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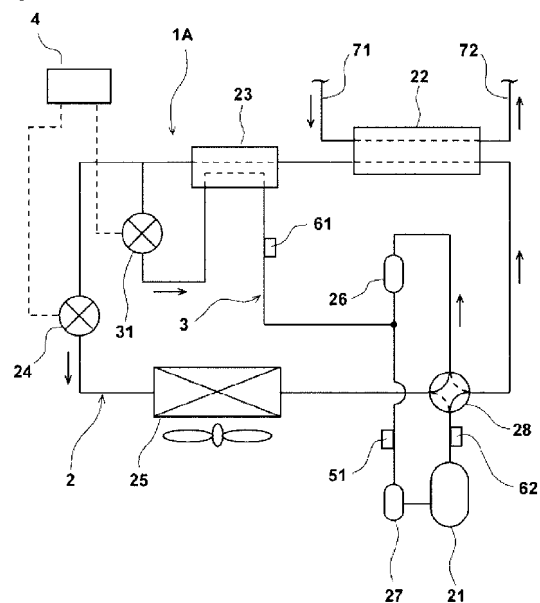
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(54) **Refrigeration cycle apparatus and hydronic heater having the refrigeration cycle apparatus**

(57) A refrigeration cycle apparatus of the present invention includes a first temperature sensor (61), a pressure sensor (51), a second temperature sensor (62), and a control device (4). The control device (4) controls operation of a bypass expansion valve (31) such that a temperature at an outlet of the bypass passage (3) becomes equal to a saturation temperature in a section until a number of rotation of the compressor (21) reaches a predetermined compressor target number of rotations after the compressor (21) is actuated. When the temperature at the outlet of the bypass passage (3) reaches the saturation temperature, the control device (4) increases the number of rotation of the compressor (21) to a number of rotations of a next stage, and the control device (4) controls the refrigeration cycle into an appropriate refrigeration cycle state.

[Fig. 1]



- 1A refrigeration cycle apparatus
- 2 refrigerant circuit
- 3 bypass passage
- 4 control device
- 21 compressor
- 22 radiator
- 23 supercooling heat exchanger
- 24 main expansion valve (main expansion means)
- 25 evaporator
- 31 bypass expansion valve (bypass expansion means)
- 51 pressure sensor (saturation temperature detection means)
- 61 first temperature sensor
- 62 second temperature sensor

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Description

[Technical Field]

[0001] The present invention relates to a refrigeration cycle apparatus which bypasses a portion of a refrigerant flowing out from a radiator, which heat-exchanges between a mainstream refrigerant and a bypassing refrigerant, thereby supercooling the mainstream refrigerant.

[Background Technique]

[0002] In a conventional refrigeration cycle apparatus and a conventional hydronic heater of this kind, a supercooling heat exchanger is provided at a location downstream of a radiator of a refrigerant circuit, an expanded refrigerant is made to flow into the supercooling heat exchanger, thereby supercooling the refrigerant which flows out from the radiator (see patent document 1 for example).

[0003] Fig. 6 shows the conventional refrigeration cycle apparatus described in patent document 1.

As shown in Fig. 6, a refrigeration cycle apparatus 100 includes a refrigerant circuit 110 through which a refrigerant is circulated, and a bypass passage 120. The refrigerant circuit 110 includes a compressor 111, a radiator 112, a supercooling heat exchanger 113, a main expansion valve 114 and an evaporator 115 which are annularly connected to one another through pipes.

The bypass passage 120 provided in the refrigeration cycle apparatus 100 branches off from the refrigerant circuit 110 between the supercooling heat exchanger 113 and the main expansion valve 114, and is connected to the refrigerant circuit 110 between the evaporator 115 and the compressor 111 through the supercooling heat exchanger 113. The bypass passage 120 is provided with a bypass expansion valve 121 at a location upstream of the supercooling heat exchanger 113.

[0004] The refrigeration cycle apparatus 100 includes a temperature sensor 141 which detects a temperature (compressor discharge pipe temperature) T_d of a refrigerant discharged from the compressor 111, a temperature sensor 142 which detects a temperature (evaporator inlet temperature) T_e of a refrigerant flowing into the evaporator 115, a temperature sensor 143 which detects a temperature (bypass-side inlet temperature) T_{bi} of a refrigerant flowing into the supercooling heat exchanger 113 in the bypass passage 120, and a temperature sensor 144 which detects a temperature (bypass-side outlet temperature) T_{bo} of a refrigerant flowing out from the supercooling heat exchanger 113 in the bypass passage 120.

A target temperature T_d (target) of a discharge pipe of the compressor is set by an evaporator inlet temperature T_e which is detected by the temperature sensor 142. A main expansion valve control unit controls the main expansion valve 114 such that a discharge pipe temperature T_d detected by the temperature sensor 141 becomes

equal to the target temperature T_d (target). Further, a bypass expansion valve control unit controls the bypass expansion valve 121 such that a difference ($T_{bo}-T_{bi}$) between the bypass-side outlet temperature T_{bo} and the bypass-side inlet temperature T_{bi} in the supercooling heat exchanger 113 becomes equal to a predetermined target value.

[Prior Art Document]

[Patent Document]

[0005]

[Patent Document 1] Japanese Patent Application Laid-open No.H10-68553

[Summary of the Invention]

[Problem to be Solved by the Invention]

[0006] According to the configuration of the conventional apparatus, however, since the bypass expansion valve 121 provided in the bypass passage 120 operates to control a temperature difference between an inlet and an outlet of the bypass passage 120, that is, degree of superheat at the outlet of the bypass passage 120, control cannot be performed such that the refrigerant state at the outlet of the bypass passage 120 is brought into a moist state.

Hence, at the time of heating operation when an outside air temperature is extremely low as low as -20°C , if the bypass expansion valve 121 is opened, a refrigerant flowing through the bypass passage 120 is extremely heated by the supercooling heat exchanger 113 until a flow rate of a refrigerant on the bypassing side is increased to an appropriate amount. Therefore, there is a possibility that the sucked refrigerant state of the compressor 111 is brought into an overheated state, and the discharge temperature of the compressor 111 abnormally rises.

Therefore, when the outside air temperature is extremely low, the bypass passage 120 can not be used, and the operation efficiency enhancing effect exerted when the bypass passage 120 is used can not be obtained. Therefore, the conventional apparatus has a problem that efficiency is poor and sufficient heating ability can not be secured.

[0007] The present invention has been accomplished to solve the conventional apparatus, and it is an object of the invention to provide a refrigeration cycle apparatus and a hydronic heater having the refrigeration cycle apparatus capable of securing efficiency and sufficient heating ability even when an outside air temperature is low by controlling the refrigeration cycle apparatus into an appropriate refrigeration cycle state.

[Means for Solving the Problem]

[0008] To solve the problem of the conventional apparatus, the present invention provides a refrigeration cycle apparatus comprising a refrigerant circuit in which a compressor, a radiator, a supercooling heat exchanger, main expansion means and an evaporator are annularly connected to one another, a bypass passage which branches off from the refrigerant circuit between the radiator and the main expansion means, and which is connected to the compressor through the supercooling heat exchanger or connected to the refrigerant circuit between the evaporator and the compressor, bypass expansion means provided in the bypass passage at a location upstream of the supercooling heat exchanger, a first temperature sensor which detects a temperature of a refrigerant flowing out from the supercooling heat exchanger, saturation temperature detecting means which detects a saturation temperature of a refrigerant sucked into the compressor, and a control device, wherein the control device controls operation of the bypass expansion means such that a temperature detected by the first temperature sensor becomes equal to the saturation temperature detected by the saturation temperature detecting means until a number of rotations of the compressor reaches a predetermined target number of rotations of the compressor after the compressor is actuated, and the control device increases the number of rotation of the compressor when the temperature detected by the first temperature sensor reaches the saturation temperature. According to the configuration of this refrigeration cycle apparatus, in a low number of rotation state in which a compression ratio of the compressor is small, control is performed such that a state of the refrigerant at the outlet of the bypass passage is brought from an overheated state to a saturated state and then, the number of rotations of the compressor is increased in stages while bypassing a gas/liquid two-phase refrigerant. Therefore, it is possible to restrain the discharge temperature of the compressor from rising abnormally.

[Effect of the Invention]

[0009] According to the present invention, it is possible to provide a refrigeration cycle apparatus and a hydronic heater having the refrigeration cycle apparatus capable of securing efficiency and sufficient heating ability even when an outside air temperature is low by controlling the refrigeration cycle apparatus into an appropriate refrigeration cycle state.

[Brief Description of the Drawings]

[0010]

Fig. 1 is a schematic block diagram of a refrigeration cycle apparatus according to an embodiment of the present invention;

Fig. 2 is a Mollier chart of different number of rotations of a compressor of the refrigeration cycle apparatus;

Fig. 3 is a diagram showing change with the passage of time of a refrigeration cycle at the time of bypassing operation in the refrigeration cycle apparatus;

Fig. 4 is a block diagram showing a control device of the refrigeration cycle apparatus in terms of function realizing means;

Fig. 5 is a flowchart of operation control of the refrigeration cycle apparatus; and

Fig. 6 is a schematic block diagram of a conventional refrigeration cycle apparatus.

Fig. 7 is a diagram showing change with the passage of time of a conventional refrigeration cycle at the time of bypassing operation in a conventional refrigeration cycle apparatus;

Fig. 8 is a Mollier chart of the conventional refrigeration cycle apparatus.

[Explanation of Symbols]

[0011]

- | | |
|----|--|
| 1A | refrigeration cycle apparatus |
| 2 | refrigerant circuit |
| 3 | bypass passage |
| 4 | control device |
| 21 | compressor |
| 22 | radiator |
| 23 | supercooling heat exchanger |
| 24 | main expansion valve (main expansion means) |
| 25 | evaporator |
| 31 | bypass expansion valve (bypass expansion means) |
| 51 | pressure sensor (saturation temperature detection means) |
| 61 | first temperature sensor |
| 62 | second temperature sensor |

[Mode for Carrying Out the Invention]

[0012] A first aspect of the invention provides a refrigeration cycle apparatus comprising a refrigerant circuit in which a compressor, a radiator, a supercooling heat exchanger, main expansion means and an evaporator are annularly connected to one another, a bypass passage which branches off from the refrigerant circuit between the radiator and the main expansion means, and which is connected to the compressor through the supercooling heat exchanger or connected to the refrigerant circuit between the evaporator and the compressor, bypass expansion means provided in the bypass passage at a location upstream of the supercooling heat exchanger, a first temperature sensor which detects a temperature of a refrigerant flowing out from the supercooling heat exchanger, saturation temperature detecting means which detects a saturation temperature of a refrigerant

sucked into the compressor, and a control device, wherein the control device controls operation of the bypass expansion means such that a temperature detected by the first temperature sensor becomes equal to the saturation temperature detected by the saturation temperature detecting means until a number of rotations of the compressor reaches a predetermined target number of rotations of the compressor after the compressor is actuated, and the control device increases the number of rotation of the compressor when the temperature detected by the first temperature sensor reaches the saturation temperature.

According to the configuration of the refrigeration cycle apparatus of the first aspect, in a low number of rotation state in which a compression ratio of the compressor is small, control is performed such that a state of the refrigerant at the outlet of the bypass passage is brought from an overheated state to a saturated state and then, the number of rotations of the compressor is increased in stages while bypassing a gas/liquid two-phase refrigerant. Therefore, it is possible to restrain the discharge temperature of the compressor from rising abnormally.

Therefore, even when the outside air temperature is extremely low as low as -20°C , it is possible to utilize an enthalpy difference increasing effect in the evaporator exerted by heat exchange between a mainstream refrigerant in the supercooling heat exchanger and a bypass flowing refrigerant by bypassing, and to utilize a pressure loss-reducing effect of a low pressure side refrigerant path by bypassing of a refrigerant. Therefore, in this refrigeration cycle apparatus, higher operation efficiency and sufficient heating ability can be obtained.

[Mode for Carrying Out the Invention]

[0013] According to a second aspect of the invention, in the first aspect, the refrigeration cycle apparatus further includes a second temperature sensor which detects a temperature of a refrigerant discharged from the compressor, the control device operates an opening degree of the main expansion means into a closing direction when a temperature detected by the second temperature sensor becomes equal to or higher than a predetermined temperature.

According to the configuration of the refrigeration cycle apparatus of the second aspect, when a refrigerant flows to the bypass passage, it is determined that the discharge temperature rises, and the main expansion means is closed by a predetermined amount. Hence, the flow rate of the refrigerant flowing toward the bypass passage is swiftly increased, and it is possible to control an excessive overheated state of a refrigerant at the outlet of the bypass passage into a saturated state within shorter time. Therefore, it is possible to reduce overshoot of the discharge temperature of the compressor connected to the refrigerant circuit with respect to a target, and in addition to the effect of the first aspect, control performance of the refrigeration cycle and reliability of the compressor

are further enhanced.

[0014] A third aspect of the invention provides a hydronic heater having the refrigeration cycle apparatus according the first or second aspect. According to the third aspect, the present invention can be applied not only to a case where the radiator is a heat exchanger between refrigerant and air, but also to a case where the radiator is a heat exchanger between refrigerant and water. In addition, the same effect as that of the first or second invention can be obtained.

[0015] An embodiment of the present invention will be explained with reference to the drawings. The invention is not limited to the embodiment.

[0016] Fig. 1 is a schematic block diagram of a hydronic heater having a refrigeration cycle apparatus according to an embodiment of the invention.

In Fig. 1, the refrigeration cycle apparatus 1A includes a refrigerant circuit 2 through which a refrigerant is circulated, a bypass passage 3 connected to the refrigerant circuit 2, and a control device 4 which controls the refrigerant circuit 2 and the bypass passage 3.

As a refrigerant used in the invention, it is possible to use a zeotropic refrigerant mixture such as R407C, a pseudo-azeotropic refrigerant mixture such as R410A or a single refrigerant.

The refrigerant circuit 2 provided in the refrigeration cycle apparatus 1A includes a compressor 21, a radiator 22, a supercooling heat exchanger 23, a main expansion valve (main expansion means) 24 and an evaporator 25, and these constituent members are annularly connected to one another through pipes.

In this embodiment, a sub-accumulator 26 and a main accumulator 27 which separate gas and liquid from each other are provided between the evaporator 25 and the compressor 21 which are annularly connected to each other through a pipe.

The refrigerant circuit 2 is provided with a four-way valve 28 which switches between a normal operation and a defrosting operation of the refrigeration cycle apparatus.

[0017] In the embodiment, the refrigeration cycle apparatus 1A configures heating means of a hydronic heater which utilizes hot water produced by the heating means for heating a room, and the radiator 22 provided in the refrigerant circuit 2 is a heat exchanger which exchanges heat between a refrigerant and water to heat the water.

More specifically, a supply pipe 71 and a collecting pipe 72 are connected to the radiator 22, water is supplied to the radiator 22 through the supply pipe 71, and water (hot water) heated by the radiator 22 is collected through the collecting pipe 72.

The hot water collected through the collecting pipe 72 connected to the radiator 22 is sent directly to a heater, or sent to the heater through a hot water tank, thereby heating a room.

[0018] In the embodiment, the bypass passage 3 connected to the refrigerant circuit 2 branches off from the refrigerant circuit 2 between the supercooling heat ex-

changer 23 and the main expansion valve (main expansion means) 24, and is connected to the refrigerant circuit 2 between the sub-accumulator 26 and the main accumulator 27 between the evaporator 25 and the compressor 21 through the supercooling heat exchanger 23.

Alternatively, the bypass passage 3 may branch off from the refrigerant circuit 2 between the supercooling heat exchanger 23 and the main expansion valve (main expansion means) 24, and connected to a compression chamber suction inlet in the compressor 21 through the supercooling heat exchanger 23.

The bypass passage 3 is provided with a bypass expansion valve (bypass expansion means) 31 at a location upstream of the supercooling heat exchanger 23.

[0019] In a normal operation (hydronic heating operation) of the refrigeration cycle apparatus, a refrigerant discharged from the compressor 21 is sent to the radiator 22 through the four-way valve 28. In a defrosting operation, a refrigerant discharged from the compressor 21 is sent to the evaporator 25 through the four-way valve 28. In Fig. 1, arrows show a flowing direction of a refrigerant at the time of the normal operation.

[0020] A state variation of a refrigerant in the normal operation (hydronic heating operation) of the refrigeration cycle apparatus will be explained below.

A high-pressure refrigerant discharged from the compressor 21 configuring the refrigerant circuit 2 flows into the radiator 22, and radiates heat to water which passes through the radiator 22. The high-pressure refrigerant which flows out from the radiator 22 flows into the supercooling heat exchanger 23, and the refrigerant is supercooled by a low-pressure refrigerant which is decompressed by the bypass expansion valve 31. The high-pressure refrigerant which flows out from the supercooling heat exchanger 23 is distributed to the main expansion valve 24 and the bypass expansion valve 31.

The high-pressure refrigerant distributed to the main expansion valve 24 (main expansion means) is decompressed by the main expansion valve 24 and expanded and then, the refrigerant flows into the evaporator 25. The low-pressure refrigerant which flows into the evaporator 25 absorbs heat from air in the evaporator 25.

The high-pressure refrigerant distributed to the bypass expansion valve (bypass expansion means) 31 is decompressed by the bypass expansion valve 31 and expanded and then, the refrigerant flows into the supercooling heat exchanger 23. The low-pressure refrigerant which flows into the supercooling heat exchanger 23 is heated by the high-pressure refrigerant which flows out from the radiator 22. Thereafter, the low-pressure refrigerant which flows out from the supercooling heat exchanger 23 merges with the low-pressure refrigerant which flows out from the evaporator 25, and these refrigerants are again sucked into the compressor 21.

[0021] The configuration of the refrigeration cycle apparatus 1A of the embodiment is for avoiding a case where pressure of a refrigerant sucked into the compressor 21 is reduced when an outside air temperature is low,

a refrigerant circulation amount is reduced and according to this, heating ability of the radiator 22 is prevented from being deteriorated.

To prevent the radiating ability of the radiator 22 from being deteriorated, an enthalpy difference in the evaporator 25 is increased by supercooling. At the same time, a refrigerant is made to flow to the bypass passage 3 through the bypass passage 3, thereby suppressing an amount of a gas-phase refrigerant which has a small heat-absorbing effect and which flows through a low-pressure side portion of the refrigerant circuit 2. According to this configuration, it is important that a pressure loss in the low-pressure side portion of the refrigerant circuit 2 is reduced.

[0022] If a pressure loss in the low-pressure side portion of the refrigerant circuit 2 provided in the refrigeration cycle apparatus 1A is reduced, pressure of a refrigerant sucked into the compressor 21 rises and specific volume is reduced correspondingly. Therefore, the refrigerant circulation amount is increased.

If the enthalpy difference in the evaporator 25 configuring the refrigerant circuit 2 is increased, it is possible to secure an endotherm amount in the evaporator 25 by making the refrigerant flow through the bypass passage 3 even if a mass flow rate of a refrigerant which passes through the evaporator 25 is reduced.

That is, if a supercooling degree of a refrigerant and a mass flow rate of a refrigerant of the bypass passage 3 are maximized, it is possible to obtain the maximum heating ability enhancing effect of the radiator 22 and the maximum coefficient of performance enhancing effect of the refrigeration cycle apparatus 1A.

[0023] However, if an effect for flowing a refrigerant to the bypass passage 3 is utilized when an outside air temperature is extremely low as low as -20°C or when a utilizing-side load is small, there is a problem that a discharging temperature of the compressor rises abnormally before a flow rate of the refrigerant flowing to the bypass passage 3 becomes an appropriate flow rate.

This problem occurs because if the bypass expansion valve is opened after the heating operation is started and the bypassing operation started, a refrigerant does not flow to the bypass passage 3 abruptly immediately after the bypassing operation is started, and the mass flow rate of the refrigerant is gradually increased from a point a to a point a' in Fig. 7.

Therefore, when the mass flow rate of the refrigerant flowing to the bypass passage 3 connected to the refrigerant circuit 2 is small, a refrigerant state at the outlet of the bypass passage 3 becomes an excessive overheated state as shown by a point a in Fig. 8 by the heat exchange in the supercooling heat exchanger 23, and the discharge temperature abnormally rises as shown by a point b in Fig. 8. To utilize the performance enhancing effect caused by flowing a refrigerant to the bypass passage 3 under wide conditions, and to enhance the efficiencies of these devices, it is important to restrain the discharge temperature from rising abnormally.

[0024] Although it will be described later in detail in the embodiment, as will be described in detail later, in a section until the number of rotations of the compressor reaches the predetermined target number of rotations of the compressor after the compressor 21 is actuated, the control device 4 which controls the refrigerant circuit 2 and the bypass passage 3 operates the bypass expansion valve 31 such that the outlet refrigerant of the bypass passage 3 is brought into the saturated state. At the same time, when the outlet refrigerant of the bypass passage 3 is brought into the saturated state, control is performed such that the number of rotations is increased to a next stage number of rotations of the compressor.

When the discharge temperature of the compressor 21 becomes equal to or higher than a predetermined temperature, the control device 4 controls such that the main expansion valve 24 operates in a closing direction by a predetermined value.

[0025] According to this configuration, the number of rotations of the compressor when a refrigerant starts flowing to the bypass passage 3 is reduced. Hence, as compared with a case where 80 Hz operation is carried out, a compression ratio is small when 40 Hz operation is carried out as shown by a point c in Fig. 2, and the discharge temperature becomes low. Therefore, the discharge temperature rise can be reduced.

As shown in Fig. 3, after the refrigerant starts flowing to the bypass passage 3, the opening degree of the main expansion valve 24 is closed earlier as compared with a normal control. Hence, the mass flow rate of the refrigerant to the bypass passage 3 is increased early, and the refrigerant state at the outlet of the bypass passage 3 is controlled into the saturated state within short time as shown by a point a" in Fig. 6. Therefore, abnormal rise of the discharge temperature of the compressor 21 is suppressed.

[0026] Control of the operation of the refrigeration cycle apparatus of the invention will be explained below.

The refrigerant circuit 2 configuring the refrigeration cycle apparatus includes a pressure sensor 51 which detects a pressure (suction pressure) P_s of a refrigerant sucked into the compressor 21, and a second pressure sensor 62 which detects a temperature (discharge temperature) T_d of a refrigerant discharged from the compressor 21. The bypass passage 3 connected to the refrigerant circuit 2 includes a first temperature sensor 61 which detects a temperature (bypass passage outlet temperature) T_{bo} of a refrigerant flowing out from the supercooling heat exchanger 23.

[0027] The control device 4 operates the number of rotations of the compressor 21, carries out the switching operation of the four-way valve 28, and adjusts opening degrees of the main expansion valve 24 and the bypass expansion valve 31 based on detection values detected by the various sensors 51, 61 and 62.

In this embodiment, when the refrigeration cycle apparatus is normally operated, the control device 4 operates the bypass expansion valve 31 such that the bypass pas-

sage outlet temperature T_{bo} becomes equal to a suction saturation temperature T_s which is calculated based on the suction pressure P_s .

When the operation of the refrigeration cycle apparatus is started, the control device 4 operates the compressor 21 at the actuation number of rotations H_{zi} which is lower than the preset predetermined compressor target number of rotations H_{zt} , and when the bypass passage outlet temperature T_{bo} becomes equal to the suction saturation temperature T_s , the control device 4 rises the number of rotations of the compressor 21 by a predetermined amount and operates the compressor 21. This operation is repeated until the number of rotations of the compressor reaches the compressor target number of rotations H_{zt} .

When the discharge temperature T_d which is a temperature of a refrigerant discharged from the compressor 21 becomes higher than the preset predetermined target discharge temperature, the control device 4 operates the main expansion valve 24 into the closing direction by a predetermined value.

[0028] Fig. 4 is a block diagram showing a control device in terms of function realizing means.

The control device 4 includes discharge temperature comparing means 40 and main valve operation determining means 41 for operating the main expansion valve 24.

For operating the bypass expansion valve 31, the control device 4 includes suction saturation temperature calculating means 42, saturation temperature comparing means 43, and bypass valve operation determining means 44.

The control device 4 includes compressor number of rotation changing means 45 which changes the number of rotations of the compressor 21, number of rotation comparing means 46 which determines whether the number of rotations of the compressor 21 is equal to the predetermined compressor target number of rotations H_{zt} , and actuation time control completion determining means 47 which determines that the control at the time of actuation is completed when the number of rotations of the compressor 21 is equal to the predetermined compressor target number of rotations H_{zt} .

[0029] The suction saturation temperature calculating means 42 calculates a suction saturation temperature T_s under pressure of a refrigerant sucked into the compressor 21 from a suction pressure P_s detected by the pressure sensor 51.

The saturation temperature comparing means 43 compared, with each other, the suction saturation temperature T_s calculated by the suction saturation temperature calculating means 42 and the bypass passage outlet temperature T_{bo} detected by the first temperature sensor 61.

[0030] When the saturation temperature comparing means 43 determines the bypass passage outlet temperature T_{bo} is not equal to the suction saturation temperature T_s , the bypass valve operation determining means 44 determines the opening degree of the bypass

expansion valve 31 such that the bypass passage outlet temperature T_{bo} becomes equal to the suction saturation temperature T_s , and the bypass valve operation determining means 44 outputs an operation amount determined for the bypass expansion valve 31.

When the bypass passage outlet temperature T_{bo} is equal to the suction saturation temperature T_s , the compressor number of rotation changing means 45 rises the number of rotations of the compressor 21 to the predetermined number of rotations.

The number of rotation comparing means 46 determines whether the current number of rotations of the compressor 21 is equal to the predetermined compressor target number of rotations H_{zt} .

When the current number of rotations of the compressor 21 is equal to the compressor target number of rotations H_{zt} , the actuation time control completion determining means 47 determines that the control at the time of actuation is completed, and control is shifted to appropriate control.

[0031] In the number of rotation comparing means 46, if the current number of rotations of the compressor 21 is not equal to the predetermined compressor target number of rotations H_{zt} , the discharge temperature comparing means 40 compares with the discharge temperature T_d detected by the second temperature sensor 62 and the preset predetermined temperature T_{dt} with each other. The target discharge temperature T_{dt} is previously stored.

Main operation determining means 41 determines an opening degree of the main expansion valve 24 such that the discharge temperature T_d becomes equal to the predetermined temperature T_{dt} based on a result of comparison carried out by the discharge temperature comparing means 40, and outputs a determined operation amount to the main expansion valve 24.

[0032] Next, control of the control device 4 at the time of the normal operation of the refrigeration cycle apparatus will be explained in detail with reference to the flowchart shown in Fig. 5.

[0033] First, the control device 4 operates the compressor 21 with the predetermined actuation number of rotations H_{zi} (step 1). Next, the opening degree of the bypass expansion valve 31 is set to a predetermined initial opening degree (step 2).

Next, the control device 4 detects the suction pressure P_s by the pressure sensor 51 and detects the bypass passage outlet temperature T_{bo} by the first temperature sensor 61 (step 3).

Then, the control device 4 calculates the suction saturation temperature T_s under a pressure of a refrigerant sucked into the compressor 21 from the suction pressure P_s detected by the pressure sensor 51 (step 4). The suction saturation temperature T_s is calculated using a refrigerant-properties equation.

Thereafter, the control device 4 compares the bypass passage outlet temperature T_{bo} and the suction saturation temperature T_s with each other, and determines

whether T_{bo} and T_s are equal to each other (step 5).

[0034] If the bypass passage outlet temperature T_{bo} is not equal to the suction saturation temperature T_s (NO in step 5), the control device 4 determines that a bypass passage outlet refrigerant is in a superheated state. According to this determination, the control device 4 adjusts the opening degree of the bypass expansion valve 31 such that the bypass passage outlet temperature T_{bo} becomes equal to the suction saturation temperature T_s (step 6), and the procedure is advanced to step 9.

If the bypass passage outlet temperature T_{bo} is substantially equal to the suction saturation temperature T_s (YES in step 5), the control device 4 determines that the bypass passage outlet refrigerant is in the saturated state. According to this determination, the number of rotations of the compressor is increased by the predetermined number of rotations and the compressor is operated (step 7), and it is determined whether the current number of rotations is equal to the predetermined compressor target number of rotations H_{zt} (step 8).

[0035] If the current number of rotations of the compressor is equal to the compressor target number of rotations H_{zt} (YES in step 8), it is determined that the control at the time of actuation is completed, and control is shifted to an appropriate control.

If the current number of rotations of the compressor is not equal to the compressor target number of rotations H_{zt} (NO in step 8), the second temperature sensor 62 detects the discharge temperature T_d (step 9). According to this, it is determined whether the discharge temperature T_d is higher than the preset predetermined temperature T_{dt} (step 10).

If the discharge temperature T_d is equal to or lower than the predetermined temperature T_{dt} (NO in step 10), it is determined that a flow rate of a refrigerant of the bypass passage 3 is secured, and the procedure is returned to step 3 as it is.

When the discharge temperature T_d is higher than the predetermined temperature T_{dt} (YES in step 10), it is determined that it is necessary to increase the flow rate of the refrigerant on the side of the bypass passage 3, and the main expansion valve 24 is operated into a predetermined closing direction.

[0036] As described above, according to this embodiment, the refrigerant circuit 2 includes the pressure sensor 51 which detects a pressure of a refrigerant sucked into the compressor 21, the second temperature sensor 62 which detects a temperature of a refrigerant discharged from the compressor 21, a first temperature sensor 61 which detects a temperature of a refrigerant flowing out from the supercooling heat exchanger 23 in the bypass passage 3, and the control device 4.

The control device 4 operates the bypass expansion valve 31 such that a refrigerant at the outlet of the bypass passage 3 is brought into the saturated state in a section until the number of rotations of the compressor 21 reaches the predetermined compressor target number of rotations after the compressor 21 is actuated. When the

refrigerant at the outlet of the bypass passage 3 is brought into the saturated state, the control device 4 controls such that the number of rotations is increased to the next stage number of rotations of the compressor.

[0037] According to the configuration of the embodiment of the refrigeration cycle apparatus, in the state of low number of rotations in which the compression ratio of the compressor is small, after the state of a refrigerant at the outlet of the bypass passage is controlled from the overheated state to the saturated state, the number of rotations of the compressor is increased in stages while bypassing the the gas/liquid two-phase refrigerant. According to this configuration, it is possible to restrain the discharge temperature of the compressor from abnormally rising.

Therefore, even if the outside air temperature is extremely low as low as -20°C , it is possible to utilize the enthalpy difference increasing effect in the evaporator obtained by heat exchange between the mainstream refrigerant and the bypassing refrigerant in the supercooling heat exchanger by bypassing, and the pressure loss reducing effect in the low pressure side refrigerant path caused by bypassing of the refrigerant. Accordingly, in the refrigeration cycle apparatus of the embodiment, it is possible to obtain higher operation efficiency and sufficient heating ability.

[0038] When the bypassing operation is started, the control device 4 determines that the discharge temperature rises and close the main expansion valve 24 by the predetermined amount. Therefore, the flow rate of the refrigerant toward the bypass passage 3 is swiftly increased. Therefore, the excessive overheated state of the refrigerant at the outlet of the bypass passage 3 can be controlled into the saturated state within shorter time. Therefore, it is possible to reduce overshoot of the discharge temperature of the compressor 21 connected to the refrigerant circuit 2 with respect to the target, and control performance of the refrigeration cycle and reliability of the compressor are further enhanced.

[0039] Although the pressure sensor 51 which detects the sucked refrigerant pressure of the compressor 21 is provided between the main accumulator 27 and a position to which the bypass passage 3 in the refrigerant circuit 2 is connected in Fig. 1, the pressure sensor 51 may be provided at any position of the refrigerant circuit 2 only if the pressure sensor 51 is provided between the evaporator 25 and the compressor 21.

Alternatively, the pressure sensor 51 may be provided at the bypass passage 3 at a location downstream of the supercooling heat exchanger 23.

[0040] Although the pressure sensor 51 calculates the suction saturation temperature T_s in the embodiment, temperatures in the refrigerant circuit 2 and the bypass passage 3 at portions through which low pressure two-phase refrigerants flow may be detected and the detected values may be used as the suction saturation temperature T_s .

It is not always necessary that the bypass passage 3

branches off from the refrigerant circuit 2 between the supercooling heat exchanger 23 and the main expansion valve 24, and the bypass passage 3 may branch off from the refrigerant circuit 2 between the radiator 22 and the supercooling heat exchanger 23.

It is not always necessary that a connection of the bypass passage 3 is a suction pipe of the compressor 21. In the case of a compressor having an injection mechanism, the connection of the bypass passage 3 may be connected to an injection port.

[0041] It is not always necessary that the main expansion valve 24 and the bypass expansion valve 31 of the invention are expansion valves, and they may be expansion devices which collect power from an expanding refrigerant. In this case, the number of rotations of the expansion device may be control by varying a load by means of a power generator connected to the expansion device.

[Industrial Applicability]

[0042] The present invention is especially effective for a hydronic heater which produces hot water by a refrigeration cycle apparatus and utilizes the hot water for heating a room.

Claims

1. A refrigeration cycle apparatus comprising
 - a refrigerant circuit in which a compressor, a radiator, a supercooling heat exchanger, main expansion means and an evaporator are annularly connected to one another,
 - a bypass passage which branches off from the refrigerant circuit between the radiator and the main expansion means, and which is connected to the compressor through the supercooling heat exchanger or connected to the refrigerant circuit between the evaporator and the compressor,
 - bypass expansion means provided in the bypass passage at a location upstream of the supercooling heat exchanger,
 - a first temperature sensor which detects a temperature of a refrigerant flowing out from the supercooling heat exchanger,
 - saturation temperature detecting means which detects a saturation temperature of a refrigerant sucked into the compressor, and
 - a control device, wherein
- the control device controls operation of the bypass expansion means such that a temperature detected by the first temperature sensor becomes equal to the saturation temperature detected by the saturation temperature detecting means until a number of rotations of the compressor reaches a predetermined target number of rotations of the compressor after the compressor is actuated, and the control de-

vice increases the number of rotation of the compressor when the temperature detected by the first temperature sensor reaches the saturation temperature.

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2. The refrigeration cycle apparatus according to claim 1, further comprising a second temperature sensor which detects a temperature of a refrigerant discharged from the compressor, wherein the control device operates an opening degree of the main expansion means into a closing direction when a temperature detected by the second temperature sensor becomes equal to or higher than a predetermined temperature.

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3. A hydronic heater having the refrigeration cycle apparatus according to claim 1 or 2.

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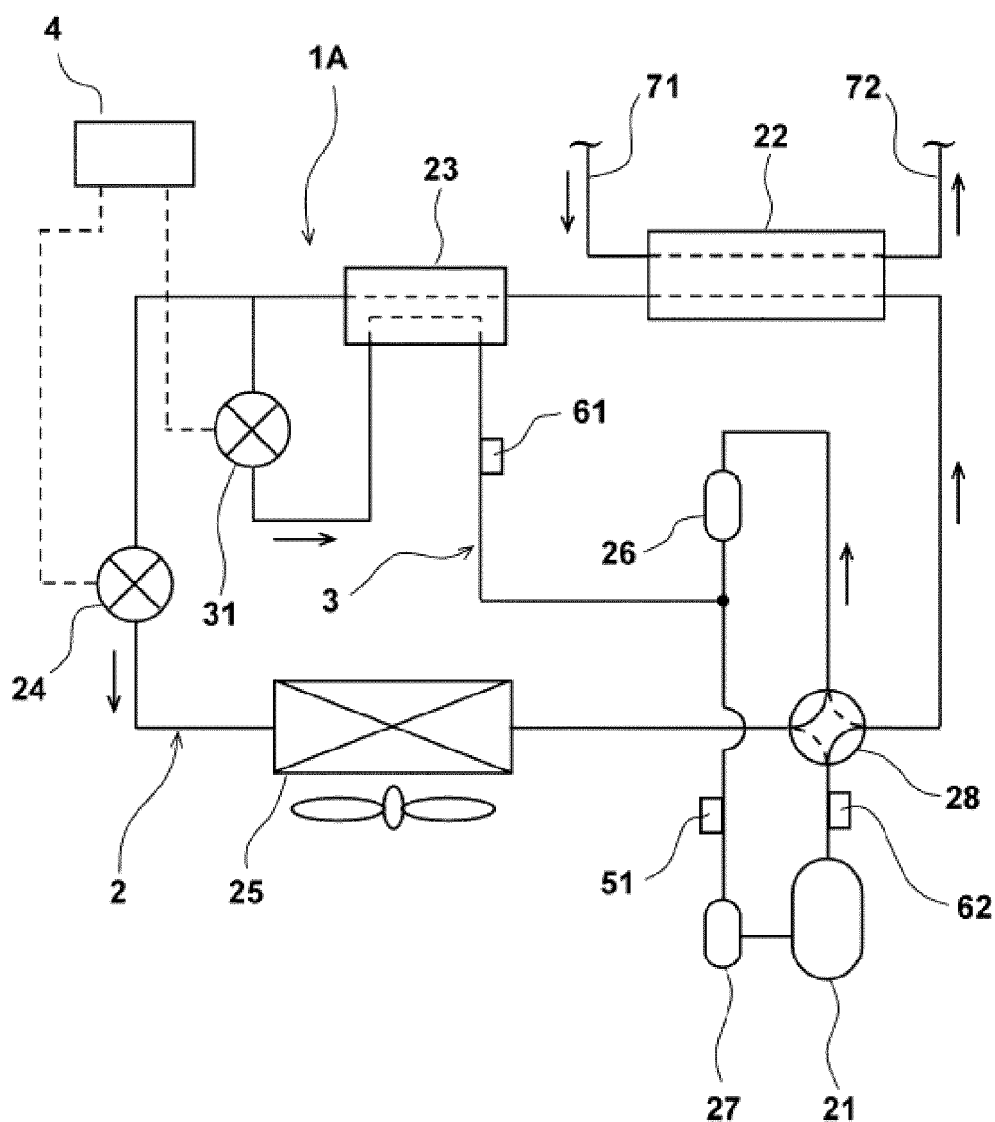
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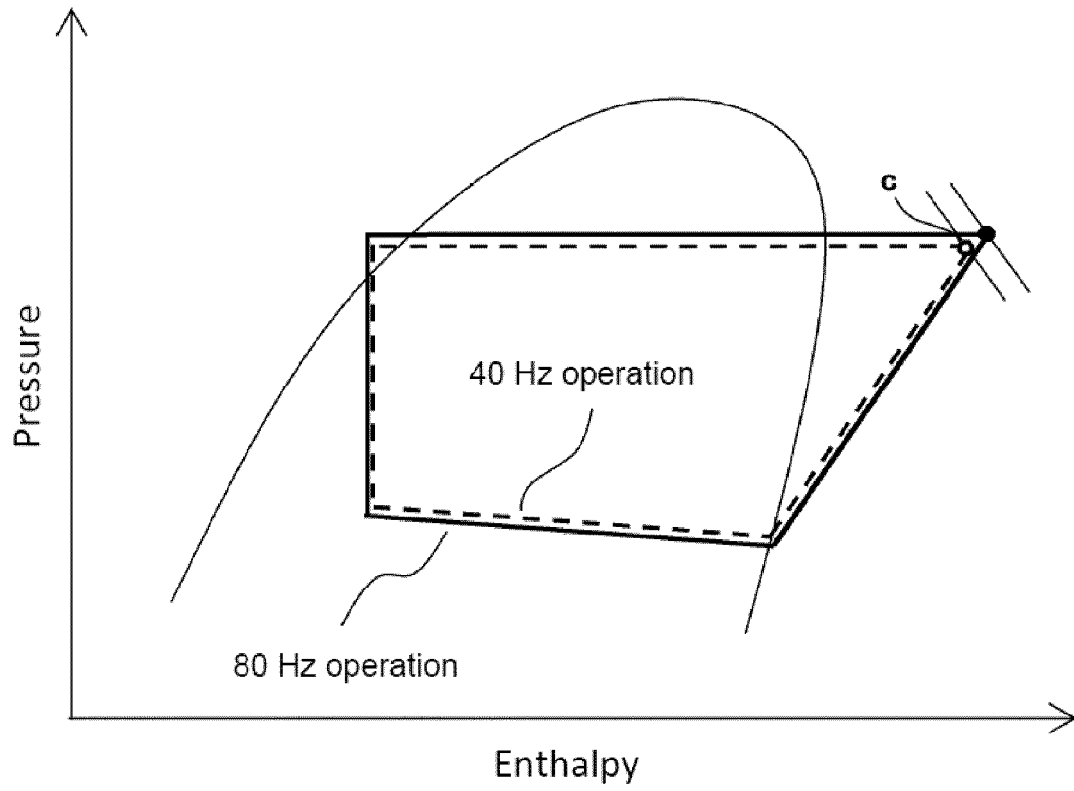
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[Fig. 1]

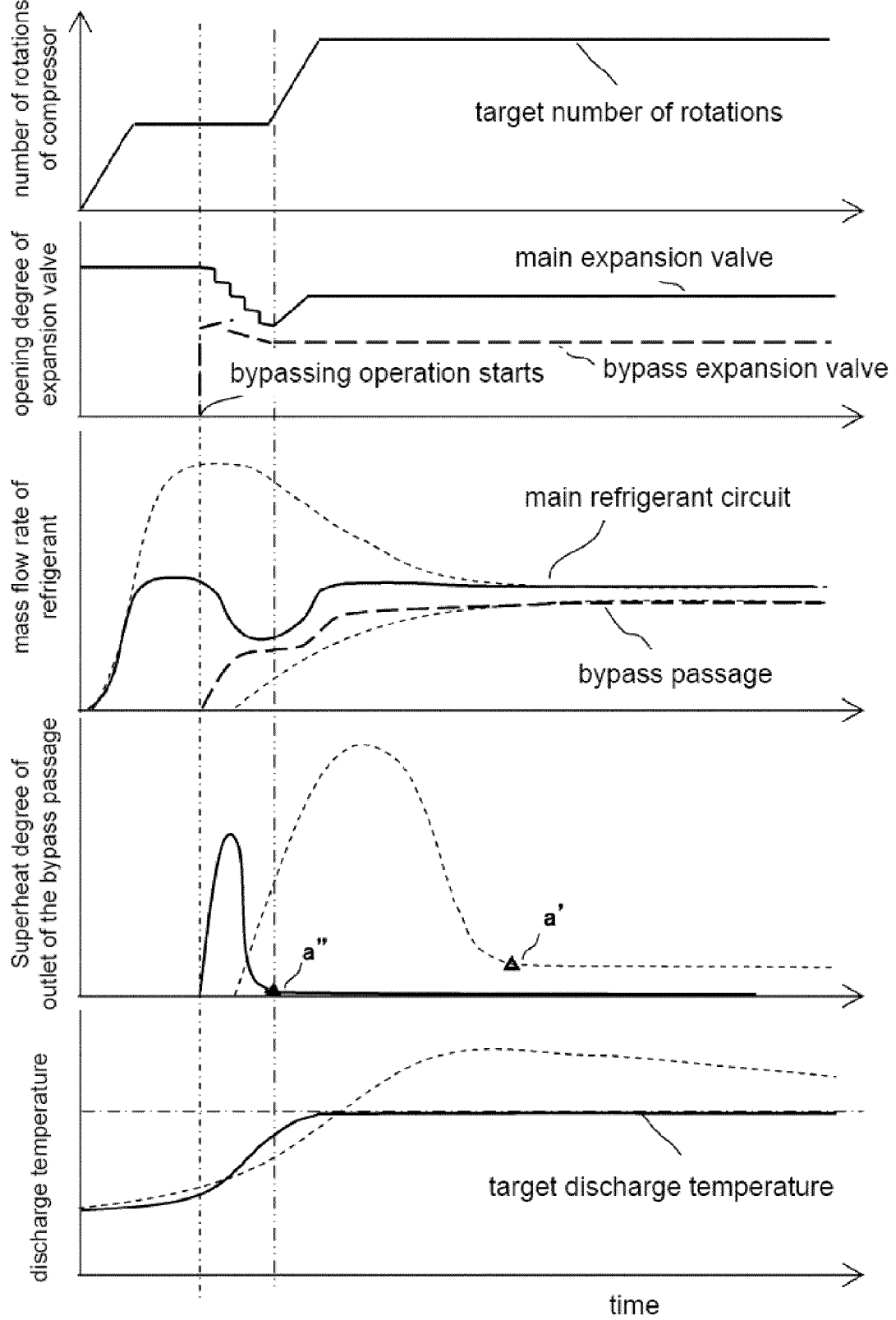


- 1A refrigeration cycle apparatus
- 2 refrigerant circuit
- 3 bypass passage
- 4 control device
- 21 compressor
- 22 radiator
- 23 supercooling heat exchanger
- 24 main expansion valve (main expansion means)
- 25 evaporator
- 31 bypass expansion valve (bypass expansion means)
- 51 pressure sensor (saturation temperature detection means)
- 61 first temperature sensor
- 62 second temperature sensor

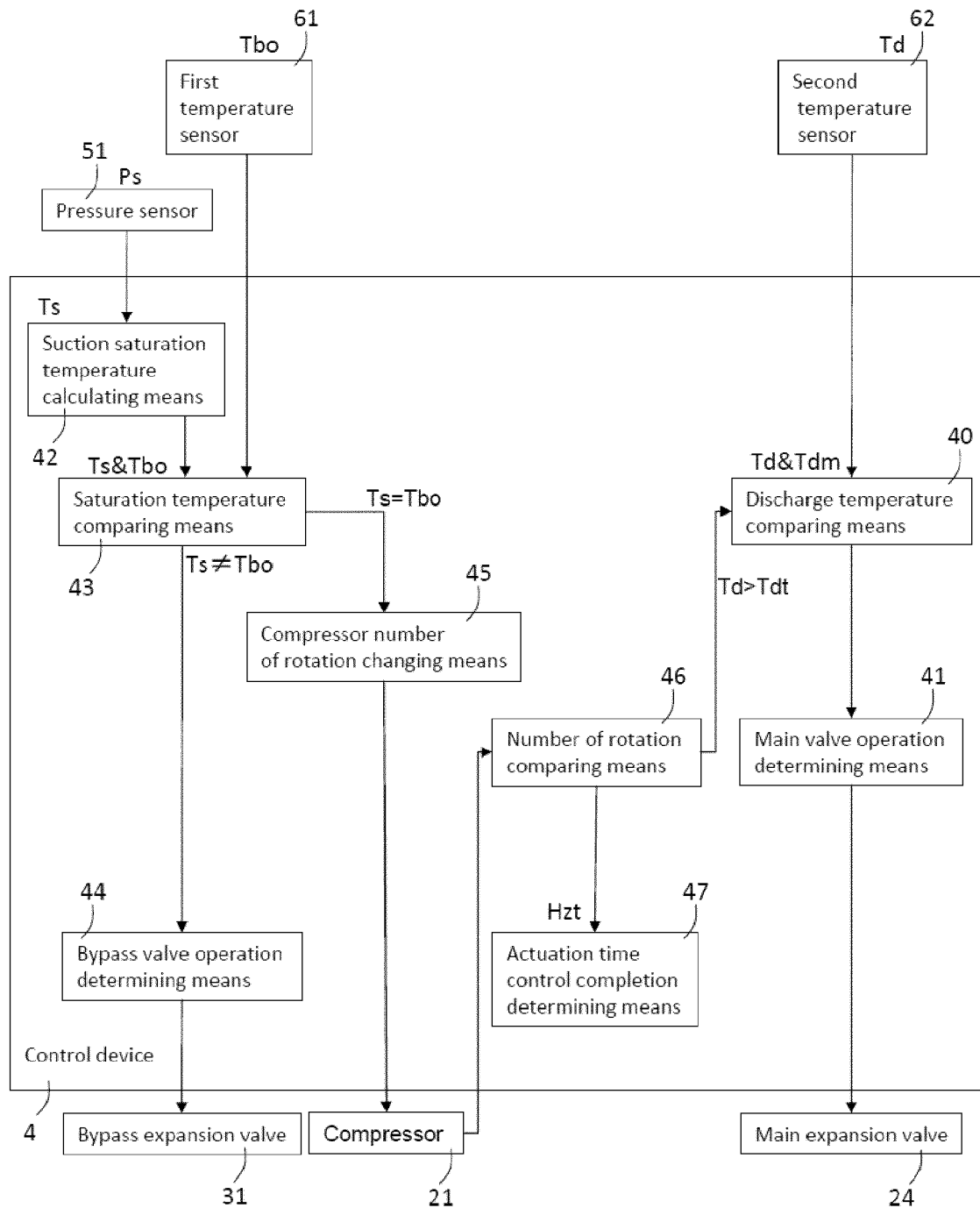
[Fig. 2]



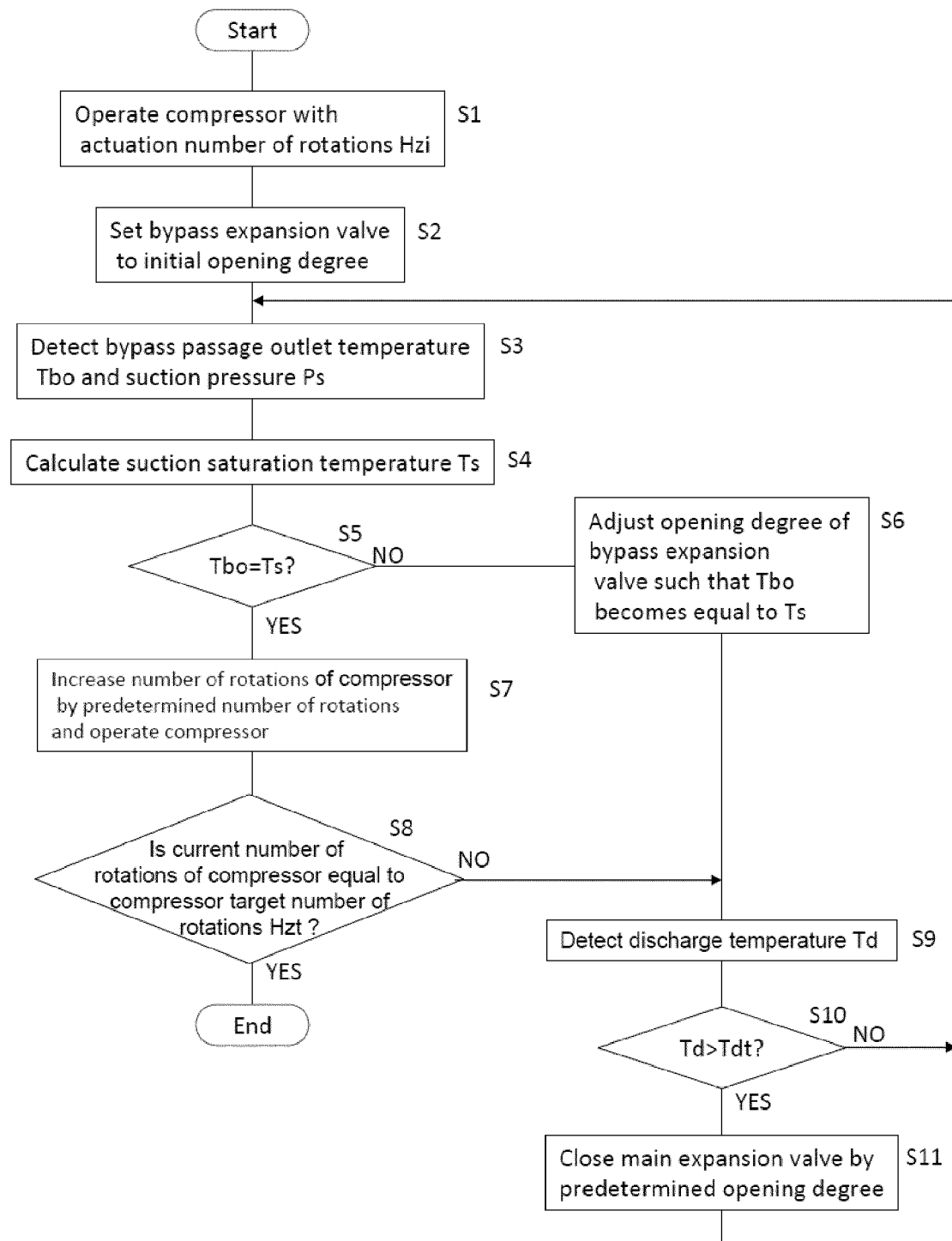
[Fig. 3]



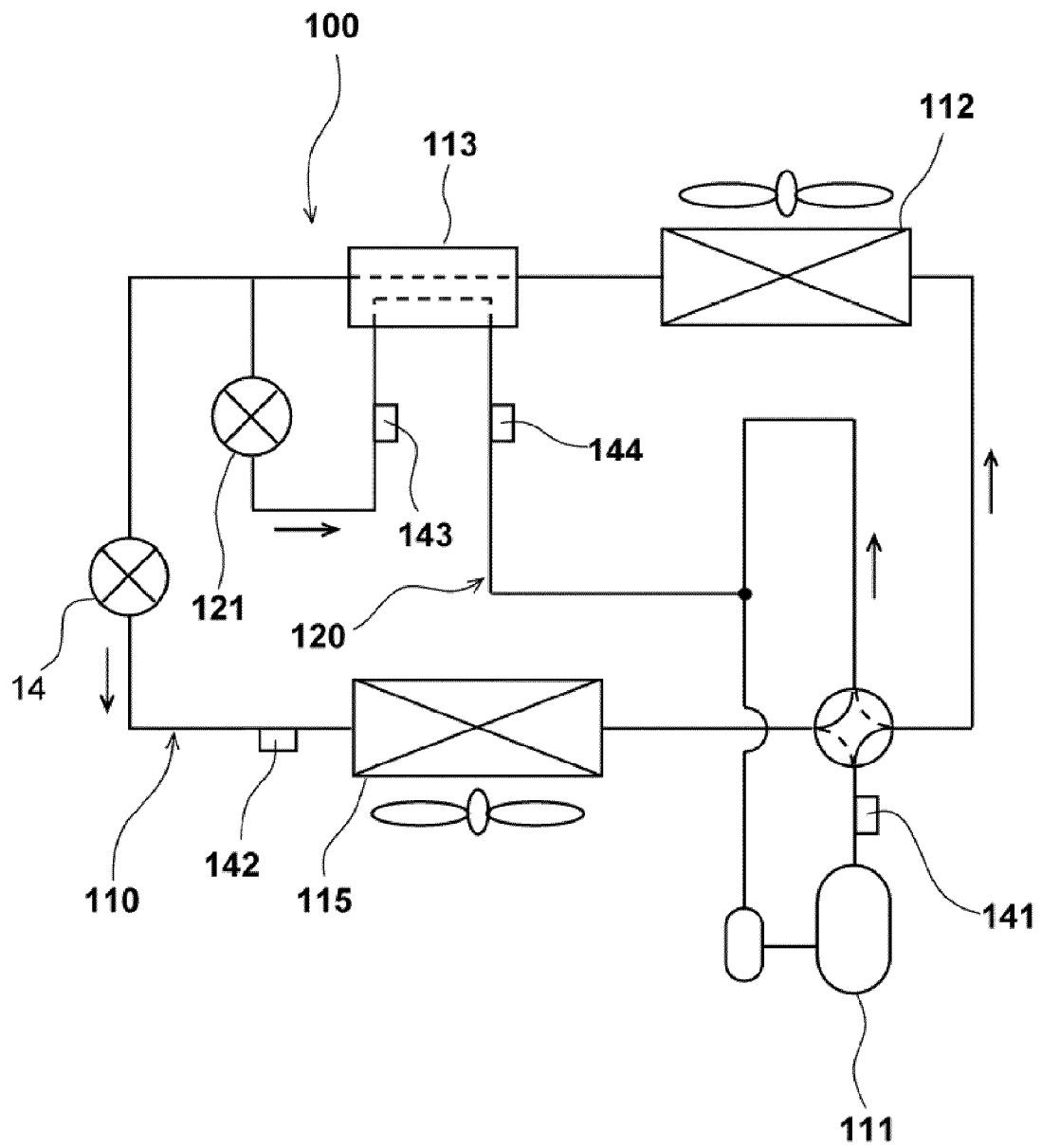
[Fig. 4]



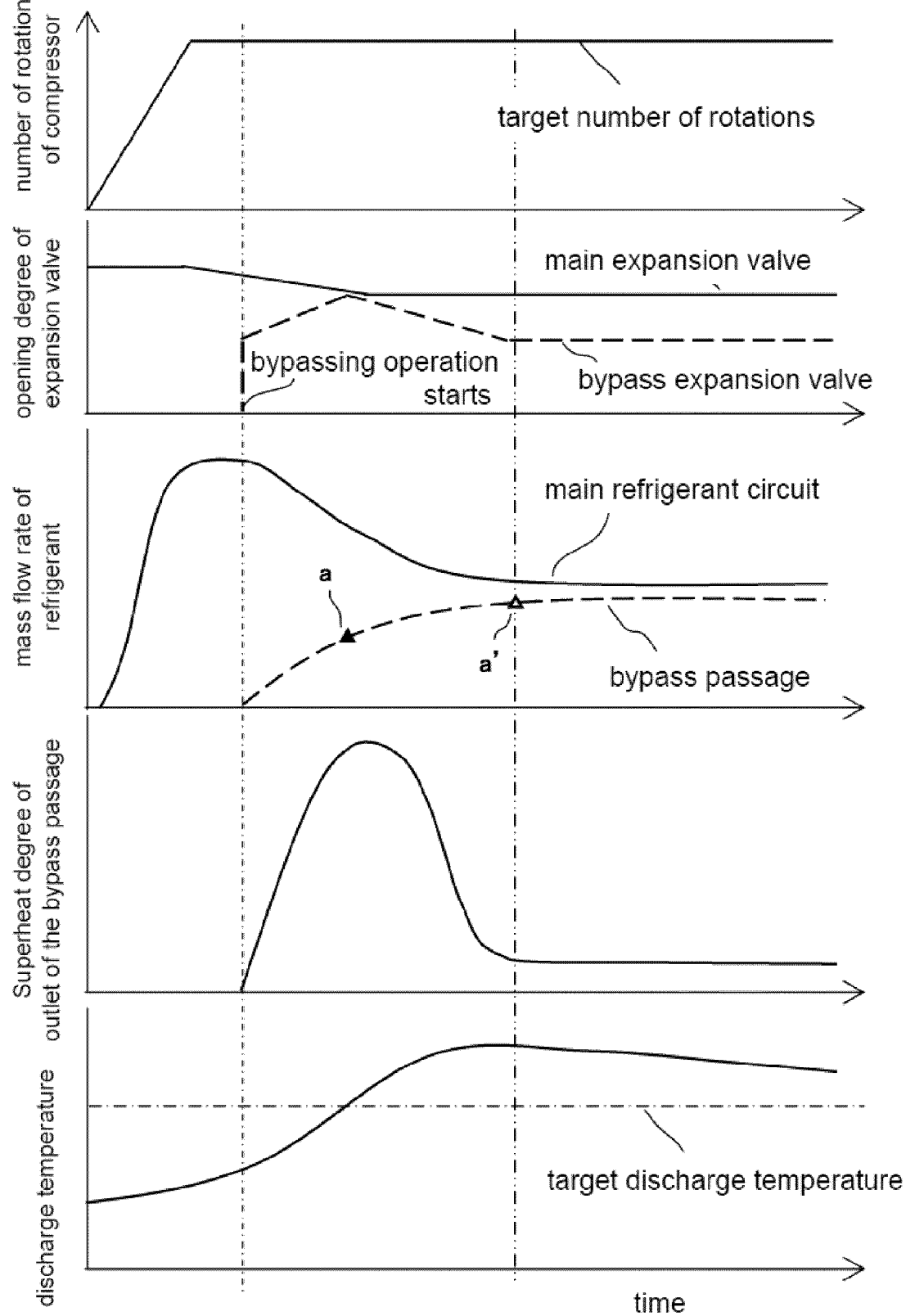
[Fig. 5]



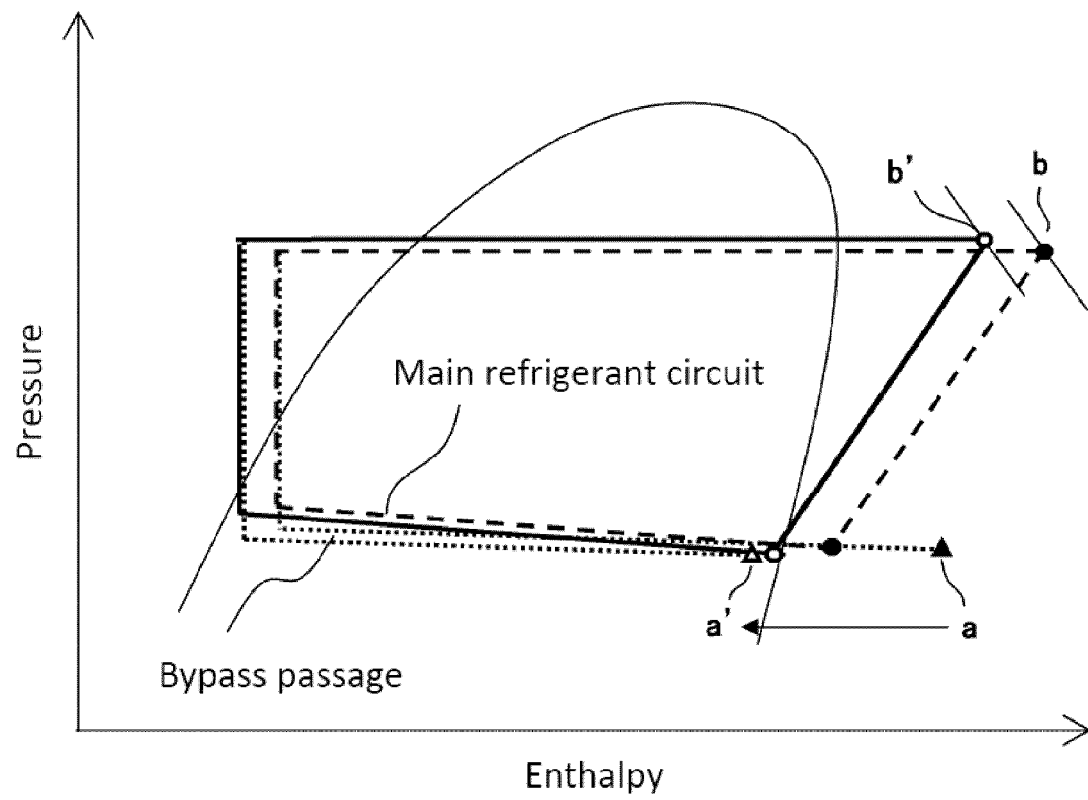
[Fig. 6]



[Fig. 7]



[Fig. 8]



REFERENCES CITED IN THE DESCRIPTION

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