (step S4), and the adjustment of the degree of opening of the third expansion valve 33 is continuously performed.

[0057] From the above, if the first degree of superheat is higher than the second threshold value, the refrigerant cooled in the condenser 11 continues to be supplied to the high-stage compressor 8 through the liquid bypass circuit 32. Further, in a case where the first temperature becomes higher than the first threshold value, a state is created where the degree of opening of the third expansion valve 33 is further opened, and thus a greater amount of refrigerant cooled in the condenser 11 is supplied to the high-stage compressor 8, so that an increase

in the first temperature and the first degree of superheat can be suppressed.

[Second Embodiment]

[0058] Next, a heat pump water heater 1 according to a second embodiment of the present invention will be described. The heat pump water heater 1 according to this embodiment is different in only the controller 40 from that of the first embodiment, and other configurations are the same as those of the first embodiment (refer to Fig. 1 or Fig. 2). Therefore, in the following, in particular, a controller 40 of the second embodiment will be described, and detailed description of the overlapping components will be omitted.

[0059] The controller 40 calculates the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8, based on the temperature and pressure of the refrigerant measured by the second temperature sensor 22 and the pressure sensor 23. Instead of the pressure sensor 23, similar to the first embodiment, the temperature of the refrigerant measured by at least one of the third temperature sensors 24A, 24B, and 24C may be used.

[0060] The controller 40 adjusts the degree of opening of the third expansion valve 33 according to the calculated degree of superheat of the refrigerant and the discharge temperature of the high-stage compressor 8. Further, the controller 40 controls the rotational frequency of the high-stage compressor 8 according to the discharge temperature of the high-stage compressor 8.

[0061] Specifically, in a case where the discharge temperature of the high-stage compressor 8 is equal to or lower than a predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is maintained. In contrast, in a case where the discharge temperature of the high-stage compressor 8 becomes higher than the predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is set to a predetermined initial value.

[0062] Further, in a case where the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8 is equal to or lower than a predetermined second threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is reduced. In contrast, in a case where the degree of superheat of the refrigerant which is sucked into the high-stage compressor 8 becomes higher than the predetermined second threshold value, the degree of opening of the third expansion valve 33 is maintained or increased according to the discharge temperature of the high-stage compressor 8.

[0063] In a case where the degree of superheat of the refrigerant which is sucked into the high-stage compres-

sor 8 becomes higher than the predetermined second threshold value, when the discharge temperature of the high-stage compressor 8 is equal to or lower than the predetermined first threshold value, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is maintained, and when the discharge temperature of the high-stage compressor 8 becomes higher than the first threshold value, whether or not the degree of opening of the third expansion valve 33 has reached the maximum opening degree is determined.

[0064] In the case described above, when the degree of opening of the third expansion valve 33 has not reached the maximum opening degree, the degree of opening of the third expansion valve 33 is controlled such that the degree of opening of the third expansion valve 33 is increased, and when the degree of opening of the third expansion valve 33 has reached the maximum opening degree, the rotational frequency of the high-stage compressor 8 is controlled such that the rotational frequency of the high-stage compressor 8 is reduced.

[0065] When the degree of opening of the third expansion valve 33 has reached the maximum opening degree, instead of controlling the rotational frequency of the high-stage compressor 8, the rotational frequency of the low-stage compressor 7 may be controlled such that the rotational frequency of the low-stage compressor 7 is increased,

[0066] Hereinafter, control of the third expansion valve 33 in the heat pump system according to the second embodiment of the present invention will be described with reference to Fig. 4.

[0067] Steps S1 to S8 are the same as those in the control of the third expansion valve 33 in the first embodiment described above, and therefore, description thereof is omitted.

[0068] In a state where the first degree of superheat is higher than the second threshold value, in step S8, whether or not the first temperature is higher than the predetermined first threshold value is determined, and thereafter, in a case where the first temperature is equal to or lower than the first threshold value, the current degree of opening of the third expansion valve 33 is continued. Thereafter, the detection of the first degree of superheat is continued (step S4), and the adjustment of the degree of opening of the third expansion valve 33 is continuously performed.

[0069] On the other hand, in a case where the first temperature becomes higher than the first threshold value, whether or not the degree of opening of the third expansion valve 33 has reached the maximum opening degree is determined (step S9).

[0070] If the degree of opening of the third expansion valve 33 has not reached the maximum opening degree, a command to increase the degree of opening of the third expansion valve 33 is sent to the third expansion valve 33 (step S10), and a state is created where the degree of opening of the third expansion valve 33 is further

opened. In this way, a greater amount of refrigerant cooled in the condenser 11 is supplied to the high-stage compressor 8 through the liquid bypass circuit 32. Thereafter, the detection of the first degree of superheat is continued (step S4), and the adjustment of the degree of opening of the third expansion valve 33 is continuously performed.

[0071] In contrast, in a case where the degree of opening of the third expansion valve 33 has reached the maximum opening degree, the rotational frequency of the high-stage compressor 8 is reduced (step S11). In this way, since the discharge pressure of the low-stage compressor 7 rises, the suction pressure of the high-stage compressor 8 also rises. As a result, as shown in Fig. 5, compared to a case where the difference between the suction pressure and the discharge pressure of the high-stage compressor 8 becomes smaller, and thus the adjustment to raise the discharge pressure of the low-stage compressor 7 is not performed, it is possible to lower the gas temperature of the refrigerant which is discharged from the high-stage compressor 8.

[0072] In the embodiment described above, in step S11, the rotational frequency of the high-stage compressor 8 is reduced in a case where the degree of opening of the third expansion valve 33 has reached the maximum opening degree. However, the rotational frequency of the low-stage compressor 7 may be increased.

[0073] Further, in the embodiment described above, a configuration has been described in which the rotational frequency of the high-stage compressor 8 or the low-stage compressor 7 is adjusted in a case where the first temperature is detected and the first temperature becomes higher than the first threshold value. However, the present invention is not limited to this example. For example, instead of the temperature detection of the first temperature, detection of the discharge pressure of the high-stage compressor 8 may be performed. In a case where the discharge pressure of the high-stage compressor 8 is detected and the discharge pressure of the high-stage compressor 8 becomes higher than a predetermined threshold value, adjustment of the rotational frequency of the high-stage compressor 8 or the low-stage compressor 7 may be performed.

Reference Signs List

[0074]

- 1: heat pump water heater
- 2: heat pump
- 7: low-stage compressor
- 8: high-stage compressor
- 11: condenser
- 12: first expansion valve
- 13: intermediate pressure receiver
- 16: second expansion valve
- 17: evaporator
- 31: gas injection circuit

- 32: liquid bypass circuit
- 33: third expansion valve
- 40: controller

Claims

1. A refrigeration cycle device having a refrigerant cycle in which a compression section having a low-stage compressor and a high-stage compressor, a condenser, an expansion section, and an evaporator are connected with one another by piping and a refrigerant is circulated, the refrigeration cycle device comprising:

a bypass pipe which branches off from a pipe connecting the condenser and the expansion section with each other and joins a pipe connecting the low-stage compressor and the high-stage compressor with each other;
a flow rate adjustment section which is provided in the bypass pipe and adjusts the amount of a refrigerant flowing through the bypass pipe; and
a controller which controls the flow rate adjustment section to increase the amount of the refrigerant flowing through the bypass pipe, when a discharge temperature of the high-stage compressor is higher than a predetermined value, and controls the flow rate adjustment section to adjust the amount of the refrigerant flowing through the bypass pipe, based on a suction superheat degree of the high-stage compressor.

2. The refrigeration cycle device according to claim 1, wherein the controller controls the flow rate adjustment section to reduce the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is equal to or lower than a predetermined value.
3. The refrigeration cycle device according to claim 1 or 2, wherein the controller controls the flow rate adjustment section to increase the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is higher than the predetermined value.
4. The refrigeration cycle device according to claim 1 or 2, wherein the controller causes the flow rate adjustment section to maintain the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is equal to or lower than the predetermined value.

5. The refrigeration cycle device according to any one of claims 1 to 3, wherein the controller increases a discharge pressure of the refrigerant which is discharged from the low-stage compressor by controlling a rotational frequency of the low-stage compressor or the high-stage compressor, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor or a discharge pressure of the high-stage compressor is higher than a predetermined value.
6. The refrigeration cycle device according to claim 5, wherein the flow rate adjustment section is an expansion valve, and the controller controls the rotational frequency of the low-stage compressor or the high-stage compressor when a degree of opening of the expansion valve has reached a maximum opening degree, when the discharge temperature of the high-stage compressor or the discharge pressure of the high-stage compressor is higher than a predetermined value.
7. A method of controlling a refrigeration cycle device having a refrigerant cycle in which a compression section having a low-stage compressor and a high-stage compressor, a condenser, an expansion section, and an evaporator are connected by piping and a refrigerant is circulated, the refrigeration cycle device including a bypass pipe which branches off from a pipe connecting the condenser and the expansion section and joins a pipe connecting the low-stage compressor and the high-stage compressor, and a flow rate adjustment section which is provided in the bypass pipe and adjusts the amount of a refrigerant flowing through the bypass pipe, the method comprising:

a step of increasing the amount of the refrigerant flowing through the bypass pipe by controlling the flow rate adjustment section when a discharge temperature of the high-stage compressor is higher than a predetermined value; and a step of adjusting the amount of the refrigerant flowing through the bypass pipe by controlling the flow rate adjustment section, based on a suction superheat degree of the high-stage compressor.

Amended claims under Art. 19.1 PCT

1. (Amended) A refrigeration cycle device having a refrigerant cycle in which a compression section having a low-stage compressor and a high-stage compressor, a condenser, an expansion section, and an evaporator are connected with one another by piping and a refrigerant is circulated, the refrigeration cycle

device comprising:

a bypass pipe which branches off from a pipe connecting the condenser and the expansion section with each other and joins a pipe connecting the low-stage compressor and the high-stage compressor with each other;
a flow rate adjustment section which is provided in the bypass pipe and adjusts the amount of a refrigerant flowing through the bypass pipe; and
a controller which controls the flow rate adjustment section to increase the amount of the refrigerant flowing through the bypass pipe, when a discharge temperature of the high-stage compressor is higher than a predetermined value, and controls the flow rate adjustment section to adjust the amount of the refrigerant flowing through the bypass pipe, based on a suction superheat degree of the high-stage compressor, wherein the controller increases a discharge pressure of the refrigerant which is discharged from the low-stage compressor by controlling a rotational frequency of the low-stage compressor or the high-stage compressor, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor or a discharge pressure of the high-stage compressor is higher than a predetermined value.

2. The refrigeration cycle device according to claim 1, wherein the controller controls the flow rate adjustment section to reduce the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is equal to or lower than a predetermined value.

3. The refrigeration cycle device according to claim 1 or 2, wherein the controller controls the flow rate adjustment section to increase the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is higher than the predetermined value.

4. The refrigeration cycle device according to claim 1 or 2, wherein the controller causes the flow rate adjustment section to maintain the amount of the refrigerant flowing through the bypass pipe, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor is equal to or lower than the predetermined value.

5. (Deleted)

6. (Amended) The refrigeration cycle device according to claim 1, wherein the flow rate adjustment section is an expansion valve, and the controller controls the rotational frequency of the low-stage compressor or the high-stage compressor when a degree of opening of the expansion valve has reached a maximum opening degree, when the discharge temperature of the high-stage compressor or the discharge pressure of the high-stage compressor is higher than a predetermined value. 5 10

7. (Amended) A method of controlling a refrigeration cycle device having a refrigerant cycle in which a compression section having a low-stage compressor and a high-stage compressor, a condenser, an expansion section, and an evaporator are connected by piping and a refrigerant is circulated, the refrigeration cycle device including a bypass pipe which branches off from a pipe connecting the condenser and the expansion section and joins a pipe connecting the low-stage compressor and the high-stage compressor, and a flow rate adjustment section which is provided in the bypass pipe and adjusts the amount of a refrigerant flowing through the bypass pipe, the method comprising: 15 20 25

a step of increasing the amount of the refrigerant flowing through the bypass pipe by controlling the flow rate adjustment section when a discharge temperature of the high-stage compressor is higher than a predetermined value; 30
a step of adjusting the amount of the refrigerant flowing through the bypass pipe by controlling the flow rate adjustment section, based on a suction superheat degree of the high-stage compressor; and 35
a step of increasing a discharge pressure of a refrigerant which is discharged from the low-stage compressor by controlling a rotational frequency of the low-stage compressor or the high-stage compressor, when the suction superheat degree of the high-stage compressor is higher than a predetermined value and the discharge temperature of the high-stage compressor or a discharge pressure of the high-stage compressor is higher than a predetermined value. 40 45

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FIG. 1

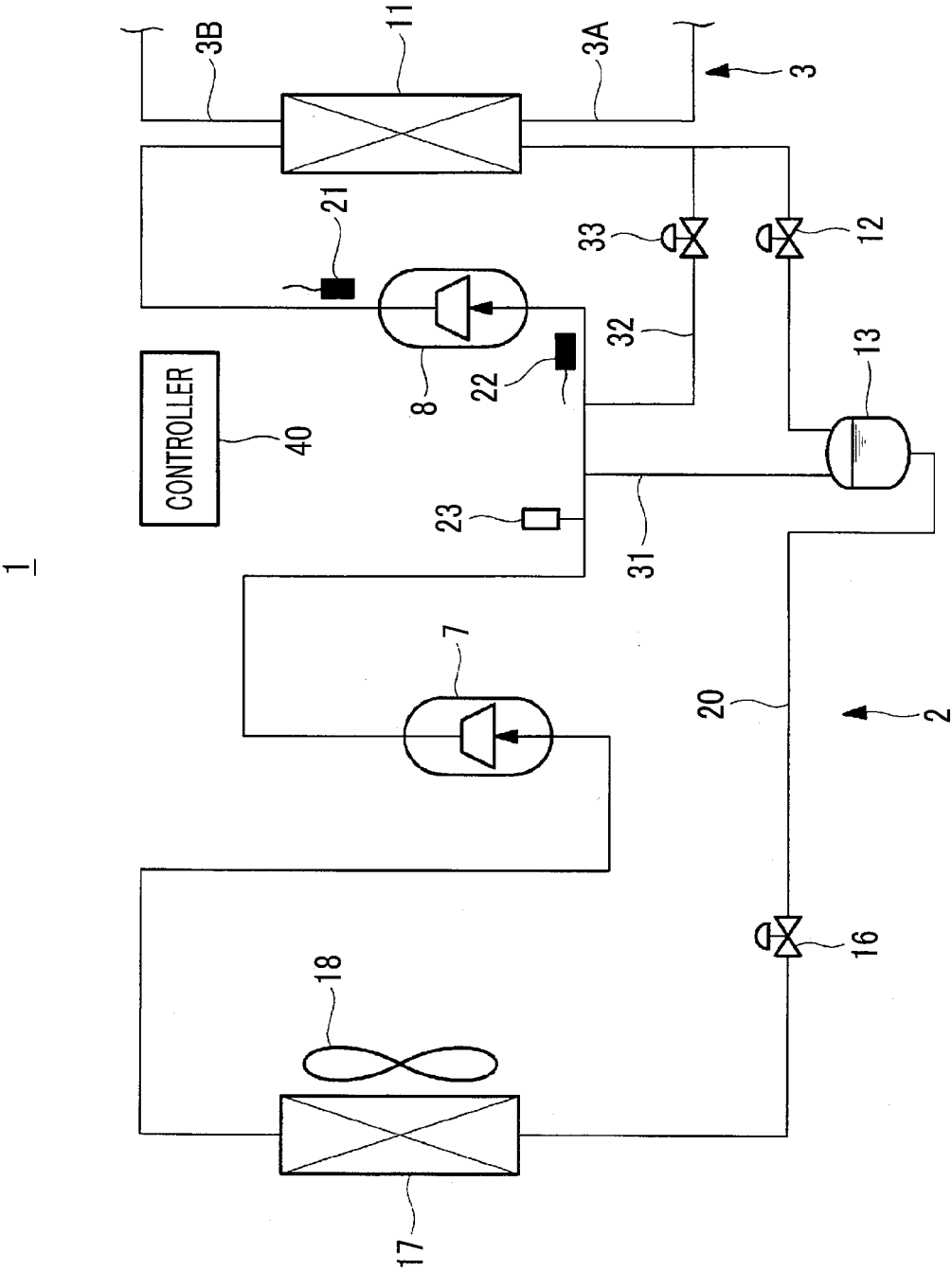


FIG. 2

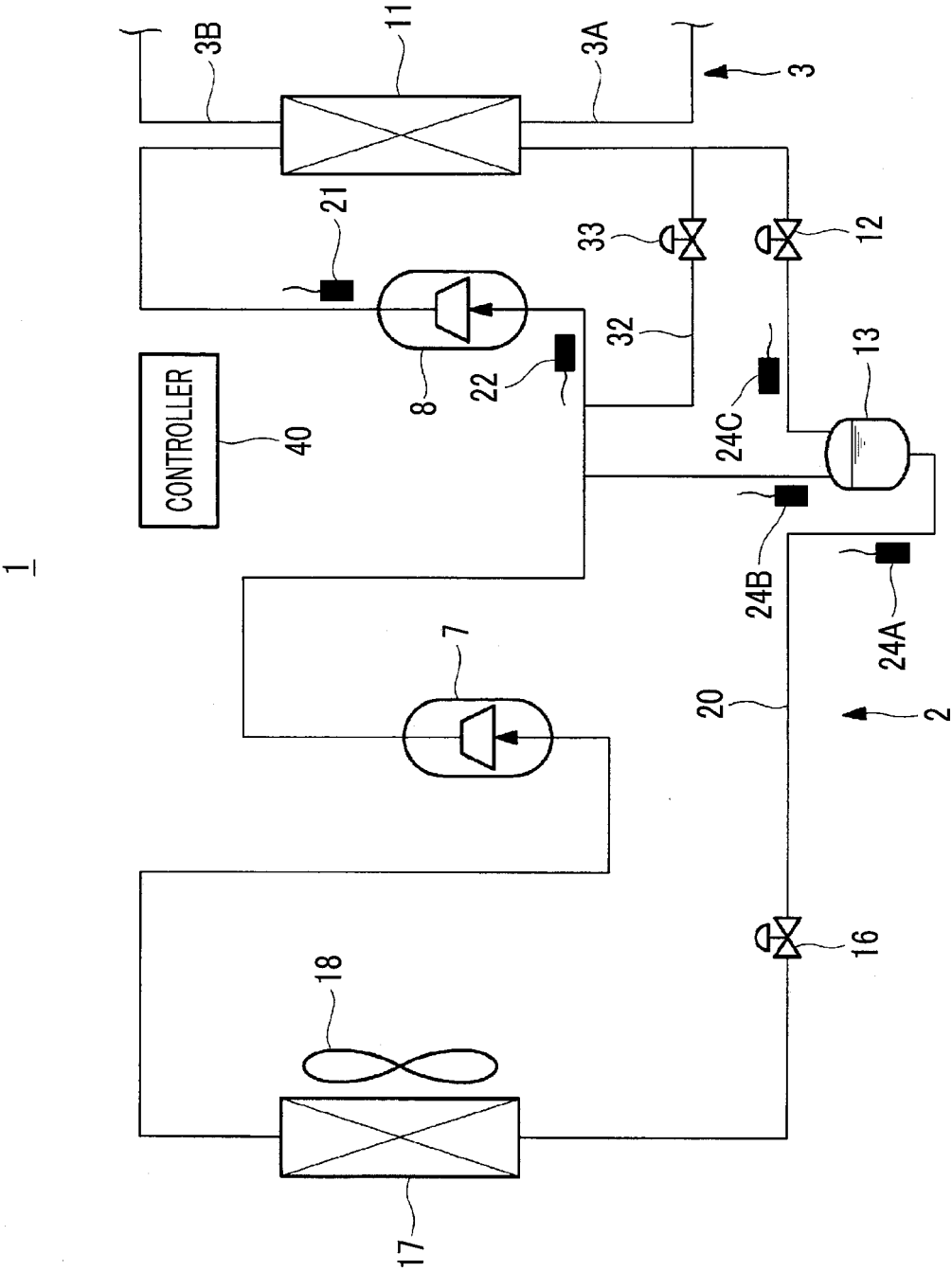


FIG. 3

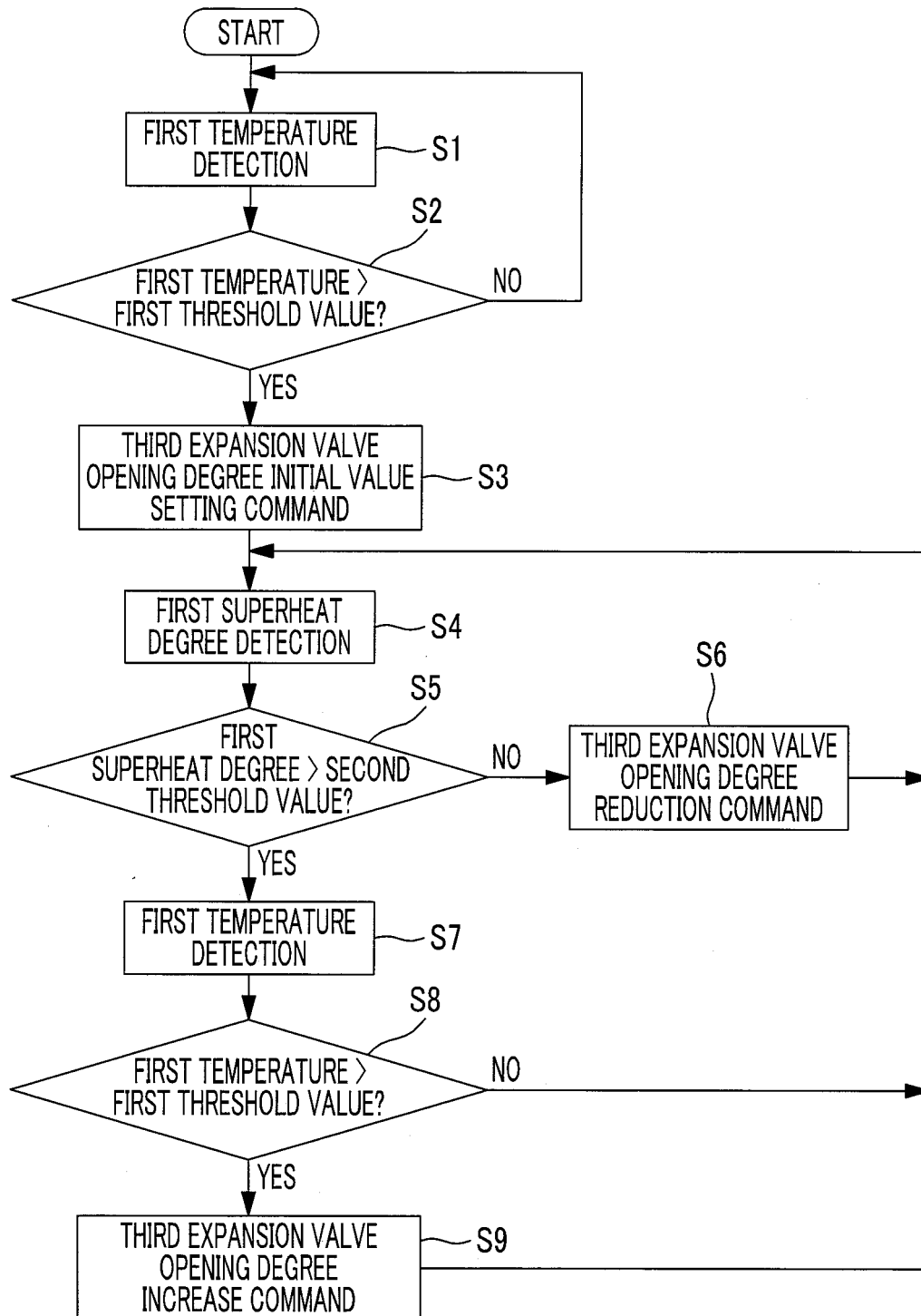


FIG. 4

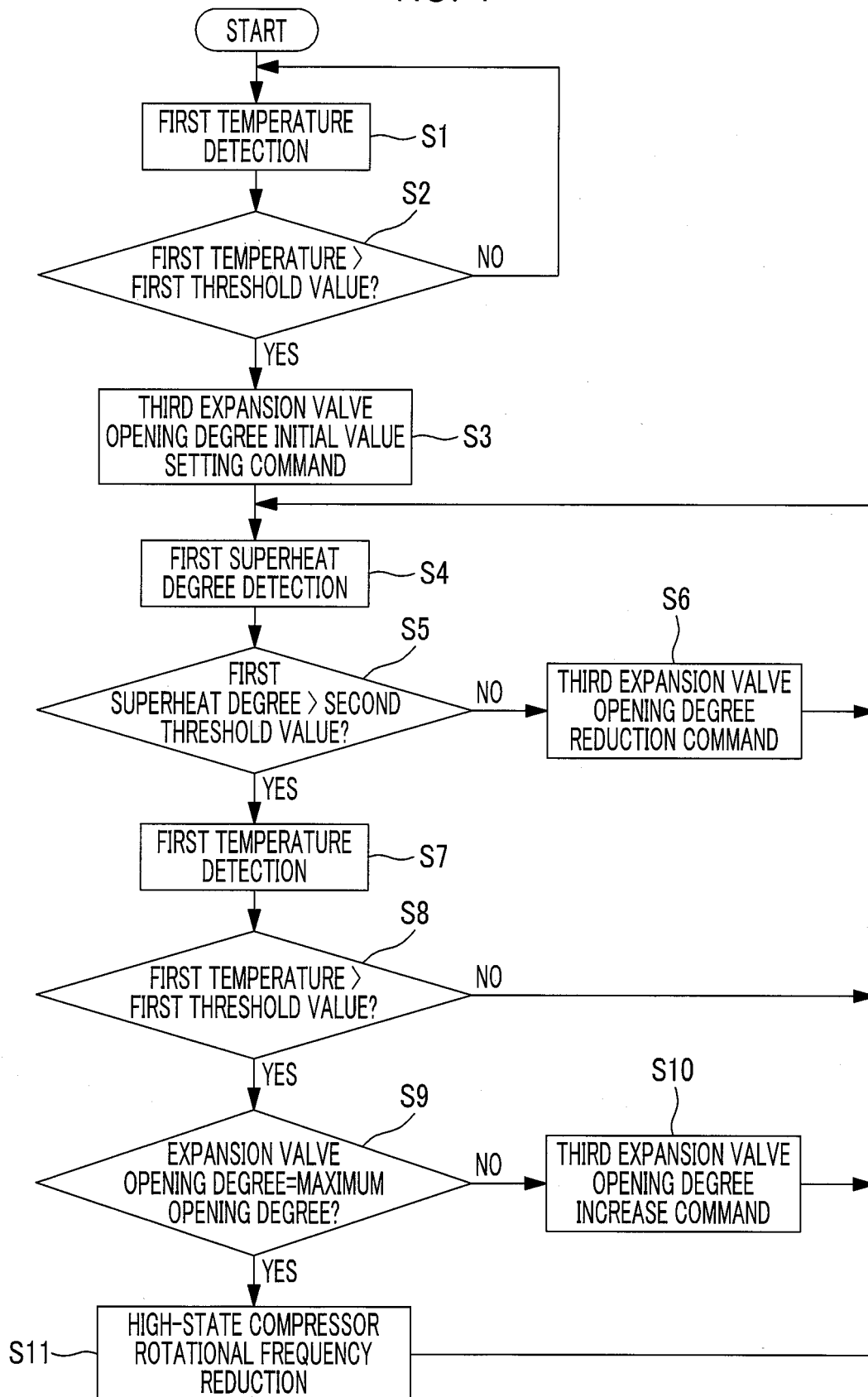
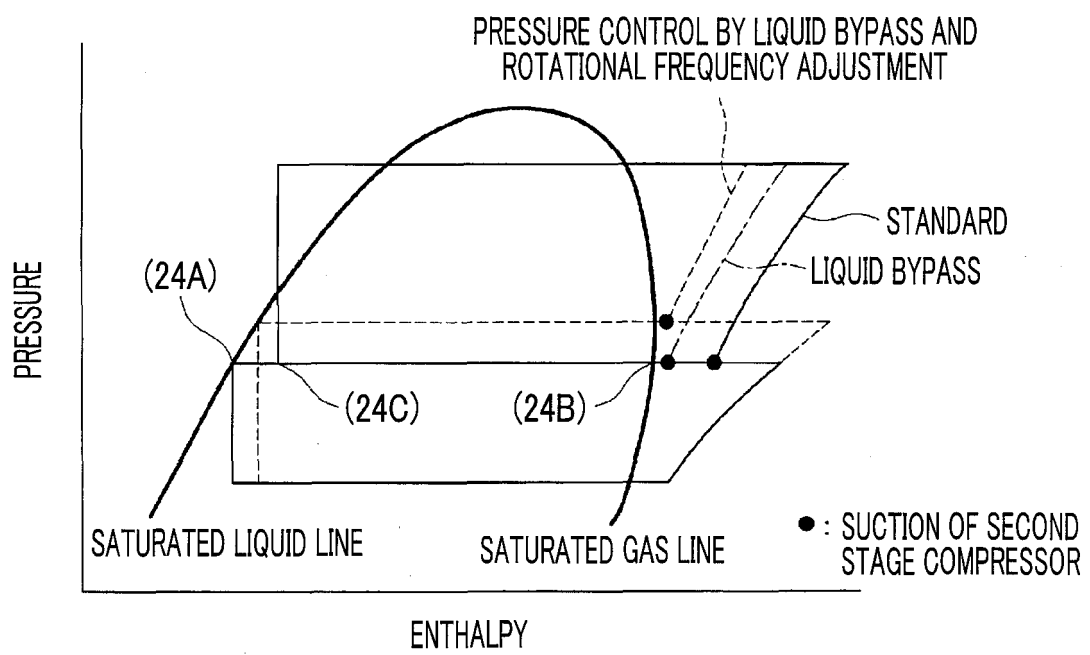


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.

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A. CLASSIFICATION OF SUBJECT MATTER

F25B1/10(2006.01)i, F25B1/00(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)

F25B1/10, F25B1/00

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 1996-2016
 Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2009-192164 A (Mitsubishi Electric Corp.), 27 August 2009 (27.08.2009), claims 1 to 3; paragraphs [0004], [0008] to [0018]; fig. 1 to 3 (Family: none)	1-4, 7 5-6
X A	JP 6-2966 A (Matsushita Electric Industrial Co., Ltd.), 11 January 1994 (11.01.1994), paragraphs [0012] to [0040]; fig. 1 to 2 (Family: none)	1-4, 7 5-6
A	JP 2007-147228 A (Daikin Industries, Ltd.), 14 June 2007 (14.06.2007), paragraphs [0072] to [0077] (Family: none)	5-6

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 Date of the actual completion of the international search
 14 July 2016 (14.07.16)

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 Japan Patent Office
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/063963

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 2001-74319 A (Daikin Industries, Ltd.), 23 March 2001 (23.03.2001), paragraphs [0013] to [0015] (Family: none)	5-6
A	JP 2002-327690 A (Daikin Industries, Ltd.), 15 November 2002 (15.11.2002), paragraphs [0017] to [0025] (Family: none)	5-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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