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(54)   **REFRIGERANT CIRCUIT SYSTEM AND METHOD FOR CONTROLLING REFRIGERANT
         CIRCUIT SYSTEM**

(57)   Provided is a refrigerant circuit system with
which it is possible to promote overcooling while ade-
quately controlling the compressor temperature. The re-
frigerant circuit system (1) is provided with: a gas-liquid
heat exchanger (20) for exchanging heat between a
high-pressure refrigerant and a low-pressure refrigerant;
a bypass path (21) for diverting the high-pressure refrig-
erant upstream of a decompression unit (151); a bypass
valve (22) capable of adjusting the flow rate; and a control
unit (25) for issuing a command corresponding to the flow
rate to the bypass valve (22). The control unit (25) deter-
mines the ratio of increase/decrease from the current
point in time of the flow rate of the high-pressure refrig-
erant to be channeled into the bypass path (21) on the
basis of $\Delta h'/\Delta h$, when: h1 is the discharge enthalpy, which
is enthalpy corresponding to the sensed temperature of
the discharged refrigerant; Δh is the enthalpy difference,
which is the difference in enthalpy corresponding to the
sensed refrigerant temperature at the inlet and outlet of
the gas-liquid heat exchanger (20); hv is the target dis-
charge enthalpy corresponding to the target temperature
Tv allowable for the compressor (14); and $\Delta h'$ is the com-
patible enthalpy difference compatible with the target dis-
charge enthalpy hv on the basis of h1 and Δh.

FIG. 1

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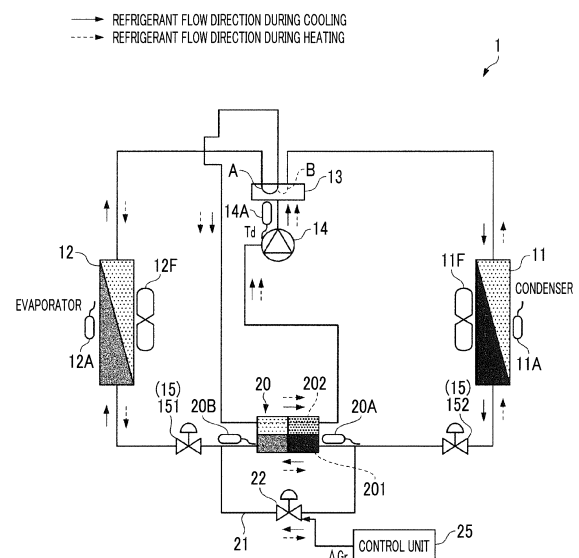
Description

Technical Field

[0001] The present invention relates to a refrigerant circuit system provided with a gas-liquid heat exchanger, and a method for controlling the refrigerant circuit system.

Background Art

[0002] In order to improve the performance of a refrigerant circuit system such as an air conditioner, how to radiate heat of a refrigerant to be able to liquefy the refrigerant is important, and a condenser plays the role. A high-temperature and high-pressure refrigerant gas compressed by a compressor releases heat by the heat exchange with air in the condenser to lower enthalpy. Here, the more the enthalpy is lowered by promoting supercooling, the more the performance is improved. However, due to advance in technology, in the present situation where heat radiation is performed such that the temperature of the refrigerant gas is lowered to a temperature close to the temperature of air, it is becoming difficult to further promote the supercooling.

[0003] Therefore, if a gas-liquid heat exchanger (also referred to as an internal heat exchanger or an intercooler) which performs heat exchange between a high-pressure refrigerant liquefied by a condenser and a low-pressure refrigerant gas which has passed through an evaporator is used, it is possible to lower enthalpy by further liquefying the high-pressure refrigerant.

[0004] However, since the temperature of the low-pressure refrigerant which is suctioned into the compressor is increased due to the heat radiation from the high-pressure refrigerant to the low-pressure refrigerant in the gas-liquid heat exchanger, the temperature of the compressor rises. In order to suppress the temperature of the compressor to an allowable temperature, there is an example in which only a part of the low-pressure refrigerant which has passed through the evaporator is caused to flow to the gas-liquid heat exchanger and the rest is caused to bypass the gas-liquid heat exchanger (PTL 1). That is, due to the bypass, the flow rate of the low-pressure refrigerant to which heat is released from the high-pressure refrigerant is adjusted. In PTL 1, a bypass path and a bypass valve are provided on the outlet side of the evaporator and the low-pressure refrigerant is suctioned from the bypass path to the compressor.

Citation List

Patent Literature

[0005] [PTL 1] Japanese Unexamined Patent Application Publication No. 2000-346466

Summary of Invention

Technical Problem

[0006] As in PTL 1, if an attempt to adjust the flow rate of the low-pressure refrigerant passing through the evaporator and flowing through the gas-liquid heat exchanger is made, it is difficult to adjust the flow rate because the refrigerant is a low-pressure gas. Further, the refrigerant which has bypassed is suctioned into the compressor, and therefore, the flow rate of the refrigerant which is caused to bypass is changed, the influence directly acts on the compressor, and thus the temperature of the compressor overshoots with respect to a target temperature or hunting easily occurs.

[0007] From the above, the present invention has an object to provide a refrigerant circuit system and a method for controlling the refrigerant circuit system, in which it is possible to promote supercooling while appropriately controlling the temperature of a compressor.

Solution to Problem

[0008] According to an aspect of the present invention, there is provided a refrigerant circuit system which includes a compressor, a condenser, a decompression unit, and an evaporator, the refrigerant circuit system further including: a gas-liquid heat exchanger which performs heat exchange between a high-pressure refrigerant which has passed through the condenser and a low-pressure refrigerant which has passed through the evaporator; a bypass path for receiving at least a part of the high-pressure refrigerant flowing from the condenser to the gas-liquid heat exchanger and causing the high-pressure refrigerant to bypass to the upstream of the decompression unit; a flow rate regulating unit capable of adjusting a flow rate of the high-pressure refrigerant flowing into the bypass path; and a control unit which gives a command corresponding to the flow rate to the flow rate regulating unit, in which the control unit determines the ratio of increase/decrease from the present time, of the flow rate of the high-pressure refrigerant which is caused to flow into the bypass path, based on ($\Delta h'/\Delta h$), when discharge enthalpy which is enthalpy corresponding to a detected temperature of a discharged refrigerant which is discharged from the compressor is hi, an enthalpy difference which is a difference between enthalpy corresponding to a detected temperature of a refrigerant at an inlet of the gas-liquid heat exchanger and enthalpy corresponding to a detected temperature of a refrigerant at an outlet of the gas-liquid heat exchanger is Δh, a target discharge enthalpy corresponding to a target temperature Tv which is allowed for the compressor is hv, and a compatible enthalpy difference which is a difference in enthalpy between the inlet and the outlet of the gas-liquid heat exchanger, which is compatible with the target discharge enthalpy hv, based on h1 and Δh, is $\Delta h'$.

[0009] In the refrigerant circuit system according to the

above aspect of the present invention, it is preferable that a target temperature range which includes the target temperature Tv and has an upper limit temperature and a lower limit temperature is set and the control unit acquires the compatible enthalpy difference $\Delta h'$ in which it is possible to cause the target discharge enthalpy hv to fall within a range from lower limit discharge enthalpy corresponding to the lower limit temperature to upper limit discharge enthalpy corresponding to the upper limit temperature.

[0010]   It is preferable that the refrigerant circuit system according to the above aspect of the present invention is an air conditioner which includes a switching unit which can switch between a cooling operation and a heating operation by changing a direction of a flow of the refrigerant, an outdoor heat exchanger which functions as the condenser during the cooling operation and functions as the evaporator during the heating operation, an indoor heat exchanger which functions as the evaporator during the cooling operation and functions as the condenser during the heating operation, a decompression unit during cooling, which is located between the gas-liquid heat exchanger and the evaporator and functions as the decompression unit during the cooling operation, and a decompression unit during heating, which is located between the gas-liquid heat exchanger and the evaporator and functions as the decompression unit during the heating operation.

[0011]   Further, according to another aspect of the present invention, there is provided a method for controlling a refrigerant circuit system which includes a compressor, a condenser, a decompression unit, and an evaporator, the refrigerant circuit system further including a gas-liquid heat exchanger which performs heat exchange between a high-pressure refrigerant which has passed through the condenser and a low-pressure refrigerant which has passed through the evaporator, a bypass path for receiving at least a part of the high-pressure refrigerant flowing from the condenser to the gas-liquid heat exchanger, and causing the high-pressure refrigerant to bypass to the upstream of the decompression unit, and a flow rate regulating unit capable of adjusting a flow rate of the high-pressure refrigerant flowing into the bypass path, the method including: a step of detecting a temperature of a discharged refrigerant which is discharged from the compressor; a step of detecting a temperature of a refrigerant at an inlet of the gas-liquid heat exchanger; a step of detecting a temperature of a refrigerant at an outlet of the gas-liquid heat exchanger; a step of acquiring a compatible enthalpy difference $\Delta h'$ which is a difference in enthalpy between the inlet and the outlet of the gas-liquid heat exchanger, which is compatible with the target discharge enthalpy hv, based on h1 and Δh, when discharge enthalpy which is enthalpy corresponding to a detected temperature of the discharged refrigerant is hi, an enthalpy difference which is a difference between enthalpy corresponding to a detected temperature of a refrigerant at the inlet and enthalpy corresponding

to a detected temperature of a refrigerant at the outlet is Δh, and a target discharge enthalpy corresponding to a target temperature Tv which is allowed for the compressor is hv; and a step of determining the ratio of increase/decrease from the present time, of the flow rate of the high-pressure refrigerant which is caused to flow into the bypass path, based on ($\Delta h'/\Delta h$).

[0012]   In the method for controlling a refrigerant circuit system according to the above aspect of the present invention, it is preferable that a target temperature range which includes the target temperature Tv and has an upper limit temperature and a lower limit temperature is set and that in the step of acquiring $\Delta h'$, the compatible enthalpy difference $\Delta h'$ in which it is possible to cause the target discharge enthalpy hv to fall within a range from lower limit discharge enthalpy corresponding to the lower limit temperature to upper limit discharge enthalpy corresponding to the upper limit temperature is acquired.

Advantageous Effects of Invention

[0013]   By performing control to change a flow rate which is caused to bypass, by the flow rate regulating unit, based on ($\Delta h'/\Delta h$) derived such that the temperature of the discharged refrigerant reaches the target temperature Tv, from the relationship between the enthalpy difference Δh corresponding to the effect of supercooling by the gas-liquid heat exchanger and the discharge enthalpy h1 corresponding to the temperature of the discharged refrigerant, it is possible to achieve improvement in performance by promoting supercooling while suppressing the temperature of the discharged refrigerant.

[0014]   According to the present invention, by changing the ratio of the flow rates of the refrigerant flowing through the gas-liquid heat exchanger and the refrigerant flowing through the bypass path, based on the present and future ratios ($\Delta h'/\Delta h$) of the magnitude of the effect of the heat exchange amount by the gas-liquid heat exchanger, it is possible to obtain an appropriate response of the compressor and stabilize the temperature of the discharged refrigerant to the target temperature Tv at an early stage.

Brief Description of Drawings

[0015]

Fig. 1 is a diagram showing a configuration of a refrigerant circuit system according to an embodiment of the present invention.
Fig. 2 is a p-h diagram showing the action of supercooling by a gas-liquid heat exchanger.
Fig. 3 is a diagram showing a flow of control for obtaining a flow rate control amount of a high-pressure refrigerant which is caused to bypass.
Fig. 4 is a diagram showing an image of control on a temperature of a discharged refrigerant.
Fig. 5 is a diagram showing a configuration of a refrigerant circuit system according to a modification example of the present invention.

Description of Embodiments

[0016]   Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings.

[First Embodiment]

[0017]   A refrigerant circuit system 1 shown in Fig. 1 is provided with a refrigerant circuit through which a refrigerant circulates. The refrigerant circuit system 1 is an air conditioner utilizing a refrigeration cycle, and includes an outdoor unit (not shown) having an outdoor heat exchanger 11 which performs heat exchange between outdoor air and a refrigerant, and an indoor unit (not shown) having an indoor heat exchanger 12 which performs heat exchange between indoor air and the refrigerant.

[0018]   The refrigerant circuit system 1 is provided with a four-way valve 13 capable of switching the flow direction of a circulating refrigerant, and is configured such that switching between a cooling operation and a heating operation can be performed by operating the four-way valve 13. In Fig. 1, the flow of the refrigerant during cooling is shown by solid arrows. During heating, instead of closing a path of A shown in the four-way valve 13, a path of B shown by a broken line is opened, so that the refrigerant flows in a direction opposite to the direction during the cooling (dashed arrows in Fig. 1).

[0019]   The outdoor heat exchanger 11 functions as a condenser during the cooling operation and functions as an evaporator during the heating operation. The indoor heat exchanger 12 functions as an evaporator during the cooling operation and functions as a condenser during the heating operation. A fan 11F for blowing air to the outdoor heat exchanger 11 and a fan 12F for blowing air toward the indoor heat exchanger 12 are provided in the refrigerant circuit system 1.

[0020]   A condenser and an evaporator as functions during the cooling operation are respectively appended to the outdoor heat exchanger 11 and the indoor heat exchanger 12 shown in Fig. 1.

[0021]   Hereinafter, on the basis of the cooling, the outdoor heat exchanger 11 is referred to as a condenser 11 and the indoor heat exchanger 12 is referred to as an evaporator 12.

[0022]   The refrigerant circuit system 1 includes, as basic elements, a compressor 14, the condenser 11, decompression units 15 (151 and 152), and the evaporator 12. As the decompression units 15, two decompression units; a decompression unit 151 for the cooling operation and a decompression unit 152 for the heating operation, are prepared. The decompression unit 151 for the cooling operation does not function during the heating operation. Similarly, the decompression unit 152 for the heating operation does not function during the cooling operation.

[0023]   The refrigerant circuit system 1 includes, in addition to the above basic elements, a gas-liquid heat exchanger 20 which performs heat exchange between a low-pressure refrigerant that has passed through the evaporator 12 and a high-pressure refrigerant that has passed through the condenser 11, a bypass path 21 for causing a part of the high-pressure refrigerant flowing to the gas-liquid heat exchanger 20 to bypass to the upstream of the decompression unit 151, a bypass valve 22 capable of adjusting the flow rate of the high-pressure refrigerant flowing into the bypass path 21, and a control unit 25 which gives the degree of opening to the bypass valve 22.

[0024]   The gas-liquid heat exchanger 20 is provided with a high-pressure path 201 through which the high-pressure refrigerant flows and a low-pressure path 202 through which the low-pressure refrigerant flows, and is configured so as to be able to perform heat exchange between the high-pressure refrigerant flowing through the high-pressure path 201 and the low-pressure refrigerant flowing through the low-pressure path 202.

[0025]   The bypass path 21 receives a part of the high-pressure refrigerant from the upstream of the high-pressure path 201 and causes the high-pressure refrigerant to bypass to the downstream of the high-pressure path 201 and the upstream of the decompression unit 151.

[0026]   The high-pressure refrigerant which passes through the condenser 11 and flows into the gas-liquid heat exchanger 20 radiates heat to the low-pressure refrigerant, thereby being supercooled, as indicated by 100 in Fig. 2, so that enthalpy is lowered. Thereafter, the high-pressure refrigerant is decompressed by the decompression unit 151 and flows to the evaporator 12.

[0027]   The high-pressure refrigerant is supercooled by the gas-liquid heat exchanger 20, and on the other hand, as indicated by 101 in Fig. 2, the low-temperature and low-pressure refrigerant which has passed through the evaporator 12 absorbs heat from the high-pressure refrigerant, thereby being overheated. Then, the temperature of the refrigerant which is suctioned into the compressor 14 rises.

[0028]   A predetermined target temperature Tv which is allowed for the compressor 14 can be determined in consideration of the performance of lubricating oil which is used in a sliding part of the compressor 14, or in a case where an electric motor is incorporated in the compressor 14, in consideration of the performance of the electric motor as well.

[0029]   In this embodiment, the target temperature Tv which is the temperature of the refrigerant flowing through a discharge pipe that discharges the refrigerant compressed by the compressor 14 to the outside of the compressor 14 is determined. A target temperature range which includes the target temperature Tv and includes an upper limit temperature X and a lower limit temperature $X-\alpha$ is set.

[0030]   In this embodiment, in order to make the temperature of the compressor 14 fall within a range from the lower limit temperature $X-\alpha$ to the upper limit temperature X while obtaining the effect of supercooling as much as possible by the gas-liquid heat exchanger 20, the flow

rate of the high-pressure refrigerant flowing through the bypass path 21 is adjusted by using the bypass path 21 and the bypass valve 22. If an opening degree command corresponding to the flow rate is given from the control unit 25 to the bypass valve 22, the amount of the degree of opening of the bypass valve 22 is changed according to the opening degree command, whereby the flow rate of the refrigerant flowing through the bypass path 21 is adjusted.

[0031] In the high-pressure refrigerant which has passed through the condenser 11, a liquid phase is dominant, and therefore, the flow rate can be easily and reliably adjusted compared to a case of adjusting the flow rate of a refrigerant gas.

[0032] In order to adjust the flow rate of the refrigerant flowing into the bypass path 21, the control unit 25 performs calculation with respect to each enthalpy derived using the pressure and temperature of the high-pressure refrigerant, the temperature of the refrigerant at an inlet of the gas-liquid heat exchanger 20, and the temperature of the refrigerant at an outlet of the gas-liquid heat exchanger 20.

[0033] In order to derive the enthalpy, the refrigerant circuit system 1 of this embodiment is provided with a condenser temperature sensor 11A, a discharge temperature sensor 14A, an inlet temperature sensor 20A, and an outlet temperature sensor 20B.

[0034] The condenser temperature sensor 11A detects the temperature of a gas-liquid two-phase refrigerant flowing through the condenser 11. The temperature detected by the condenser temperature sensor 11A is regarded as the temperature of a saturated vapor, and the pressure of the high-pressure refrigerant can be obtained as the saturated vapor pressure corresponding thereto.

[0035] In a case where a pressure gauge indicating the pressure of the high-pressure refrigerant is provided in the outdoor unit, the value measured by the pressure gauge can be used as the pressure of the high-pressure refrigerant.

[0036] The refrigerant circuit system 1 is also provided with a temperature sensor 12A which detects the temperature of a gas-liquid two-phase refrigerant flowing through the indoor heat exchanger 12 which functions as a condenser during the heating operation, for the control during the heating operation. During the heating operation, the pressure of the high-pressure refrigerant can be obtained by using the temperature detected by the temperature sensor 12A.

[0037] The discharge temperature sensor 14A detects the temperature of the refrigerant flowing through the discharge pipe of the compressor 14 (hereinafter referred to as a discharged refrigerant).

[0038] The inlet temperature sensor 20A detects the temperature of the high-pressure refrigerant flowing into the inlet of the gas-liquid heat exchanger 20.

[0039] The outlet temperature sensor 20B detects the temperature of the high-pressure refrigerant flowing out from the outlet of the gas-liquid heat exchanger 20.

[0040] An example of the processing by the control unit 25 will be described.

[0041] The control unit 25 acquires h1 which is the enthalpy of the discharged refrigerant, based on the measurement value by the condenser temperature sensor 11A, or by using the pressure of the high-pressure refrigerant obtained by the pressure gauge and a temperature Td of the discharged refrigerant detected by the discharge temperature sensor 14A.

[0042] Further, enthalpy h2 of the refrigerant at the inlet of the gas-liquid heat exchanger 20 is acquired by using the temperature detected by the inlet temperature sensor 20A and the pressure of the high-pressure refrigerant, and enthalpy h3 of the refrigerant at the outlet of the gas-liquid heat exchanger 20 is acquired by using the temperature detected by the outlet temperature sensor 20B and the pressure of the high-pressure refrigerant.

[0043] An enthalpy difference Δh is acquired by the calculation of the value of h2-h3 using the enthalpy h2 at the inlet and the enthalpy h3 at the outlet acquired in this way. This corresponds to the effect of supercooling of the high-pressure refrigerant by the gas-liquid heat exchanger 20, and in other words, corresponds to the effect of overheating of the low-pressure refrigerant.

[0044] If the high-pressure refrigerant is caused to bypass to the bypass path 21, the effects of supercooling and overheating by the gas-liquid heat exchanger 20 are reduced by an amount corresponding to the ratio of the flow rate which is caused to bypass, and therefore, a rise in the temperature of the low-pressure refrigerant according to heat radiation from the high-pressure refrigerant in the gas-liquid heat exchanger 20 is suppressed. Then, the temperature of the low-pressure refrigerant which is suctioned into the compressor 14 is lowered, and therefore, it becomes possible to suppress the temperature inside the compressor 14.

[0045] The detected enthalpy difference Δh indicates the effect that the gas-liquid heat exchanger 20 rises the temperature of the low-pressure refrigerant at the present time. Then, when discharge enthalpy corresponding to the temperature of the discharged refrigerant and the pressure of the high-pressure refrigerant, which will be detected in a case where the high-pressure refrigerant does not flow through the gas-liquid heat exchanger 20, is set to be h1', the current discharge enthalpy h1 can be expressed by the following expression (1).

$$\mathrm{h1=h1'+\Delta h} \ \ldots \ (1)$$

[0046] In this embodiment, the case where the high-pressure refrigerant does not flow through the gas-liquid heat exchanger 20 corresponds to a case where the degree of opening of the bypass valve 22 is in a fully open condition.

[0047] When the pressure of the high-pressure refrig-

erant is stable, if the enthalpy difference Δh is changed to Δh', the discharge enthalpy h1 changes accordingly.

[0048] Therefore, a target discharge enthalpy hv corresponding to the target temperature Tv of the discharged refrigerant, which is allowable for the compressor 14, can be expressed by the following expression (2) when an enthalpy difference by gas-liquid heat exchange is set to be Δh'.

$$hv = h1' + \Delta h' \quad \dots \quad (2)$$

[0049] From the above expression (2), Δh' is a compatible enthalpy difference which is compatible with the target discharge enthalpy hv. Δh' can be calculated by calculating the value of hv-h1' by the control unit 25.

[0050] From the ratio of Δh' to the current enthalpy difference Δh based on the detected temperature, the control unit 25 obtains the control amount of the flow rate of the refrigerant which is caused to bypass through the bypass path 21, and gives it to the bypass valve 22 as the degree of opening.

[0051] That is, in order to realize the compatible enthalpy difference Δh' which is compatible with the target discharge enthalpy hv, the control unit 25 determines the ratio of increase/decrease from the present time, of the flow rate of the high-pressure refrigerant which is caused to flow into the bypass path 21, based on the ratio of (Δh'/Δh) at the present time, and gives an opening degree command corresponding to the flow rate multiplied by the ratio of increase/decrease to the bypass valve 22.

[0052] As will be described later, it is preferable that a width is given to the target discharge enthalpy hv such that the temperature of the discharged refrigerant falls within a predetermined temperature range which includes the target temperature Tv, and Δh' is calculated so as to be compatible with a range from the upper limit to the lower limit of the enthalpy.

[0053] The action by the control unit 25 has been described taking the cooling operation as an example. However, the same applies to the heating operation.

[0054] During the heating operation, due to the switching operation of the four-way valve 13, the refrigerant circulates through the compressor 14, the indoor heat exchanger 12 as a condenser, the decompression unit 152, the gas-liquid heat exchanger 20, and the outdoor heat exchanger 11 as an evaporator in this order.

[0055] Since the inlet and the outlet of the gas-liquid heat exchanger 20 become opposite to those during the cooling operation, the enthalpy difference Δh due to the heat exchange in the gas-liquid heat exchanger 20 corresponds to the value of h3-h2, which is obtained by subtracting the enthalpy h2 corresponding to the temperature detected by the temperature sensor 20A from the enthalpy h3 corresponding to the temperature detected by the temperature sensor 20B.

[0056] The processing which is the same as during the cooling operation except that the enthalpy difference Δh corresponds to the value of h3-h2 and that the discharge enthalpy h1 is acquired by using the pressure of the high-pressure refrigerant corresponding to the condenser temperature detected by the temperature sensor 12A of the indoor heat exchanger 12 can be performed.

[0057] Hereinafter, an example of a procedure of the control which is performed by the control unit 25 will be described with reference to Fig. 3. In the following, (Δh'/Δh) is referred to as ΔGr. ΔGr corresponds to an increase/decrease magnification of the heat exchange amount by the gas-liquid heat exchanger 20.

[0058] During the cooling operation or the heating operation of the refrigerant circuit system 1, the control unit 25 performs calculation according to the procedure shown in Fig. 3 and changes the degree of opening of the bypass valve 22, based on the calculated ΔGr.

[0059] It is preferable to promote supercooling by causing the high-pressure refrigerant to flow to the gas-liquid heat exchanger 20 as much as possible under the restriction of the temperature of the compressor 14. In this embodiment, the operation is started in a state where the bypass valve 22 is fully closed.

[0060] During the cooling operation, first, as described above, the discharge enthalpy h1 is acquired by using the condenser temperature sensor 11A or using the pressure of the high-pressure refrigerant obtained by the pressure gauge and the temperature Td of the discharged refrigerant detected by the discharge temperature sensor 14A (step S1).

[0061] Next, the enthalpy h2 of the refrigerant at the inlet of the gas-liquid heat exchanger 20 and the enthalpy h3 of the refrigerant at the outlet are acquired by using the temperatures which are respectively detected by the temperature sensors 20A and 20B and the enthalpy difference Δh due to gas-liquid heat exchange is calculated (step S2).

[0062] Next, the enthalpy difference Δh' corresponding to the heat exchange amount of the gas-liquid heat exchanger 20, which is necessary for making the temperature of the discharged refrigerant reach the target temperature Tv, is calculated (step S3).

[0063] Here, the target temperature range is set by using a threshold value. The target temperature range includes the target temperature Tv and has an upper limit temperature X and a lower limit temperature (X-α). An enthalpy range which includes the target discharge enthalpy hv is also set by an upper limit discharge enthalpy corresponding to the upper limit temperature X and a lower limit discharge enthalpy corresponding to the lower limit temperature (X-α).

[0064] The control unit 25 calculates Δh' which is allowed to be added to the discharge enthalpy h1' in a case where the high-pressure refrigerant does not flow through the gas-liquid heat exchanger 20, such that the target discharge enthalpy hv falls within a range equal to or more than the lower limit enthalpy corresponding to the temperature (X-α) and equal to or less than the upper

limit enthalpy corresponding to the temperature X.

[0065] After the calculating of Δh', the ratio (Δh'/Δh) of Δh' to Δh is calculated as the increase/decrease magnification ΔGr of the gas-liquid heat exchange amount (step S4). If ΔGr is smaller than 1, in order to suppress the temperature of the discharged refrigerant, it is necessary to further reduce the flow rate of the high-pressure refrigerant flowing through the gas-liquid heat exchanger 20 than at the present time. Conversely, if ΔGr is larger than 1, since the temperature of the discharged refrigerant is lower than the allowable temperature of the compressor 14, there is room for further increasing the flow rate of the high-pressure refrigerant flowing through the gas-liquid heat exchanger 20 than at the present time to promote the liquefaction of the high-pressure refrigerant.

[0066] Therefore, the degree of opening of the bypass valve 22 can be changed by the following procedure according to the calculated ΔGr.

[0067] For example, in a case where ΔGr is smaller than 1 (Y in step S5), as long as the degree of opening of the bypass valve 22 is not in a fully open condition (N in step S6), an opening degree command to increase the degree of opening is given to the bypass valve 22 in order to reduce the flow rate of the high-pressure refrigerant flowing through the gas-liquid heat exchanger 20 (step S7). Then, the bypass valve 22 is driven to the opening degree amount corresponding to (1/ΔGr) times that at the present time, based on the opening degree command. For example, the bypass valve 22 is driven by a drive pulse in which a pulse number per unit time is about (1/ΔGr) times that at the present time.

[0068] For example, the minimum pulse number is set to be 0.01 or the like such that the bypass valve 22 can be opened even if the current pulse number is 0, because the bypass valve 22 is fully closed at the present time.

[0069] Further, in a case where ΔGr is larger than 1 (Y in step S8), as long as the degree of opening of the bypass valve 22 is not in a fully closed condition (N in step S9), an opening degree command to reduce the degree of opening is given to the bypass valve 22 in order to increase the flow rate of the high-pressure refrigerant flowing in the gas-liquid heat exchanger 20 (step S10).

[0070] Then, in a case where ΔGr is 1 (step S11), the heat exchange amount by the gas-liquid heat exchanger 20 is compatible with the target temperature Tv, and therefore, the degree of opening of the bypass valve 22 is maintained as it is.

[0071] According to this embodiment described above, by performing control to change the degree of opening of the bypass valve 22, based on ΔGr derived such that the temperature of the discharged refrigerant reaches the target temperature Tv, from the relationship between the enthalpy difference Δh corresponding to the effect of supercooling by the gas-liquid heat exchanger 20 and the discharge enthalpy h1 corresponding to the temperature Td of the discharged refrigerant, it is possible to achieve improvement in the performance of the air conditioner by promoting supercooling while suppressing the

temperature of the discharged refrigerant.

[0072] In addition, since the high-pressure refrigerant bypassing to the bypass path 21 is caused to flow to the upstream of the decompression unit 151, unlike a case where the high-pressure refrigerant caused to bypass is caused to flow to the front of the compressor 14, the refrigerant circulation amount to the evaporator 12 does not decrease and the heat exchange performance of the evaporator 12 can be maintained.

[0073] In this embodiment, by changing the ratio of the flow rates of the refrigerant flowing through the gas-liquid heat exchanger 20 and the refrigerant flowing through the bypass path 21, based on the present and future ratios (Δh'/Δh) of the magnitude of the effect of the heat exchange amount by the gas-liquid heat exchanger 20, it is possible to obtain an appropriate response of the compressor 14 and stabilize the temperature of the discharged refrigerant to the target temperature Tv at an early stage.

[0074] The dot-and-dash line shown in Fig. 4 shows a case where the bypass flow rate is lowered at once by the bypass valve 22 because the temperature of the discharged refrigerant has exceeded the temperature Tv which is allowed for the compressor. In this case, the temperature of the discharged refrigerant excessively responds, and thus overshoot or hunting easily occurs.

[0075] The broken line shown in Fig. 4 shows a case where the bypass flow rate is gradually lowered by the bypass valve 22 when the temperature of the discharged refrigerant has exceeded the temperature Tv which is allowed for the compressor 14. In this case, the bypass flow rate is insufficient, and thus there is a possibility that the discharge temperature cannot be lowered to the allowable temperature Tv.

[0076] According to the control of this embodiment, as shown by the thick solid line in Fig. 4, the temperature of the discharged refrigerant appropriately follows a change in the magnitude of the effect of the gas-liquid heat exchange according to a change in ΔGr, and therefore, the temperature of the discharged refrigerant is stabilized to the target temperature Tv at an early stage. Since the refrigerant caused to bypass is caused to flow into the upstream of the decompression unit 151 which is distant from the compressor 14, avoidance of oversensitive response of the temperature of the discharged refrigerant also contributes to the stabilization of the discharge temperature.

[0077] Instead of the bypass valve 22 of this embodiment, it is also possible to use a flow rate regulating unit 23 capable of adjusting the flow rate of the refrigerant flowing into the bypass path 21, as shown in Fig. 5.

[0078] The flow rate regulating unit 23 and the control unit 25 on the right side in Fig. 5, which function during the cooling operation, and the flow rate regulating unit 23 and the control unit 25 on the left side in Fig. 5, which function during the heating operation, are switched and used.

[0079] The flow rate regulating unit 23 can cause the

whole amount of the high-pressure refrigerant that passes through the condenser 11 and flows toward the gas-liquid heat exchanger 20 to flow into the bypass path 21, as necessary. If the whole amount of the high-pressure refrigerant flows into the bypass path 21, the high-pressure refrigerant does not flow through the gas-liquid heat exchanger 20 at all, and therefore, heat is not radiated from the high-pressure refrigerant to the low-pressure refrigerant, so that it is possible to suppress the temperature of the compressor 14 into which the low-pressure refrigerant is suctioned.

[0080] Even in a case of using the flow rate regulating unit 23, by calculating the enthalpy difference $\Delta h'$ by the control unit 25 in the same manner as in the above embodiment and giving a command corresponding to the bypass flow rate of ($\Delta h' / \Delta h$) times that at the present time to the flow rate regulating unit 23, it is possible to obtain the same effect as that in the above embodiment.

[0081] In addition to the above, as long as it does not depart from the gist of the present invention, it is possible to appropriately select the configurations mentioned in the above embodiment or to appropriately change them to other configurations.

[0082] The refrigerant circuit system according to the present invention can also be configured as a system for only the cooling operation or a system for only the heating operation. In this case, the four-way valve 13 is not necessary and only one decompression unit 15 is needed. Further, it is sufficient if the condenser temperature sensor is also prepared for only the heat exchanger functioning as a condenser, out of the two heat exchangers 11 and 12.

[0083] The refrigerant circuit system according to the present invention can be applied not only to an air conditioner but also to an appropriate device using a refrigeration cycle, such as a freezer or a water heater.

Reference Signs List

[0084]

1: refrigerant circuit system
11: outdoor heat exchanger (condenser/evaporator)
11A: condenser temperature sensor
12: indoor heat exchanger (evaporator/condenser)
12A: temperature sensor
13: four-way valve
14: compressor
14A: discharge temperature sensor
15: decompression unit
151: decompression unit (decompression unit during cooling)
152: decompression unit (decompression unit during heating)
20: gas-liquid heat exchanger
20A, 20B: temperature sensor
21: bypass path
22: bypass valve (flow rate regulating unit)

23: flow rate regulating unit
25: control unit
201: high-pressure path
202: low-pressure path
Td: temperature
ΔGr: increase/decrease magnification

Claims

1. A refrigerant circuit system which comprises a compressor, a condenser, a decompression unit, and an evaporator, the refrigerant circuit system further comprising:

   a gas-liquid heat exchanger which performs heat exchange between a high-pressure refrigerant which has passed through the condenser and a low-pressure refrigerant which has passed through the evaporator;
   a bypass path for receiving at least a part of the high-pressure refrigerant flowing from the condenser to the gas-liquid heat exchanger and causing the high-pressure refrigerant to bypass to the upstream of the decompression unit;
   a flow rate regulating unit capable of adjusting a flow rate of the high-pressure refrigerant flowing into the bypass path; and
   a control unit which gives a command corresponding to the flow rate to the flow rate regulating unit,
   wherein the control unit determines the ratio of increase/decrease from the present time, of the flow rate of the high-pressure refrigerant which is caused to flow into the bypass path, based on ($\Delta h'/\Delta h$), when discharge enthalpy which is enthalpy corresponding to a detected temperature of a discharged refrigerant which is discharged from the compressor is h1,
   an enthalpy difference which is a difference between enthalpy corresponding to a detected temperature of a refrigerant at an inlet of the gas-liquid heat exchanger and enthalpy corresponding to a detected temperature of a refrigerant at an outlet of the gas-liquid heat exchanger is Δh,
   a target discharge enthalpy corresponding to a target temperature Tv which is allowed for the compressor is hv, and
   a compatible enthalpy difference which is a difference in enthalpy between the inlet and the outlet of the gas-liquid heat exchanger, which is compatible with the target discharge enthalpy hv, based on h1 and Δh, is $\Delta h'$.

2. The refrigerant circuit system according to claim 1, wherein a target temperature range which includes the target temperature Tv and has an upper limit tem-

perature and a lower limit temperature is set, and the control unit acquires the compatible enthalpy difference Δh' in which it is possible to cause the target discharge enthalpy hv to fall within a range from lower limit discharge enthalpy corresponding to the lower limit temperature to upper limit discharge enthalpy corresponding to the upper limit temperature.

3. The refrigerant circuit system according to claim 1 or 2, wherein the refrigerant circuit system is an air conditioner which includes
a switching unit which can switch between a cooling operation and a heating operation by changing a direction of a flow of the refrigerant,
an outdoor heat exchanger which functions as the condenser during the cooling operation and functions as the evaporator during the heating operation,
an indoor heat exchanger which functions as the evaporator during the cooling operation and functions as the condenser during the heating operation,
a decompression unit during cooling, which is located between the gas-liquid heat exchanger and the evaporator and functions as the decompression unit during the cooling operation, and
a decompression unit during heating, which is located between the gas-liquid heat exchanger and the evaporator and functions as the decompression unit during the heating operation.

4. A method for controlling a refrigerant circuit system which includes a compressor, a condenser, a decompression unit, and an evaporator, the refrigerant circuit system further including
a gas-liquid heat exchanger which performs heat exchange between a high-pressure refrigerant which has passed through the condenser and a low-pressure refrigerant which has passed through the evaporator,
a bypass path for receiving at least a part of the high-pressure refrigerant flowing from the condenser to the gas-liquid heat exchanger, and causing the high-pressure refrigerant to bypass to the upstream of the decompression unit, and
a flow rate regulating unit capable of adjusting a flow rate of the high-pressure refrigerant flowing into the bypass path, the method comprising:

a step of detecting a temperature of a discharged refrigerant which is discharged from the compressor;
a step of detecting a temperature of a refrigerant at an inlet of the gas-liquid heat exchanger;
a step of detecting a temperature of a refrigerant at an outlet of the gas-liquid heat exchanger;
a step of acquiring a compatible enthalpy difference Δh' which is a difference in enthalpy between the inlet and the outlet of the gas-liquid heat exchanger, which is compatible with a tar-

get discharge enthalpy hv, based on h1 and Δh, when discharge enthalpy which is enthalpy corresponding to a detected temperature of the discharged refrigerant is h1, an enthalpy difference which is a difference between enthalpy corresponding to a detected temperature of a refrigerant at the inlet and enthalpy corresponding to a detected temperature of a refrigerant at the outlet is Δh, and a target discharge enthalpy corresponding to a target temperature Tv which is allowed for the compressor is hv; and
a step of determining the ratio of increase/decrease from the present time, of the flow rate of the high-pressure refrigerant which is caused to flow into the bypass path, based on (Δh'/Δh).

5. The method for controlling a refrigerant circuit system according to claim 4, wherein a target temperature range which includes the target temperature Tv and has an upper limit temperature and a lower limit temperature is set, and
in the step of acquiring Δh', the compatible enthalpy difference Δh' in which it is possible to cause the target discharge enthalpy hv to fall within a range from lower limit discharge enthalpy corresponding to the lower limit temperature to upper limit discharge enthalpy corresponding to the upper limit temperature is acquired.
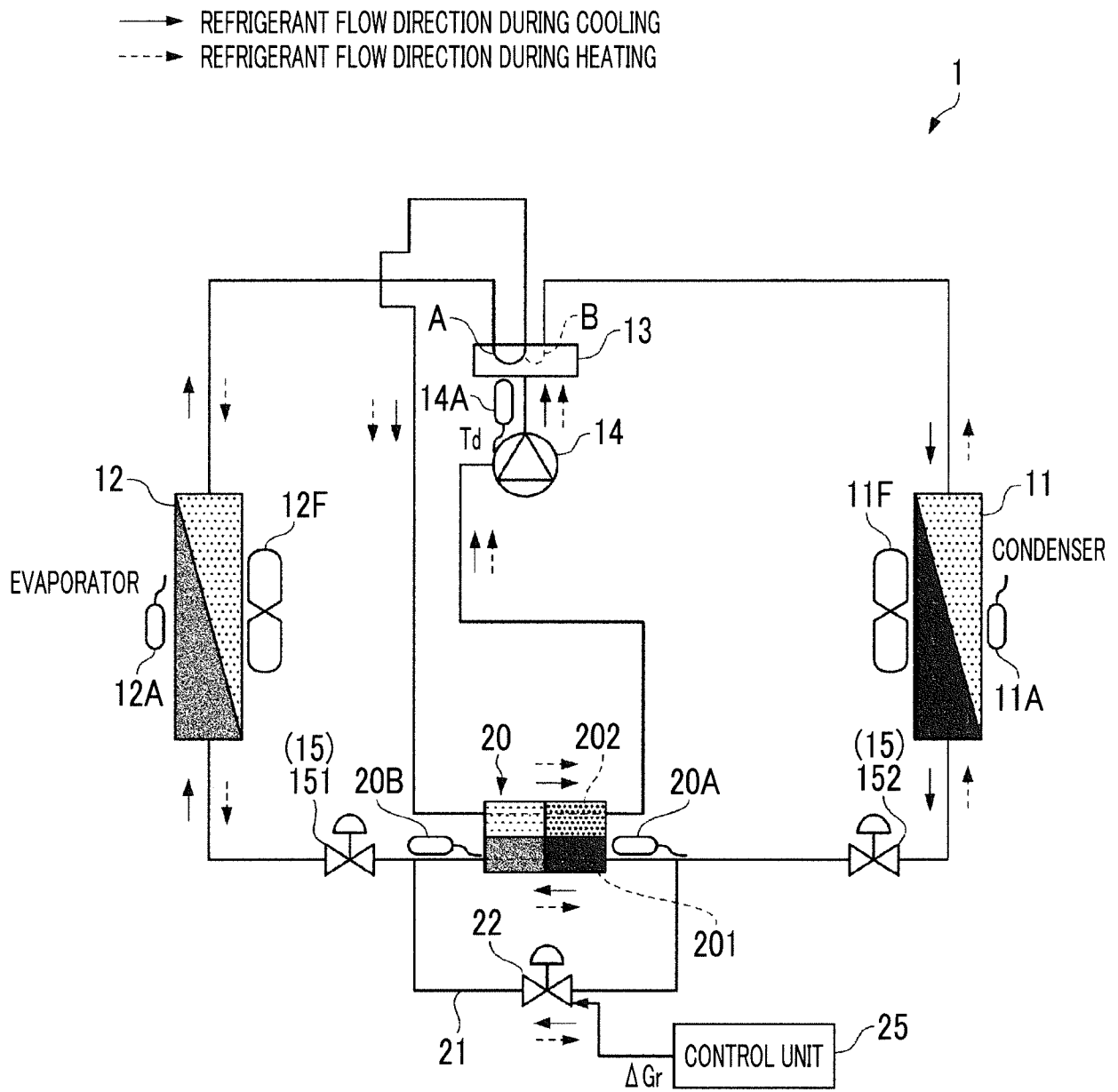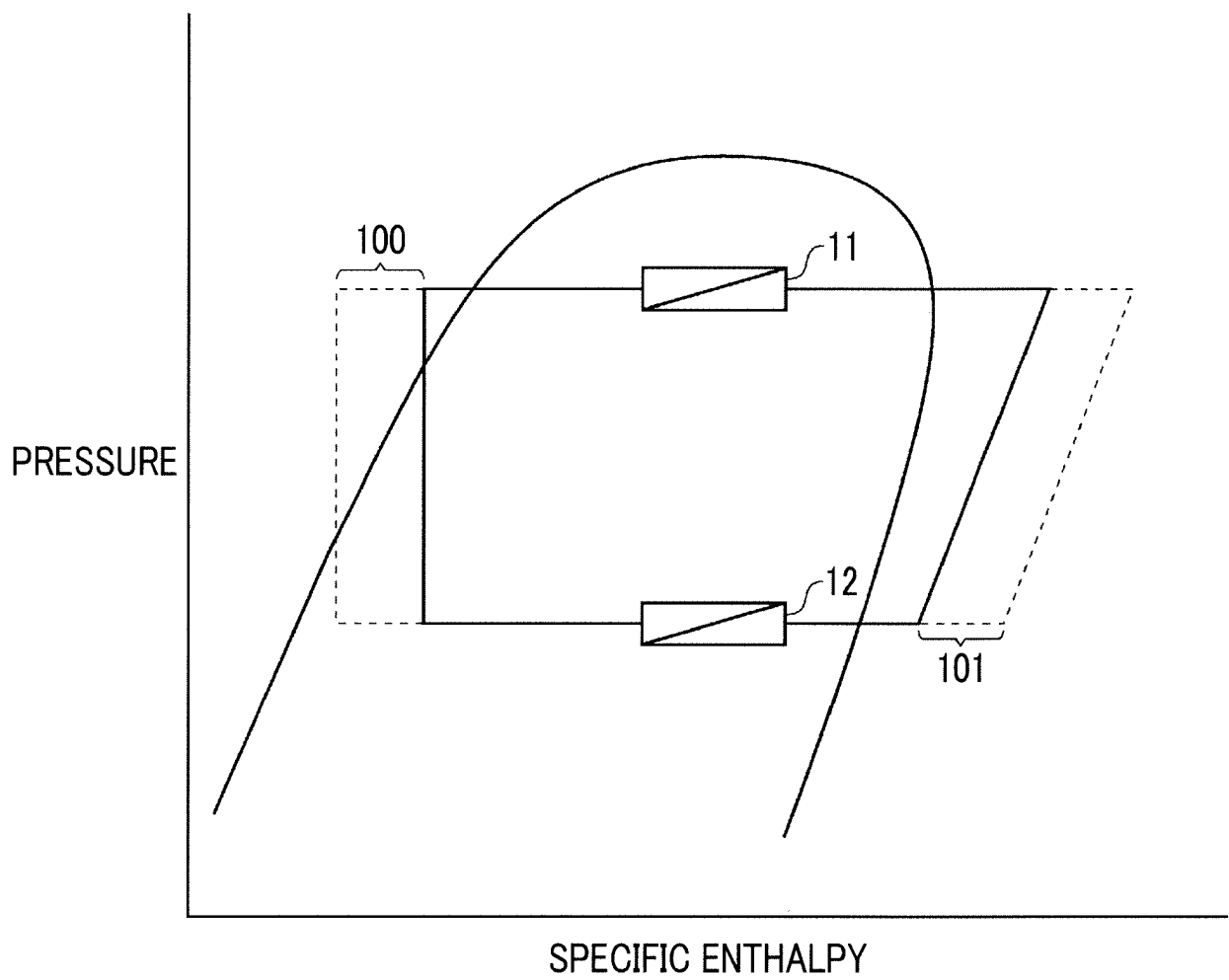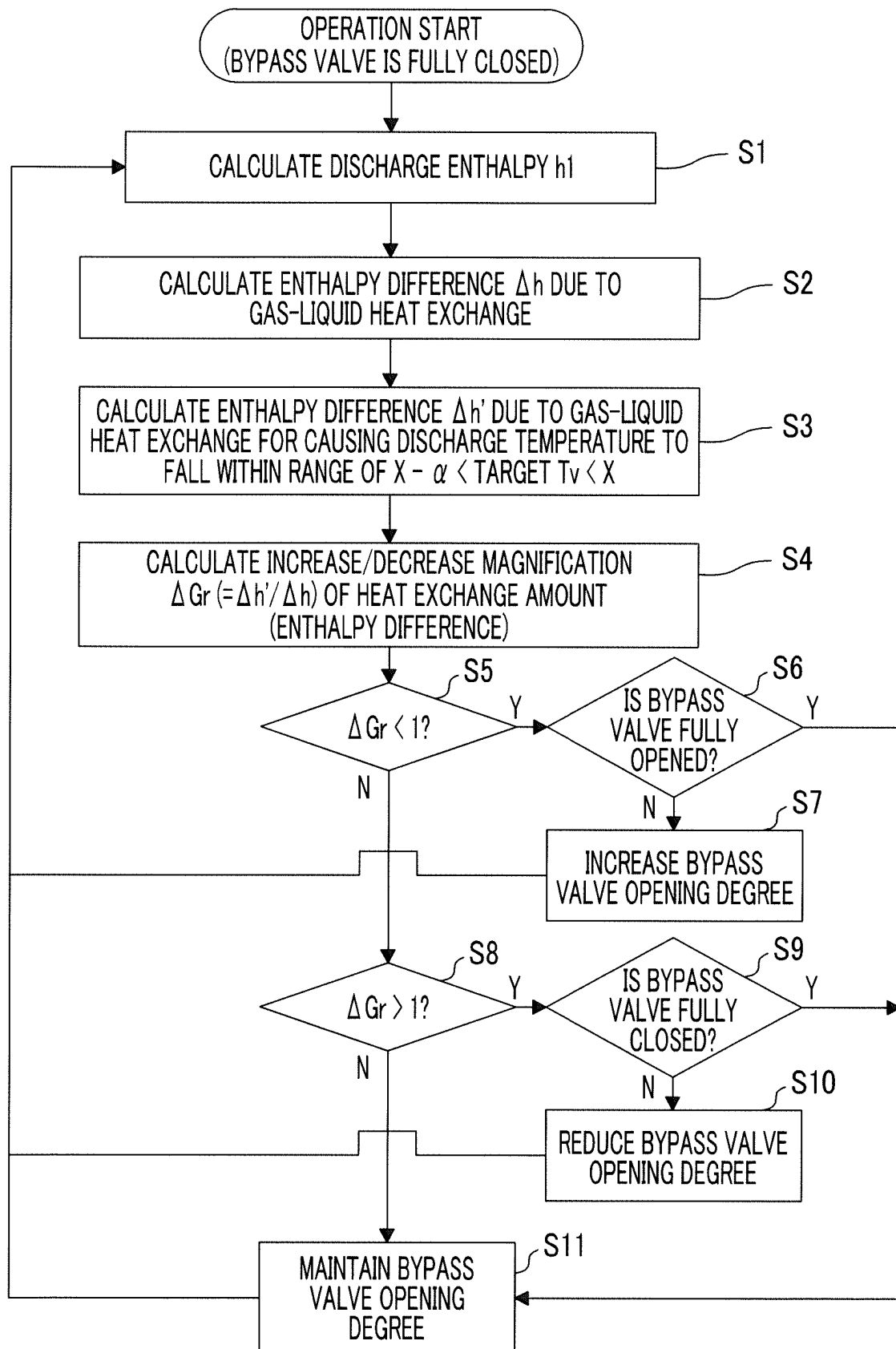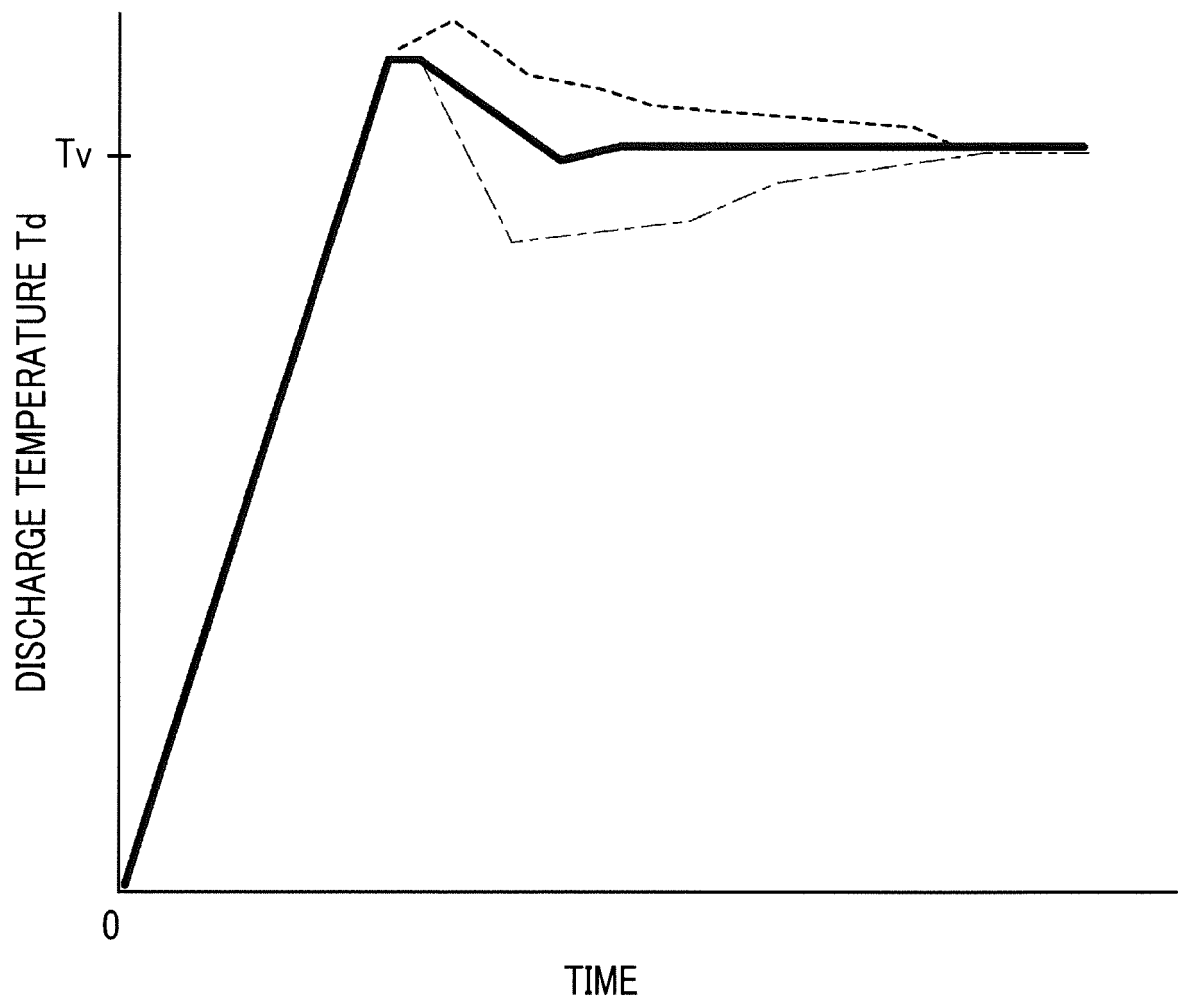
FIG. 1

→ REFRIGERANT FLOW DIRECTION DURING COOLING

--→ REFRIGERANT FLOW DIRECTION DURING HEATING

1

FIG. 2

PRESSURE

SPECIFIC ENTHALPY

FIG. 3

```
        OPERATION START
   (BYPASS VALVE IS FULLY CLOSED)
                 │
                 ▼
   ┌─────────────────────────────────────┐
   │  CALCULATE DISCHARGE ENTHALPY h1     │──── S1
   └─────────────────────────────────────┘
                 │
                 ▼
   ┌─────────────────────────────────────┐
   │  CALCULATE ENTHALPY DIFFERENCE Δh DUE TO │──── S2
   │       GAS-LIQUID HEAT EXCHANGE       │
   └─────────────────────────────────────┘
                 │
                 ▼
   ┌─────────────────────────────────────┐
   │  CALCULATE ENTHALPY DIFFERENCE Δh' DUE TO GAS-LIQUID │──── S3
   │  HEAT EXCHANGE FOR CAUSING DISCHARGE TEMPERATURE TO  │
   │  FALL WITHIN RANGE OF X − α < TARGET Tv < X          │
   └─────────────────────────────────────┘
                 │
                 ▼
   ┌─────────────────────────────────────┐
   │  CALCULATE INCREASE/DECREASE MAGNIFICATION │──── S4
   │  ΔGr (=Δh'/Δh) OF HEAT EXCHANGE AMOUNT      │
   │         (ENTHALPY DIFFERENCE)               │
   └─────────────────────────────────────┘
                 │
                 ▼
```

S5 ΔGr < 1? ──Y──→ S6 IS BYPASS VALVE FULLY OPENED? ──Y──→

S5 ΔGr < 1? ──N──→ (down)

S6 IS BYPASS VALVE FULLY OPENED? ──N──→ S7 INCREASE BYPASS VALVE OPENING DEGREE

S8 ΔGr > 1? ──Y──→ S9 IS BYPASS VALVE FULLY CLOSED? ──Y──→

S8 ΔGr > 1? ──N──→ (down)

S9 IS BYPASS VALVE FULLY CLOSED? ──N──→ S10 REDUCE BYPASS VALVE OPENING DEGREE

S11 MAINTAIN BYPASS VALVE OPENING DEGREE

FIG. 4

FIG. 5

→ REFRIGERANT FLOW DIRECTION DURING COOLING
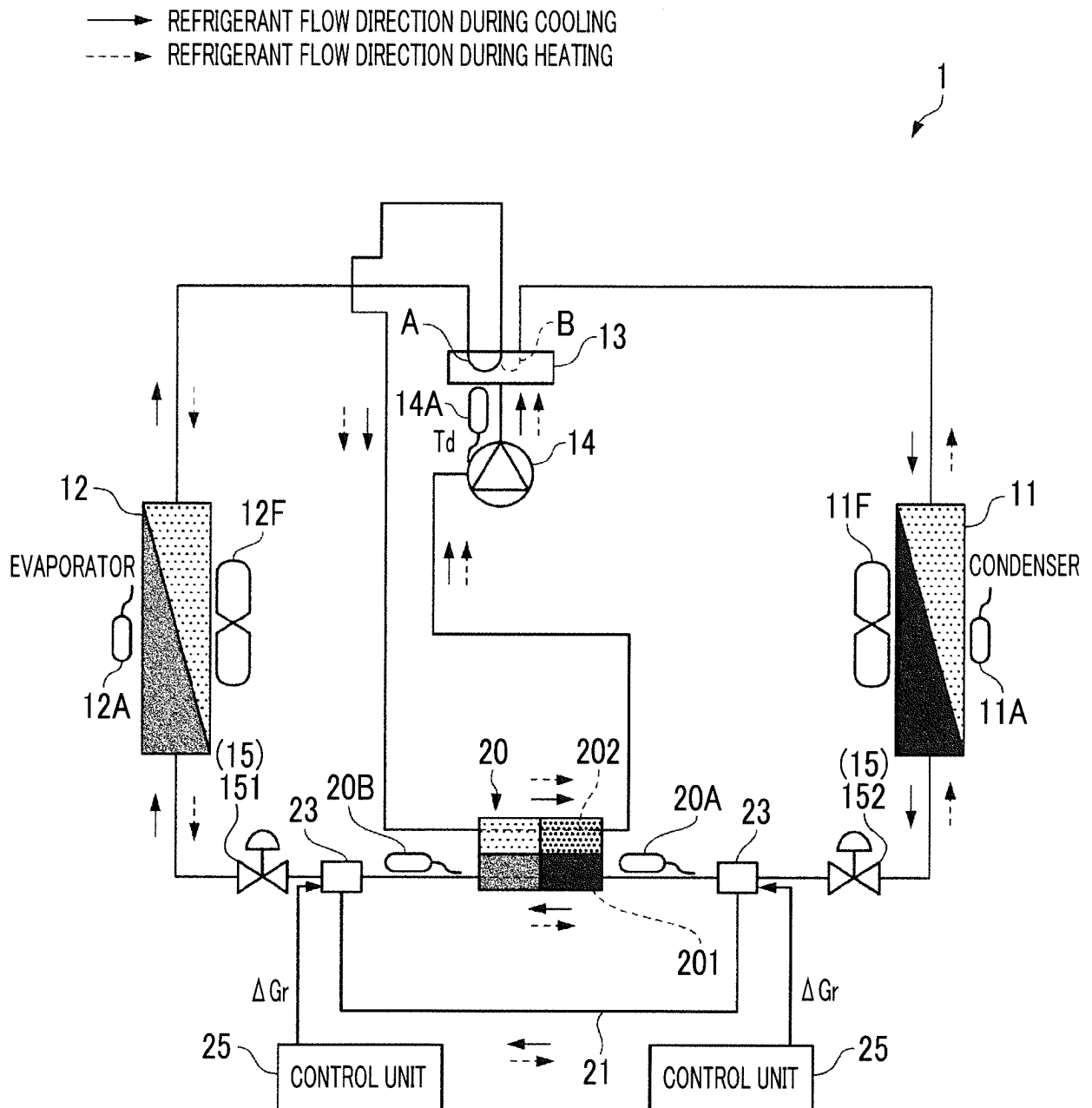---→ REFRIGERANT FLOW DIRECTION DURING HEATING

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2017/040965

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i, F24F11/84(2018.01)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)
F25B1/00-1/10, F25B13/00, F25B40/00, F24F11/84

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Published examined utility model applications of Japan   1922-1996
Published unexamined utility model applications of Japan   1971-2018
Registered utility model specifications of Japan   1996-2018
Published registered utility model applications of Japan   1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI (Derwent Innovation), Japio-GPG/FX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2015-152262 A (TOSHIBA CARRIER CORP.) 24 August 2015, paragraphs [0013]-[0014], fig. 1-3 (Family: none)	1-5
A	JP 2010-2109 A (MITSUBISHI ELECTRIC CORP.) 2010. 01.07, paragraphs [0068]-[0069], fig. 9 (Family: none)	1-5
A	JP 2008-121977 A (MITSUBISHI ELECTRIC CORP.) 29 May 2008, paragraph [0028], fig. 1 (Family: none)	1-5

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
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"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

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

Name and mailing address of the ISA/	Authorized officer
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Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/040965

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 2011-43273 A (PANASONIC CORP.) 03 March 2011, paragraphs [0047]-[0048], fig. 4 (Family: none)	1-5
A	JP 2003-214713 A (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.) 30 July 2003, paragraphs [0017]-[0018], fig. 3-4 (Family: none)	1-5
A	JP 9-105560 A (MITSUBISHI ELECTRIC CORP.) 22 April 1997, paragraphs [0092]-[0097], [0099], fig. 22-24, 26 & KR 10-0248683 B & CN 1143735 A & TW 344022 B	1-5
A	JP 2002-349977 A (DENSO CORP.) 04 December 2002, paragraphs [0030]-[0031], [0039], fig. 1, 4, 10 (Family: none)	1-5
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A	JP 10-68553 A (DAIKIN INDUSTRIES, LTD.) 10 March 1998, paragraphs [0065]-[0068], fig. 7 & WO 1998/009118 A1	1-5

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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