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(54) Refrigeration cycle apparatus and hot-water heating apparatus

(57) A refrigeration cycle apparatus includes a first temperature sensor 61 which detects discharge temperature Td of refrigerant discharged from a compressor 21, a second temperature sensor 62 which detects evaporator outlet temperature Teo of refrigerant flowing out from an evaporator 25 in a refrigerant circuit 2, and a control apparatus 4. The control apparatus 4 adjusts an amount of refrigerant flowing through a bypass expansion valve 31 based on the discharge temperature Td and based on superheat degree SHe at the output of the evaporator 25 calculated from the evaporator outlet temperature Teo. According to this, optimal refrigerant flow rate distribution can always be secured, and it is possible to obtain high operation efficiency and sufficient heating ability.

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Description

[Technical Field]

[0001] The present invention relates to a refrigeration cycle apparatus and a hot-water heating apparatus which bypass a portion of refrigerant flowing out from a condenser, which exchange heat between refrigerant flowing through a refrigeration cycle and refrigerant flowing through a bypass passage, and which supercool the refrigerant flowing through the refrigeration cycle.

[Background Technique]

[0002] According to a conventional refrigeration cycle apparatus and a conventional hot-water heating apparatus of this kind, a supercooling heat exchanger is provided at a location downstream of a condenser of a refrigeration cycle, expanded refrigerant is made to flow into the supercooling heat exchanger, thereby supercooling refrigerant which flows out from the condenser (see patent document 1 for example).

Fig. 4 shows a conventional refrigeration cycle apparatus described in the patent document 1.

As shown in Fig. 4, a refrigeration cycle apparatus 100 includes a refrigerant circuit 110 through which refrigerant circulates, and a bypass passage 120. The refrigerant circuit 110 is formed circularly by connecting a compressor 111, a condenser 112, a supercooling heat exchanger 113, a main expansion valve 114 and an evaporator 115 to one another through pipes.

The bypass passage 120 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.

The refrigeration cycle apparatus 100 includes a temperature sensor 141 which detects temperature (discharge temperature) Td of refrigerant discharged from the compressor 111, a temperature sensor 142 which detects temperature (evaporator inlet temperature) Te of refrigerant flowing into the evaporator 115, a temperature sensor 143 which detects temperature (bypass inlet temperature) Tbi of refrigerant flowing into the supercooling heat exchanger 113 in the bypass passage 120, a temperature sensor 144 which detects temperature (bypass outlet temperature) Tbo of refrigerant flowing out from the supercooling heat exchanger 113 in the bypass passage 120, a main expansion valve controller in which target temperature Td (target) of a discharge pipe of the compressor 111 is set from evaporator inlet temperature Te detected by the temperature sensor 142 and which controls the main expansion valve 114 such that discharge temperature Td detected by the temperature sensor 141 becomes equal to the target temperature Td (target) , and a bypass expansion valve controller which controls the bypass expansion valve 121 such that a difference (Tbo-Tbi) between bypass outlet temperature Tbo and bypass inlet temperature Tbi at the supercooling heat exchanger 113 becomes equal to a predetermined target value.

[Prior Art Document]

[Patent Document]

[0003]

[Patent Document 1] Japanese Patent Application Laid-open No.10-63553

[Summary of the Invention]

[Problem to be Solved by the Invention]

[0004] According to the conventional configuration, however, when a refrigerant state of an outlet of the bypass passage 120 is adjusted into a moist state to obtain an operation efficiency enhancing effect of the bypass to a maximum extent, since a dry degree can not be controlled, a flow rate of the bypass passage 120 can not be controlled. Discharge temperature Td is substantially determined by suction refrigerant of the compressor 111 which is a mixture of refrigerant flowing through the refrigerant circuit 110 and refrigerant flowing through the bypass passage 120. Even if the discharge temperature Td is near the target temperature Td (target), there is a possibility that control of the main expansion valve 114 is converged in a poor-efficient refrigeration cycle state in which a circulation amount of refrigerant of the refrigerant circuit 110 and a circulation amount of refrigerant of the bypass passage 120 before merging is not appropriate. In this case, since sufficient heat absorption amount in the evaporator 115 can not be obtained and the supercooling heat exchanger 113 does not sufficiently act, there is a problem that an enthalpy difference increasing effect in the evaporator 115 and a pressure loss reducing effect of a low pressure pipe by the bypass are reduced, efficiency becomes poor, and a refrigeration cycle state in which heating ability is insufficient is maintained for a long time.

Especially when a circulation amount of refrigerant flowing through the refrigerant circuit 110 is excessively large and a circulation amount of refrigerant flowing through the bypass passage 120 is excessively small, since the discharge temperature Td becomes lower than the target temperature Td (target), the main expansion valve 114 is controlled in its closing direction, and an operation efficiency is further deteriorated, moreover, a suction pressure is lowered, a back-flow of liquid is generated, there is a possibility that the compressor 111 is damaged and reliability of the system is deteriorated.

[0005] The present invention is achieved for solving the conventional problem, and it is an object of the invention to provide a refrigeration cycle apparatus and a hot-water heating apparatus capable of enhancing the heating ability by swiftly controlling a refrigeration cycle state into an appropriate state.

[Means for Solving the Problem]

[0006] To solve the conventional problem, the present invention provides a refrigeration cycle apparatus comprising: a refrigeration circuit to which a compressor, a condenser, a supercooling heat exchanger, main expansion means and an evaporator are circularly connected to one another; a bypass passage which branches off from the refrigeration circuit between the supercooling heat exchanger and the main expansion means, and which is connected to the refrigeration circuit between the evaporator and the compressor through the supercooling heat exchanger; bypass expansion means provided at a location upstream of the supercooling heat exchanger of the bypass passage; a first temperature sensor which detects discharge temperature of refrigerant discharged from the compressor; a second temperature sensor which detects evaporator outlet temperature of refrigerant flowing out from the evaporator in the refrigeration circuit; and a control apparatus, wherein the control apparatus adjusts an amount of refrigerant flowing through the bypass expansion means based on the discharge temperature and based on an evaporator outlet superheat degree calculated from the evaporator outlet temperature.

[0007] According to this, from temperature of refrigerant discharged form the compressor and a superheat degree of the outlet of the evaporator, it is possible to determine that the main expansion means and the bypass expansion means are controlled into a poor-efficient refrigeration cycle state caused by an improper flow rate distribution of refrigerant (a circulation amount of refrigerant flowing through the bypass passage is excessively large and a circulation amount of refrigerant flowing through the refrigeration circuit is excessively small). In this case, since the bypass expansion means is forcibly closed by a predetermined operation amount, the circulation amount of refrigerant flowing through the bypass passage is reduced, the circulation amount of refrigerant flowing through the refrigeration circuit is increased, and the refrigerant distribution is swiftly improved. It is possible to make full use of increase in the heat absorption amount in the evaporator, the enthalpy difference increasing effect in the evaporator obtained by heat exchange between refrigerant flowing through the refrigeration circuit and refrigerant flowing through the bypass passage in the supercooling heat exchanger, and the pressure loss reducing effect in a low pressure refrigerant path obtained by making the refrigerant bypass. It is possible to provide an efficient refrigeration cycle apparatus capable of obtaining sufficient heating ability.

[Effect of the Invention]

[0008] The refrigeration cycle apparatus and the hot-water heating apparatus of the present invention determine an improper distribution between a flow rate of refrigerant flowing through the refrigeration circuit and a flow rate of refrigerant flowing through the bypass passage, and always control the flow rate distribution into an appropriate distribution swiftly. Therefore, it is possible to sufficiently secure a heat absorption amount in the evaporator, and it is possible to maximize the enthalpy difference increasing effect in the evaporator obtained by the heat exchange between refrigerant flowing through the refrigeration circuit and refrigerant flowing through the bypass passage in the supercooling heat exchanger, and the pressure loss reducing effect of the low pressure refrigerant path obtained by bypassing of refrigerant. It is possible to provide a refrigeration cycle apparatus and a hot-water heating apparatus capable of obtaining higher operation efficiency and sufficient heating ability even when outside temperature is low.

[Brief Description of the Drawings]

[0009]

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

Fig. 2 is a Mollier diagram of the refrigeration cycle apparatus shown in Fig. 1;

Fig. 3 is a flowchart of operation control of the refrigeration cycle apparatus of the first embodiment of the invention; and

Fig. 4 is a schematic block diagram of a conventional refrigeration cycle apparatus.

[Explanation of Symbols]

[0010]

1A refrigeration cycle apparatus

2 refrigerant circuit

3 bypass passage

4 control apparatus

4A first control apparatus

4B second control apparatus

21 compressor

22 condenser

23 supercooling heat exchanger

24 main expansion valve (main expansion means)

25 evaporator

31 bypass expansion valve (bypass expansion means)

51 pressure sensor

61 first temperature sensor

62 second temperature sensor

[Mode for Carrying Out the Invention]

[0011] A first invention provides a refrigeration cycle apparatus comprising: a refrigeration circuit to which a compressor, a condenser, a supercooling heat exchanger, main expansion means and an evaporator are circularly connected to one another; a bypass passage which branches off from the refrigeration circuit between the supercooling heat exchanger and the main expansion means, and which is connected to the refrigeration circuit between the evaporator and the compressor through the supercooling heat exchanger; bypass expansion means provided at a location upstream of the supercooling heat exchanger of the bypass passage; a first temperature sensor which detects discharge temperature of refrigerant discharged from the compressor; a second temperature sensor which detects evaporator outlet temperature of refrigerant flowing out from the evaporator in the refrigeration circuit; and a control apparatus, wherein the control apparatus adjusts an amount of refrigerant flowing through the bypass expansion means based on the discharge temperature and based on an evaporator outlet superheat degree calculated from the evaporator outlet temperature.

[0012] According to this, it is possible to determine that the refrigeration circuit is in the poor-efficient refrigeration cycle state caused by the improper refrigerant distribution in which the circulation amount of the refrigerant flowing through the bypass passage is excessively large and the circulation amount of the refrigerant flowing through the refrigeration circuit is excessively small. In this case, since the bypass expansion means is forcibly closed by a predetermined operation amount, since the circulation amount of the refrigerant flowing through the bypass passage is reduced, the circulation amount of the refrigerant flowing through the refrigeration circuit is increased, and the refrigerant distribution is improved. Therefore, it is possible to secure sufficient heat absorption amount in the evaporator. It is possible to make full use of the enthalpy difference increasing effect in the evaporator obtained by heat exchange between refrigerant flowing through The refrigeration circuit and refrigerant flowing through the bypass passage in the supercooling heat exchanger, and the pressure loss reducing effect in the low pressure refrigerant path obtained by making the refrigerant bypass. It is possible to obtain the high operation efficiency and sufficient heating ability even when outside temperature is low.

[0013] According to a second invention, in the first invention, the control apparatus reduces the amount of refrigerant flowing through the bypass expansion means when the discharged temperature is lower than a predetermined temperature and the evaporator outlet superheat degree is higher than a predetermined superheat degree. According to this, when the temperature of the refrigerant discharged from the compressor is lower than the target temperature and a superheat degree at the outlet of the evaporator becomes excessively high, it is possible to more precisely determine that the refrigeration circuit is in the poor-efficient refrigeration cycle state caused by the improper refrigerant distribution in which the circulation amount of the refrigerant flowing through the bypass passage is excessively large and the circulation amount of the refrigerant flowing through the refrigeration circuit is excessively small. Therefore, efficiency is not deteriorated by mistaken decision, and the effect of the first invention can further be enhanced.

[0014] According to a third invention, especially in the first or second invention, the refrigeration cycle apparatus further includes a pressure sensor which detects a suction pressure of refrigerant sucked into the compressor, the control apparatus calculates saturation temperature under the suction pressure from the suction pressure, and the control apparatus calculates a bypass passage outlet superheat degree from the saturation temperature and the evaporator outlet temperature. According to this, the saturation temperature under a pressure of refrigerant sucked by the compressor is calculated from a pressure detected by the pressure sensor, thereby precisely calculating a superheat degree at the outlet of the bypass passage.

[0015] According to a fourth invention, especially in the first or second invention, as the evaporator outlet superheat degree becomes greater, the control apparatus more increases the changing opening of the bypass expansion means. According to this, it is possible to determine whether a proper degree of the refrigerant flow rate distribution is high or low from the superheat degree in the outlet of the evaporator, and the bypass expansion means can be closed by an operation amount corresponding to the proper degree. Therefore, the control response is enhanced. Hence, the effect of the invention can swiftly be obtained and comfort can also be enhanced.

[0016] According to a fifth invention, especially in the third or fourth invention, the control apparatus increases an amount of refrigerant flowing through the main expansion means when the discharge temperature is lower than predetermined temperature and the evaporator outlet superheat degree is higher than a predetermined superheat degree. According to this, even if the bypass expansion means is closed, the main expansion means is opened. Therefore, it is possible to avoid a case where a suction pressure is abnormally reduced by excessively narrowing the main expansion means, and the reliability of the compressor in addition to the effect of the invention can be enhanced.

[0017] According to a sixth invention, especially in the third or fourth invention, the control apparatus increases an amount of refrigerant flowing through the main expansion means when the discharge temperature is lower than predetermined temperature, the evaporator outlet superheat degree is higher than a predetermined superheat degree and the suction pressure is lower than a predetermined pressure value- According to this, since it is determined that the suction pressure is lowered from the detection value of the pressure sensor, it is possible to open the main expansion means while determining that the main expansion means is excessively narrowed. Therefore, it is possible to reliably prevent the suction pressure from being abnormally lowered, to improve the flow rate distribution more swiftly, and to further enhance the effect of the invention.

[0018] According to a seventh invention, especially in the fifth or sixth invention, as the suction pressure becomes lower than the predetermined pressure value, the control apparatus more increases the changing opening of the main expansion means. According to this, since the opening amount is adjusted to a value corresponding to a reduction state of the suction pressure when the bypass expansion means is closed. Therefore, it is possible to swiftly handle abrupt variation of the suction pressure caused by variation in an operation state and a load state, and it is possible to especially enhance the reliability of the compressor in the effect of the invention.

[0019] An embodiment of the present invention will be described with reference to the drawings. The invention is not limited to the embodiment.

(Embodiment)

[0020] Fig. 1 is a schematic block diagram in the embodiment of the invention. In Fig. 1, a refrigeration cycle apparatus 1A includes a refrigerant circuit 2 through which refrigerant is circulated, a bypass passage 3 and a control apparatus 4. As the refrigerant, it is possible to use zeotropic refrigerant mixture zeotropic refrigerant mixture such as R407C, pseudo azerotropic refrigerant mixture such as R410A and a single refrigerant.

The refrigerant circuit 2 is formed circularly by connecting a compressor 21, a condenser 22, a supercooling heat exchanger 23, a main expansion valve (main expansion means) 24 and an evaporator 25 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. The refrigerant circuit 2 is provided with a four-way valve 28 which switches between a normal operation and a defrosting operation.

[0021] In this embodiment, the refrigeration cycle apparatus 1A configures heating means of the hot-water heating apparatus which utilizes hot water produced by the heating means for a heating operation. The condenser 22 is a heat exchanger which exchanges heat between the refrigerant and water, thereby heating water.

More specifically, a supply pipe 71 and a recovering pipe 72 are connected to the condenser 22, water is supplied to the condenser 22 through the supply pipe 71, and water (hot water) heated by the condenser 22 is recovered through the recovering pipe 72. Hot water recovered by the recovering pipe 72 is directly sent to a heater such as a radiator or sent to the heater through a hot water tank, thereby carrying out the heating operation.

[0022] The bypass passage 3 branches off from the refrigerant circuit 2 between the supercooling heat exchanger 23 and the main expansion valve 24, and is connected to the refrigerant circuit 2 between the evaporator 25 and the compressor 21 through the supercooling heat exchanger 23. In this embodiment, the bypass passage 3 is connected to the refrigerant circuit 2 between the sub-accumulator 26 and the main accumulator 27. The bypass passage 3 is provided with the bypass expansion valve (bypass expansion means) 31 at a location upstream of the supercooling heat exchanger 23.

In the normal operation, refrigerant discharged from the compressor 21 is sent to the condenser 22 through the four-way valve 28. In the defrosting operation, refrigerant discharged from the compressor 21 is sent to the evaporator 25 through the four-way valve 28. In Fig. 1, a flowing direction of refrigerant at the time of the normal operation is shown with solid lines.

[0023] A variation in a state of refrigerant at time of the normal operation will be described below.

High pressure refrigerant discharged from the compressor 21 flows into the condenser 22, and dissipates heat to water passing through the condenser 22. The high pressure refrigerant which flows out from the condenser 22 flows into the supercooling heat exchanger 23, is supercooled by low pressure refrigerant which is decompressed by the bypass expansion valve 31. High pressure refrigerant which flows out from the supercooling heat exchanger 23 is distributed to a pipe connected to the main expansion valve 24 and a pipe connected to the bypass expansion valve 31.

The high pressure refrigerant distributed to the pipe connected to the main expansion valve 24 is decompressed and expanded by the main expansion valve 24 and then, the high pressure refrigerant flows into the evaporator 25. Here, the low pressure refrigerant which flows into the evaporator 25 absorbs heat from air.

[0024] The high pressure refrigerant distributed to the pipe connected to the bypass expansion valve 31 is decompressed and expanded by the bypass expansion valve 31 and then, 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 condenser 22. Thereafter, the low pressure refrigerant flowing out from the supercooling heat exchanger 23 merges with the low pressure refrigerant flowing out from the evaporator 25 and is again sucked Into the compressor 21.

[0025] The refrigeration cycle apparatus 1A of the embodiment is configured such that a pressure of refrigerant sucked into the compressor 21 is lowered when outside air temperature is low, the refrigeration circulation amount is reduced, and this prevents the heating ability of the condenser 22 from being deteriorated.
To realize this, it is important that an enthalpy difference at the evaporator 25 is increased by the supercooling, the bypass passage 3 makes refrigerant bypass, thereby suppressing gas phase refrigerant having a small endothermic effect flowing through a low pressure pipe of the refrigerant circuit 2 and this reduces a pressure loss in the low pressure pipe of the refrigerant circuit 2.
If the pressure loss in the low pressure pipe of the refrigerant circuit 2 is reduced, a pressure of refrigerant which is sucked into the compressor 21 is increased correspondingly and a specific volume is reduced. Hence, the refrigeration circulation amount is increased. If the enthalpy difference at the evaporator 25 is increased, even if a mass flow rate of refrigerant which passes through the evaporator 25 is lowered by the bypass, it is possible to secure the heat absorption amount at the evaporator 25. That is, the supercooling degree of refrigerant and the bypass amount are maximized, it is possible to obtain the maximum heating ability enhancing effect of the condenser 22 and the maximum coefficient of performance enhancing effect of the refrigeration cycle apparatus 1A.

[0026] According to the embodiment, although it will be described in detail later, when a refrigerant flow rate distribution becomes improper, i.e. , when a circulation amount of refrigerant flowing through the bypass passage 3 becomes excessively large and a circulation amount of refrigerant flowing through the refrigerant circuit 2 becomes excessively small, control is performed such that the bypass expansion valve 31 is closed by a predetermined opening degree and the main expansion valve 24 is opened by a predetermined opening degree. Therefore, in the bypass passage 3, a circulation amount of refrigerant flowing through the bypass passage 3 is reduced and a state of refrigerant flowing out from the supercooling heat exchanger 23 approaches a saturation state as shown with a dot a' in Fig. 2 from a state where a drying degree is small as shown with a dot a in Fig. 2.

[0027] In the evaporator 25, since the circulation amount of refrigerant flowing through the refrigerant circuit 2 is increased, the state of refrigerant flowing out from the evaporator 25 approaches a saturation state as shown with a dot b' in Fig. 2 from the supercooled state as shown with a dot b in Fig. 2. That is, the heat absorption amount in the evaporator 25 is increased and the discharge refrigerant temperature of the compressor 21 is appropriately secured in a state where the supercooling heat exchanger 23 sufficiently acts and the enthalpy difference increasing effect in the evaporator 25 and the pressure loss reducing effect caused by the bypass are sufficiently obtained.

[0028] Action of the operation control will be described below. The refrigerant circuit 2 includes a pressure sensor 51 which detects a pressure (suction pressure) Ps of refrigerant sucked into the compressor 21, a first temperature sensor 61 which detects temperature (discharge temperature) Td of refrigerant discharged from the compressor 21, and a second temperature sensor 62 which detects temperature (evaporator outlet temperature) Teo of refrigerant flowing out from the evaporator 25. The bypass passage 3 includes a third temperature sensor 63 which detects temperature (bypass passage outlet temperature) Tbo of refrigerant flowing out from the supercooling heat exchanger 23.
The control apparatus 4 includes a first control apparatus 4A and a second control apparatus 4B. The control apparatus 4 controls, based on detection values detected by the various sensors such as the pressure sensor 51, the first temperature sensor 61, the second temperature sensor 62 and the third temperature sensor 63, the number of rotations of the compressor 21 and the four-way valve 28, the opening degrees of the main expansion valve 24 and the bypass expansion valve 31.

[0029] In this embodiment, at the time of the normal operation, the first control apparatus 4A controls the bypass expansion valve 31 such that a superheat degree SHb at the outlet of the bypass passage, 3 calculated based on bypass outlet temperature Tbo detected by the third temperature sensor 63 and based on a suction pressure Ps detected by the pressure sensor 51 becomes equal to a predetermined superheat degree (bypass superheat degree control target value), and controls such that the bypass expansion valve 31 is closed by a predetermined first operation amount when temperature detected by the first temperature sensor 61 is lower than predetermined temperature and when a superheat degree SHe at the outlet of the evaporator 25 calculated based on evaporator outlet temperature Teo detected by the second temperature sensor 62 and suction pressure Ps detected by the pressure sensor 51 becomes higher than a predetermined superheat degree (evaporator superheat degree control target value).

[0030] At the time of the normal operation, the second control apparatus 4B controls the main expansion valve 24 such that discharge temperature Td detected by the first temperature sensor 61 becomes equal to predetermined temperature (discharge temperature control tarter value), and controls such that the main expansion valve 24 opens by a predetermined second operation amount when temperature detected by the first temperature sensor 61 is lower than predetermined temperature, and when a superheat degree SHe at the outlet of the evaporator 25 calculated based on the evaporator outlet temperature Teo detected by the second temperature sensor 62 and based on the suction pressure Ps detected by the pressure sensor 51 becomes higher than the predetermined superheat degree, and when the suction pressure Ps detected by the pressure sensor 51 becomes lower than a predetermined pressure.

[0031] Next, control of the control apparatus 4 at the time of the normal operation will be described in detail with reference to a flowchart shown in Fig. 3.

First, the control apparatus 4 detects discharge temperature Td by the first temperature sensor 61, evaporator outlet temperature Teo by the second temperature sensor 62 and bypass outlet temperature Tbo by the third temperature sensor 63 (step 1).

Next, the control apparatus 4 detects a suction pressure Ps by the pressure sensor 51 (step 2), and calculates saturation temperature STs under a pressure of refrigerant sucked into compressor 21 from the detected suction pressure Ps (step 3) . The saturation temperature STs is calculated using a refrigerant physical property equation. Thereafter, the control apparatus 4 calculates the superheat degree SHe at the outlet of the evaporator 25 by an equation SHe = Teo - STs, and calculates the superheat degree SHb at the outlet of the bypass passage 3 by an equation SHb = Tbo - STs (step 4).

[0032] Here, the control apparatus 4 determines whether the discharge temperature Td is lower than the predetermined discharge temperature (step 5).

If the discharge temperature Td is higher than the predetermined discharge temperature, it can be considered that in the current state, the circulation amount of refrigerant flowing through the bypass passage 3 is appropriate amount or slightly small and in this region, and a flow rate distribution can be adjusted by the normal control. Therefore, the control apparatus 4 adjusts an opening degree of the bypass expansion valve 31 such that the superheat degree SHb becomes equal to the superheat degree control target value (step 6). Then, the control apparatus 4 adjusts an opening degree of the main expansion valve 24 such that the discharge temperature Td becomes equal to the discharge temperature control target value (step 7) and returns to step 1.

On the other hand, if the discharge temperature Td is lower than the predetermined discharge temperature in step 5, there is a possibility that the circulation amount of refrigerant flowing through the bypass passage 3 is excessively large. Therefore, to determine whether the refrigerant distribution is in the proper state, the control apparatus 4 determines whether the superheat degree SHe at the outlet of the evaporator 25 is higher than a predetermined superheat degree (step 8).

[0033] When the superheat degree SHe is smaller than the predetermined superheat degree in step 8, it is considered that the refrigeration cycle state is in a transient state and the entire decompressing amount by the expansion valve is insufficient. Therefore, the control apparatus 4 adjusts the opening degree of the bypass expansion valve 31 such that the superheat degree SHb becomes equal to the bypass superheat degree control target value (step 6), adjusts the opening degree of the main expansion valve 24 such that the discharge temperature Td becomes equal to the discharge temperature control target value (step 7), and the procedure returns to step 1.

If the superheat degree SHe is higher than the predetermined superheat degree in step 8, refrigerant flowing through the refrigerant circuit 2 is in a state (the superheat degree is excessively high due to insufficient flow rate) of the dot b shown in Fig. 2, refrigerant flowing through the bypass passage 3 is in a state (excessively moist because the flow rate is excessively large) of the dot a, and it can be considered that performance of the evaporator 25 and the performance of the supercooling heat exchanger 23 can not be made fully used. Therefore, control apparatus 4 closes the opening degree of the bypass expansion valve 31 by a predetermined first operation amount (step 9).

[0034] Thereafter, the control apparatus 4 determines whether the suction pressure Ps is lower than a predetermined pressure (step 10). If the suction pressure Ps is higher than the predetermined pressure in step 10, it can be considered that the opening degree of the main expansion valve 24 is appropriate and thus, the procedure is returned to step 1 as it is.

If the suction pressure Ps is lower than the predetermined pressure in step 10 on the other hand, it is considered that the opening degree of the main expansion valve 24 is excessively small. Therefore, the control apparatus 4 opens the opening degree of the bypass expansion valve 31 by a predetermined second operation amount (step 11), and the procedure returns to step 1.

[0035] A bypass passage outlet temperature Tbo is detected by the first temperature sensor 61 which detects temperature of refrigerant discharged from the compressor 21 in the refrigerant circuit 2, the second temperature sensor 62 which detects temperature of refrigerant flowing out from the evaporator 25, the pressure sensor 51 which detects a pressure of refrigerant sucked into the compressor 21, and the third temperature sensor 63 which detects temperature of refrigerant flowing out from the supercooling heat exchanger 23 in the bypass passage 3. As described above, in this embodiment, the first control apparatus 4A controls the bypass expansion valve 31 such that the superheat degree SHb at the outlet of the bypass passage 3 calculated based on the bypass passage outlet temperature Tbo detected by the third temperature sensor 63 and the suction pressure Ps detected by the pressure sensor 51 becomes equal to the predetermined superheat degree. Further, when temperature detected by the first temperature sensor 61 is lower than predetermined temperature and when the superheat degree SHe at the outlet of the evaporator 25 is higher than a predetermined superheat degree, the first control apparatus 4A controls the bypass expansion valve 31 such that it closes by the predetermined first operation amount.

[0036] According to this, it can be determined from the temperature of refrigerant discharged from the compressor 21 and the superheat degree SHe at the outlet of the evaporator 25 that the refrigeration circuit is in a poor-efficient refrigeration cycle state caused by an improper refrigerant flow rate distribution (the circulation amount of refrigerant flowing through the bypass passage 3 is excessively large and the circulation amount of refrigerant flowing through the refrigerant circuit 2 is excessively small). In this case, since the bypass expansion valve 31 is forcibly closed by the predetermined operation amount, the circulation amount of refrigerant flowing through the bypass passage 3 is reduced, the circulation amount of refrigerant flowing through the refrigerant circuit 2 is increased, and the circulation amount of refrigerant can swiftly be distributed appropriately. Therefore, the heat absorption amount in the evaporator 25 can sufficiently be secured. It is possible to make full use of the enthalpy difference increasing effect in the evaporator 25 by heat exchange between refrigerant flowing through the refrigerant circuit 2 and refrigerant flowing through the bypass passage 3 in the supercooling heat exchanger 23, and the pressure loss reducing effect of the low pressure refrigerant path by the bypass of refrigerant. High operation efficiency and sufficient heating ability can be obtained even when outside air temperature is low.

[0037] In this embodiment, at the time of the normal operation, the second control apparatus 4B controls the main expansion valve 24 such that the discharge temperature Td detected by the first temperature sensor 61 becomes equal to the predetermined temperature. The second control apparatus 4B controls the main expansion valve 24 such that it opens by the second operation amount when temperature detected by the first temperature sensor 61 is lower than the predetermined temperature, when the superheat degree SHe at the outlet of the evaporator 25 calculated based on the evaporator outlet temperature Teo detected by the second temperature sensor 62 and the suction pressure Ps detected by the pressure sensor 51 is higher than the predetermined superheat degree, and when the suction pressure Ps detected by the pressure sensor 51 becomes lower than the predetermined pressure.

[0038] According to this, from the detection value of the pressure sensor 51, it is determined that the suction pressure Ps is lowered. Therefore, the main expansion valve 24 can be opened while limiting the current state to a state where the main expansion valve 24 is excessively narrowed. Therefore, abnormal reduction in the suction pressure Ps is reliably prevented, the flow rate distribution can more swiftly be improved, and the reliability of the compressor in addition to the effect of the invention can be enhanced.

[0039] The predetermined first operation amount of the embodiment is determined in accordance with the superheat degree SHe at the outlet of the evaporator 25 such that the larger the superheat degree SHe at the outlet of the evaporator 25 becomes, the larger the operation amount becomes. According to this configuration, it is possible to determine from the superheat degree SHe at the outlet of the evaporator 25 whether the proper degree of the refrigerant distribution is high or low and since the bypass expansion valve 31 is closed by the operation amount in accordance with the proper degree, the control response is enhanced. Therefore, the effect of the invention can swiftly be obtained and comfort can be enhanced.

[0040] The predetermined second operation amount of the embodiment is determined in accordance with a pressure such that as a pressure detected by the pressure sensor 51 becomes lower than the predetermined pressure value, the operation amount is more increased. According to this, since the opening operation amount is secured in accordance with a pressure reduction state, it is possible to swiftly handle abrupt variation in the suction pressure Ps caused by variation in the operation state and the load state, and it is possible to especially enhance the reliability of the compressor 21 in the effect of the invention.

[0041] In Fig. 1, the pressure sensor 51 is provided between the main accumulator 27 and the position where the bypass passage 3 is connected to the refrigerant circuit 2, but the pressure sensor 51 may be provided at any position of the refrigerant circuit 2 only if the pressure sensor 51 is located between the evaporator 25 and the compressor 21. Alternatively, the pressure sensor 51 may be provided at a location downstream of the supercooling heat exchanger 23 of the bypass passage 3.

[0042] Although the bypass expansion valve 31 is controlled such that the superheat degree SHb at the outlet of the bypass passage 3 becomes equal to the target value in the embodiment, the controlling method of the bypass expansion valve 31 is not limited to this. For example, the bypass expansion valve 31 may be controlled such that temperature of supercooling degree of the outlet of the supercooling heat exchanger 23 becomes equal to the target value.

Alternatively, the bypass expansion valve 31 may be controlled based on the supercooling degree of refrigerant at the outlet of the condenser 22.

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 condenser 22 and the supercooling heat exchanger 23.

[0043] Further, it is not always necessary that the main expansion valve 24 and the bypass expansion valve 31 of the invention are expansion valves, and may be expansion devices which recover power from expanding refrigerant. In this case, the number of rotations of the expansion device may be controlled by changing a load by a power generator connected to the expansion device.

[0044] In this embodiment, the superheat degree SHe at the outlet of the evaporator 25 is calculated based on the evaporator outlet temperature Teo detected by the second temperature sensor 62 and the suction pressure Ps detected by the pressure sensor 51. Alternatively, steam temperature of the evaporator 25 can be used instead of using the suction pressure Ps detected by the pressure sensor 51. That is, the second temperature sensor 62 is disposed at a position where the steam temperature of the evaporator 25 can be measured (substantially at a central portion of the evaporator 25 where refrigerant flows in a two-phase state under most operation conditions for example), and the steam temperature is detected. If the evaporating temperature is subtracted from temperature detected by the second temperature sensor 62, the superheat degree SHe of the outlet of the evaporator 25 can be calculated.

[Industrial Applicability]

[0045] The present invention is especially useful for a hot-water heating apparatus which produces hot water by a refrigeration cycle apparatus and which utilizes the hot water for a heating operation.

Claims

1. A refrigeration cycle apparatus comprising: a refrigeration circuit to which a compressor, a condenser, a supercooling heat exchanger, main expansion means and an evaporator are circularly connected to one another; a bypass passage which branches off from the refrigeration circuit between the supercooling heat exchanger and the main expansion means, and which is connected to the refrigeration circuit between the evaporator and the compressor through the supercooling heat exchanger; bypass expansion means provided at a location upstream of the supercooling heat exchanger of the bypass passage; a first temperature sensor which detects discharge temperature of refrigerant discharged from the compressor; a second temperature sensor which detects evaporator outlet temperature of refrigerant flowing out from the evaporator in the refrigeration circuit; and a control apparatus, wherein the control apparatus adjusts an amount of refrigerant flowing through the bypass expansion means based on the discharge temperature and based on an evaporator outlet superheat degree calculated from the evaporator outlet temperature.

2. The refrigeration cycle apparatus according to claim 1,
wherein the control apparatus reduces the amount of refrigerant flowing through the bypass expansion means when the discharge temperature is lower than a predetermined temperature and the evaporator outlet superheat degree is higher than a predetermined superheat degree.

3. The refrigeration cycle apparatus according to claim 1 or 2, further comprising a pressure sensor which detects a suction pressure of refrigerant sucked into the compressor,
wherein
the control apparatus calculates saturation temperature under the suction pressure from the suction pressure, and
the control apparatus calculates a bypass passage outlet superheat degree from the saturation temperature and the evaporator outlet temperature.

4. The refrigeration cycle apparatus according to claim 1 or 2, wherein
as the evaporator outlet superheat degree becomes greater, the control apparatus more increases the changing opening of the bypass expansion means.

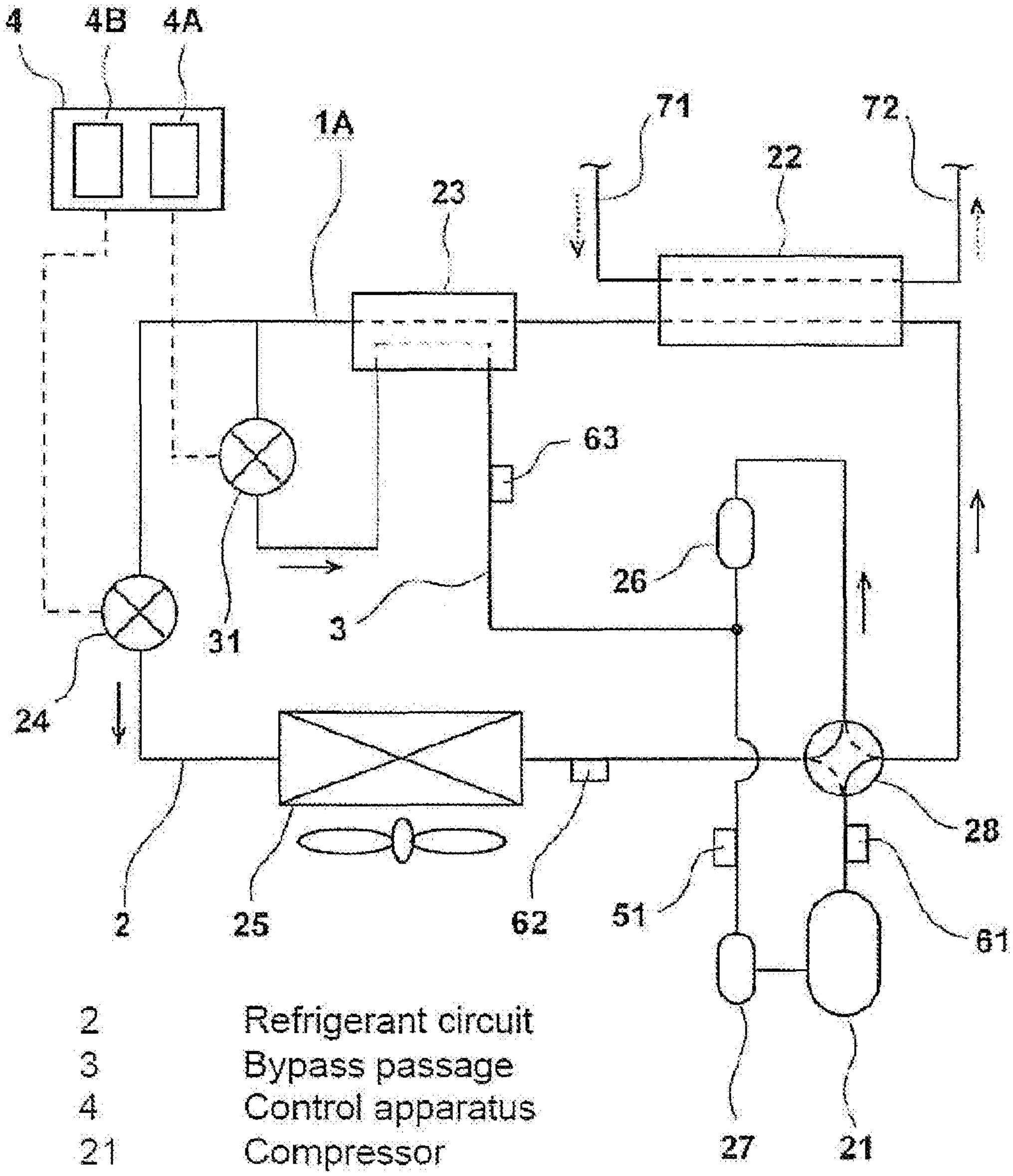
5. The refrigeration cycle apparatus according to claim 3 or 4, wherein
the control apparatus increases an amount of refrigerant flowing through the main expansion means when the discharge temperature is lower than predetermined temperature and the evaporator outlet superheat degree is higher than a predetermined superheat degree.

6. The refrigeration cycle apparatus according to claim 3 or 4, wherein
the control apparatus increases an amount of refrigerant flowing through the main expansion means when the discharge temperature is lower than predetermined temperature, the evaporator outlet superheat degree is higher than a predetermined superheat degree and the suction pressure is lower than a predetermined pressure value.

7. The refrigeration cycle apparatus according to claim 5 or 6, wherein
as the suction pressure becomes lower than the predetermined pressure value, the control apparatus more increases the changing opening of the main expansion means.

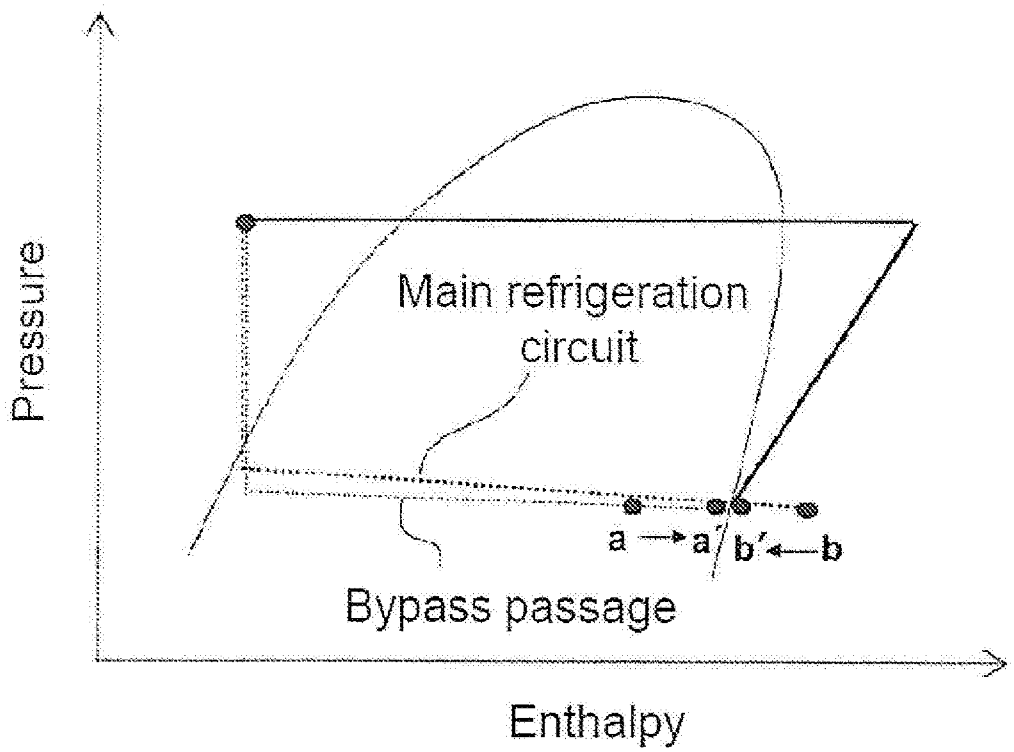
8. A hot-water heating apparatus comprising the refrigeration cycle apparatus according to any one of claims 1 to 7.

[Fig. 1]

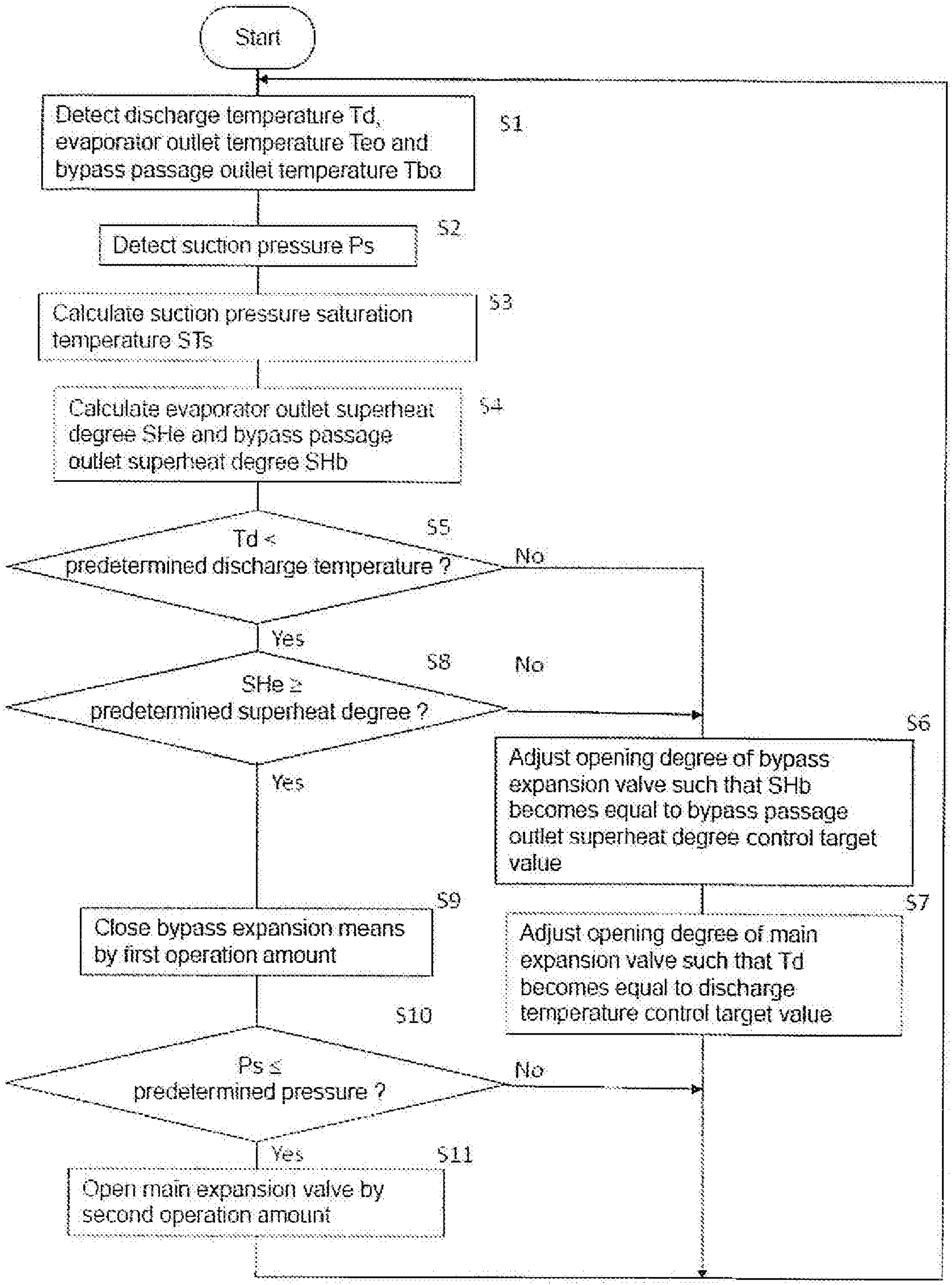


2	Refrigerant circuit
3	Bypass passage
4	Control apparatus
21	Compressor
22	Condenser
23	Supercooling heat exchanger
24	Main expansion valve
25	Evaporator
31	Bypass expansion valve
51	Pressure sensor
61	First temperature sensor
62	Second temperature sensor

[Fig. 2]

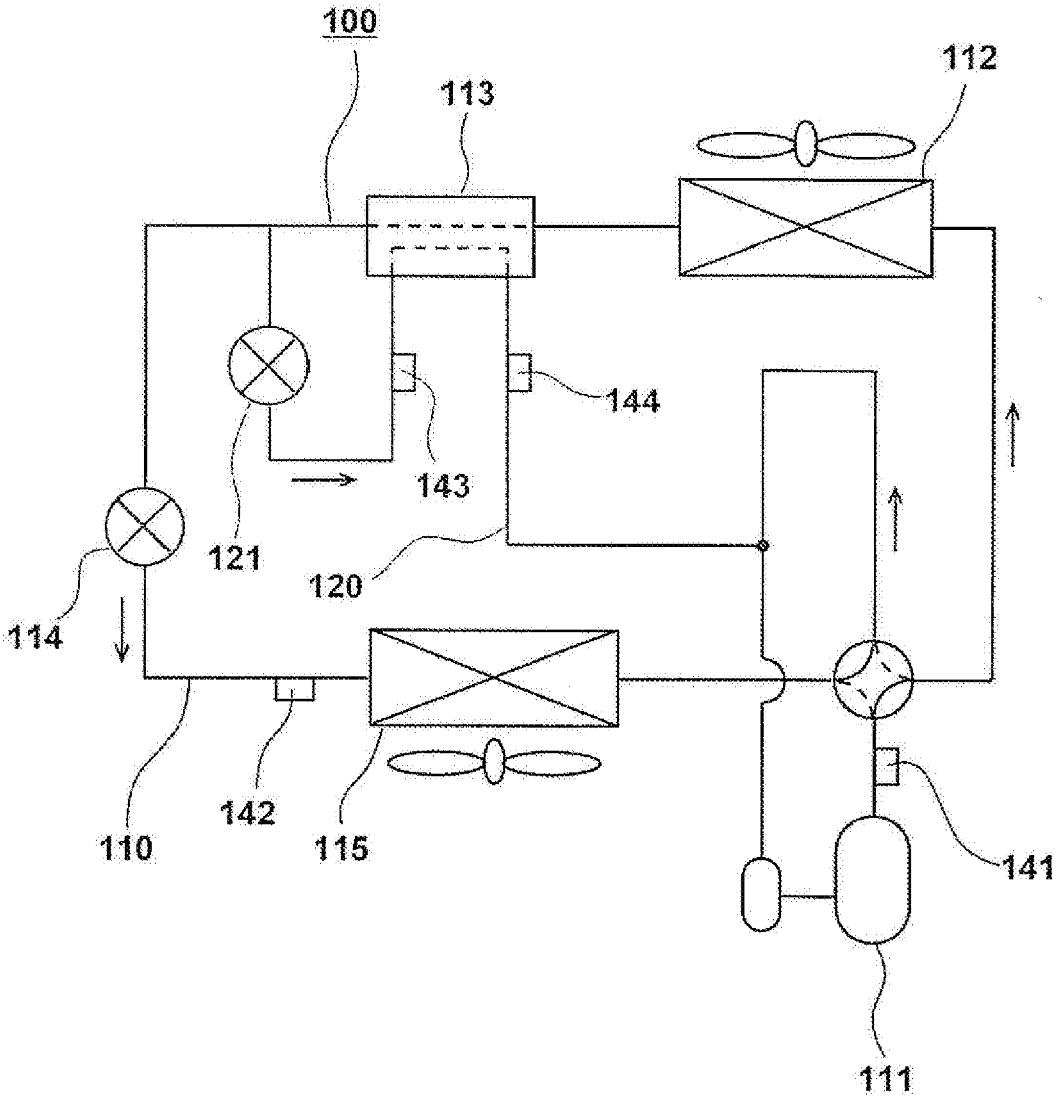

Pressure
Main refrigeration circuit
a
a'
b'
b
Bypass passage
Enthalpy

[Fig. 3]



Start
Detect discharge temperature Td, evaporator outlet temperature Teo and bypass passage outlet temperature Tbo
S1
Detect suction pressure Ps
S2
Calculate suction pressure saturation temperature STs
S3
Calculate evaporator outlet superheat degree SHe and bypass passage outlet superheat degree SHb
S4
Td < predetermined discharge temperature ?
S5
No
Yes
SHe ≥ predetermined superheat degree ?
S8
No
Yes
Adjust opening degree of bypass expansion valve such that SHb becomes equal to bypass passage outlet superheat degree control target value
S6
Adjust opening degree of main expansion valve such that Td becomes equal to discharge temperature control target value
S7
Close bypass expansion means by first operation amount
S9
Ps ≤ predetermined pressure ?
S10
No
Yes
Open main expansion valve by second operation amount
S11

[Fig. 4]



REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 10063553 A **[0003]**