



(11)

EP 2 508 821 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
24.02.2016 Bulletin 2016/08

(51) Int Cl.:
F25B 49/02 ^(2006.01) **F25B 40/02** ^(2006.01)

(21) Application number: **12163185.7**

(22) Date of filing: **04.04.2012**

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

Kältekreislaufvorrichtung und hydronisches Heizgerät mit Kältekreislaufvorrichtung

Appareil de cycle de réfrigération et dispositif de chauffage hydronique utilisant l'appareil de cycle de réfrigération

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

(30) Priority: **07.04.2011 JP 2011085142**

(43) Date of publication of application:
10.10.2012 Bulletin 2012/41

(73) Proprietor: **Panasonic Corporation
Osaka 571-8501 (JP)**

(72) Inventors:
• **Moriwaki, Shunji
Chuo-ku, OSAKA, 540-6207 (JP)**

• **Aoyama, Shigeo
Chuo-ku, OSAKA, 540-6207 (JP)**
• **Kusaka, Michiyoshi
Chuo-ku, OSAKA, 540-6207 (JP)**

(74) Representative: **Eisenführ Speiser
Patentanwälte Rechtsanwälte PartGmbB
Postfach 31 02 60
80102 München (DE)**

(56) References cited:
**EP-A1- 1 876 403 EP-A1- 1 970 653
JP-A- 2010 091 135 US-A1- 2006 048 539**

EP 2 508 821 B1

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

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, and which supercools the mainstream refrigerant.

[Background Technique]

[0002] In a conventional refrigeration cycle apparatus 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. Such a refrigeration cycle apparatus according to the preamble of claim 1 is known from US-A1-2006/0048539.

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

[0004] 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.

[0005] 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.

[0006] 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, 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 main expansion valve control unit which controls the main expansion valve 114 such that the discharge pipe temperature T_d detected by the temperature sensor 141 becomes equal to a target temperature T_d (target) of the discharge pipe of the compressor, which is set from the evaporator inlet temperature T_e detected by the temperature sensor 142, and a bypass expansion valve con-

trol unit which 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]

[0007] [Patent Document 1] Japanese Patent Application Laid-open No.H10-68553

[Summary of the Invention]

[Problem to be Solved by the Invention]

[0008] According to the conventional configuration, however, since the bypass expansion valve operates in order to control a temperature difference between an inlet of the bypass passage and an outlet of the bypass passage, that is, degree of superheat at the outlet of the bypass passage, control cannot be performed such that the refrigerant state at the bypass outlet becomes equal to a moist state.

[0009] Hence, it is necessary to limit a bypass amount, and a supercooling heat exchanger cannot be used maximally. Therefore, an operation efficiency-enhancing effect generated by a bypassing operation can not be maximized. Further, in order to suppress a case where the discharge temperature rises due to the bypassing operation when a temperature is extremely low, e.g., when an outside air temperature is -20°C , and when a connection pipe between a using-side heat exchanger and a heat source-side heat exchanger becomes long, it is necessary to lower the pressure-reducing amount of the main expansion valve and to rise an evaporation temperature, and there is a problem that the efficiency is poor and sufficient heating ability can not be secured.

[0010] The present invention has been accomplished to solve the conventional problem, and it is an object of the invention to provide a refrigeration cycle apparatus capable of securing efficiency and sufficient heating ability even when an outside air temperature is low by always controlling the refrigeration cycle apparatus into an appropriate state.

[Means for Solving the Problems]

[0011] To solve the conventional problems, 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 in this order, a bypass passage which branches off from the refrigerant circuit between the radiator and the main expansion means, and which is connected to the refrigerant circuit between the evaporator

and the compressor or is connected to a compression chamber of the compressor through the supercooling heat exchanger, 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, first saturation temperature detecting means which detects a saturation temperature of a refrigerant sucked into the compressor, a second temperature sensor which detects a temperature of a refrigerant flowing out from the radiator, and second saturation temperature detecting means which detects a saturation temperature of refrigerant in the radiator, characterized in that a control device operates the bypass expansion means such that a temperature detected by the first temperature sensor comes close to a temperature detected by the first saturation temperature detecting means when the temperature detected by the first temperature sensor is higher than the temperature detected by the first saturation temperature detecting means, and the control device operates the bypass expansion means such that a temperature detected by the second temperature sensor becomes lower than a temperature detected by the second saturation temperature detecting means by a predetermined temperature when the temperature detected by the first temperature sensor is substantially equal to the temperature detected by the first saturation temperature detecting means.

[0012] According to this, control is performed such that a bypass outlet refrigerant is always brought into a saturated state, and when the refrigerant at the outlet of the bypass passage is in the saturated state, a supercooling degree at the outlet of a radiator is appropriately controlled. Hence, excessive opening or closing of the bypass expansion means is suppressed, and a bypass amount can be optimized.

[Effect of the Invention]

[0013] According to the present invention, it is possible to provide a refrigeration cycle apparatus having excellent efficiency even when an outside air temperature is low, and capable of securing sufficient heating ability by controlling such that a refrigerant circuit state always becomes appropriate state.

[Brief Description of the Drawings]

[0014]

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 the refrigeration cycle apparatus;
 Fig. 3 is an another Mollier chart of 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.

[Explanation of Symbols]

10 [0015]

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 first pressure sensor (first saturation temperature detection means)
 52 second pressure sensor (second saturation temperature detection means)
 61 first temperature sensor
 62 second temperature sensor
 63 third temperature sensor

[Mode for Carrying Out the Invention]

[0016] A first aspect of the present invention provides a refrigeration cycle apparatus comprising 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 in this order, a bypass passage which branches off from the refrigerant circuit between the radiator and the main expansion means, and which is connected to the refrigerant circuit between the evaporator and the compressor or is connected to a compression chamber of the compressor through the supercooling heat exchanger, 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, first saturation temperature detecting means which detects a saturation temperature of a refrigerant sucked into the compressor, a second temperature sensor which detects a temperature of a refrigerant flowing out from the radiator, and second saturation temperature detecting means which detects a saturation temperature of refrigerant in the radiator, characterized in that a control device operates the bypass expansion means such that a temperature detected by the first temperature sensor comes close to a temperature detected by the first saturation temperature

detecting means when the temperature detected by the first temperature sensor is higher than the temperature detected by the first saturation temperature detecting means, and the control device operates the bypass expansion means such that a temperature detected by the second temperature sensor becomes lower than a temperature detected by the second saturation temperature detecting means by a predetermined temperature when the temperature detected by the first temperature sensor is substantially equal to the temperature detected by the first saturation temperature detecting means.

[0017] According to this, control is performed such that a bypass outlet refrigerant is always brought into a saturated state, and when the refrigerant at the outlet of the bypass passage is in the saturated state, a supercooling degree at the outlet of a radiator is appropriately controlled. Hence, excessive opening or closing of the bypass expansion means is suppressed, and a bypass amount can be optimized.

[0018] Therefore, the discharge temperature is appropriately controlled while maintaining the refrigerant state at the outlet of the bypass passage in the saturated state. Hence, it is possible to maximize the enthalpy difference increasing effect in the evaporator caused by heat exchange between the mainstream refrigerant and the bypassing refrigerant in the supercooling heat exchanger, and to maximize the pressure loss reducing effect of the low pressure-side refrigerant path caused by bypass of the refrigerant. It is possible to obtain higher operating efficiency and sufficient heating ability. It is possible to maintain efficient heating operation while suppressing the abnormal discharge temperature rise even when a temperature is extremely low, e.g., when an outside air temperature is -20°C .

[0019] According to a second aspect of the invention, in the first aspect, the refrigeration cycle apparatus further comprising a third temperature sensor which detects a temperature of a refrigerant flowing out from the evaporator, characterized in that the control device controls such that as a temperature difference between a temperature detected by the third temperature sensor and the temperature detected by the first saturation temperature detecting means is greater, a value of the predetermined temperature becomes smaller.

[0020] According to this, control is performed such that a bypass outlet refrigerant is always brought into a saturated state, and when the refrigerant at the outlet of the bypass passage is in the saturated state, a supercooling degree at the outlet of a radiator is appropriately controlled. Hence, excessive opening or closing of the bypass expansion means is suppressed, and a bypass amount can be optimized.

[0021] Therefore, in addition to the effect of the first aspect, it is possible to prevent the compressor from being damaged by moist compression, and the reliability of the compressor is enhanced.

[0022] A third aspect of the invention is a hydronic heater including the refrigeration cycle apparatus according

to the first or second aspect. According to this, 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, and the same effect as that of the first or second invention can be obtained.

[0023] An embodiment of the present invention will be explained with reference to the drawings. The invention is not limited to the embodiment.

[0024] Fig. 1 is a schematic block diagram of a refrigeration cycle apparatus according to the embodiment 1 of the invention. Fig. 2 is a Mollier chart of the refrigeration cycle apparatus. Fig. 3 is another Mollier chart of the refrigeration cycle apparatus.

[0025] In Fig. 1, the refrigeration cycle apparatus 1A includes a refrigerant circuit 2 through which a refrigerant is circulated, a bypass passage 3, and a control device 4. As a refrigerant, it is possible to use a zeotropic refrigerant mixture such as R407C, a pseudo-azeotropic refrigerant mixture such as R410A or a single refrigerant.

[0026] The refrigerant circuit 2 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. The refrigerant circuit 2 is provided with a four-way valve 28 which switches between a normal operation and a defrosting operation.

[0027] 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 is a heat exchanger which exchanges heat between a refrigerant and water to heat the water.

[0028] 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 is sent directly to a heater, or sent to the heater through a hot water tank, thereby heating a room.

[0029] In the embodiment, 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 sub-accumulator 26 and the main accumulator 27 between the evaporator 25 and 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.

[0030] In a normal operation, 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

erant 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. A state variation in a refrigerant at the time of the normal operation will be explained.

[0031] A high-pressure refrigerant discharged from the compressor 21 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.

[0032] The high-pressure refrigerant distributed to the main expansion valve 24 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.

[0033] The high-pressure refrigerant distributed to the bypass expansion valve 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.

[0034] 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 deteriorated.

[0035] To realize this, it is important that an enthalpy difference in the evaporator 25 is increased by supercooling, a refrigerant is made to bypass through the bypass passage 3 to suppress an amount of a gas-phase refrigerant which has a small heat-absorbing effect and which flows through a low-pressure side refrigerant circuit of the refrigerant circuit 2, thereby reducing a pressure loss in the low-pressure side refrigerant circuit of the refrigerant circuit 2. Here, the low-pressure side refrigerant circuit is a refrigerant circuit 2 extending from the main expansion valve 24 to the compressor 21.

[0036] If a pressure loss in the low-pressure side refrigerant circuit of the refrigerant circuit 2 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 is increased, it is possible to secure an endotherm amount in the evap-

orator 25 even if a mass flow rate of a refrigerant which passes through the evaporator 25 is reduced by the bypassing operation. That is, if a supercooling degree of a refrigerant and a bypass amount 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.

[0037] Although it will be described later in detail in the embodiment, in this embodiment, as will be described in detail later, when an outlet refrigerant of the bypass passage 3 is in a superheated state, the control device 4 controls such that the bypass expansion valve 31 is operated to bring the outlet refrigerant into a saturated state, and when the outlet refrigerant of the bypass passage 3 is in the saturated state, the control device 4 controls such that the bypass expansion valve 31 is operated to bring a supercooling degree of the outlet of the radiator 22 into a preset predetermined supercooling degree. The control device 4 controls such that as the superheating degree of the evaporator 25 is greater, the predetermined supercooling degree of the outlet of the radiator 22 becomes smaller.

[0038] According to this, a refrigerant state of the outlet of the bypass passage 3 is always controlled into saturated state as shown with points a, b and c in Fig. 2. However, even if the refrigerant state of the outlet of the bypass passage 3 is the saturated state as shown with the points a and c in Fig. 2, the bypass amount becomes excessively great or excessively small in some cases. In such a case, the supercooling degree of the outlet of the radiator 22 becomes excessively great or excessively small as shown with points a' and c' in Fig. 2 due to a difference in a decompression amount of the bypass expansion valve 31. Therefore, it can be determined that the bypass amount is inappropriate. By performing control such that the supercooling degree becomes equal to a present predetermined value (point b' in Fig. 2), the bypass amount is appropriately controlled as shown with the point b in Fig. 2.

[0039] If a length of the connection pipe becomes long due to an installation state of the device, a refrigerant amount becomes insufficient as a refrigeration cycle. Therefore, if control is performed using the same supercooling degree as an appropriate refrigerant amount is used as shown with a point a' in Fig. 3, the decomposition amount of the bypass expansion valve 31 becomes excessively great and a suction pressure is reduced. In such a case, a refrigerant state of the outlet of the evaporator 25 becomes superheated state as shown with a point a in Fig. 3. Hence, the control device 4 lowers the predetermined supercooling degree as shown with a point b' in Fig. 3. Therefore, the decompression amount of the bypass expansion valve 31 is reduced and the bypass amount is controlled into an appropriate value.

[0040] Control of the operation will be explained below. The refrigerant circuit 2 includes a first pressure sensor 51 which detects pressure (suction pressure) Ps of a re-

frigerant sucked into the compressor 21, a second pressure sensor 52 which detects a pressure (radiator outlet pressure) P_c of a refrigerant flowing out from the radiator 22, a second temperature sensor 62 which detects a temperature (radiator outlet temperature) T_{co} of a refrigerant flowing out from the radiator 22, a third temperature sensor 63 which detects a temperature (evaporator outlet temperature) T_{eo} of a refrigerant flowing out from the evaporator 25 and a fourth temperature sensor 64 which detects a temperature (discharge temperature) T_d of a refrigerant discharged from the compressor 21. The bypass passage 3 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.

[0041] The control device 4 operates the number of rotations of the compressor 21, the switching operation of the four-way valve 28, and opening degrees of the main expansion valve 24 and the bypass expansion valve 31 based on detection values of the first pressure sensor 51, the second pressure sensor 52, the first temperature sensor 61, the second temperature sensor 62, the third temperature sensor 63 and the fourth temperature sensor 64.

[0042] Fig. 4 is a block diagram showing a control device in terms of function realizing means.

[0043] The control device 4 includes discharge temperature comparing means 40 and main valve operation determining means 41 for operating the main expansion valve 24.

[0044] For operating the bypass expansion valve 31, the control device 4 includes suction saturation temperature calculating means 42, saturation temperature comparing means 43, bypass valve operation determining means 44, radiator saturation temperature calculating means 45, refrigerant supercooling degree calculating means 46, refrigerant superheating degree calculating means 47, target supercooling degree calculating means 48 and supercooling degree comparing means 49.

[0045] The discharge temperature comparing means 40 compares a discharge temperature T_d detected by the fourth temperature sensor 64 and a preset target discharge temperature T_{dm} with each other. The target discharge temperature T_{dm} is previously stored.

[0046] The main valve 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 target discharge temperature T_{dm} based on a result of comparison made by the discharge temperature comparing means 40, and outputs an operation amount determined for the main expansion valve 24.

[0047] 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 first pressure sensor 51.

[0048] 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.

[0049] 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.

[0050] The radiator saturation temperature calculating means 45 calculates a radiator saturation temperature T_c under pressure of a refrigerant flowing out from the radiator 22 from a radiator outlet pressure P_c detected by the second pressure sensor 52.

[0051] The refrigerant supercooling degree calculating means 46 calculates a refrigerant supercooling degree Sc ($T_c - T_{co}$) at the outlet of the radiator 22 from the radiator saturation temperature T_c detected by the radiator saturation temperature calculating means 45 and from a radiator outlet temperature T_{co} detected by the second temperature sensor 62.

[0052] The refrigerant superheating degree calculating means 47 calculates a refrigerant supercooling degree Sh ($T_{eo} - T_s$) at the outlet of the evaporator 25 from the suction saturation temperature T_s detected by the suction saturation temperature calculating means 42 and an evaporator outlet temperature T_{eo} detected by the third temperature sensor 63.

[0053] The target supercooling degree calculating means 48 calculates a target supercooling degree S_{ct} (e.g., $a \times Sh + b$) at the outlet of the radiator 22 from the refrigerant supercooling degree Sh detected by the refrigerant superheating degree calculating means 47.

[0054] The supercooling degree comparing means 49 compares, with each other, the refrigerant supercooling degree Sc at the outlet of the radiator 22 calculated by the refrigerant supercooling degree calculating means 46 with the target supercooling degree S_{ct} at the outlet of the radiator 22 calculated by the target supercooling degree calculating means 48.

[0055] When the saturation temperature comparing means 43 determines that the bypass passage outlet temperature T_{bo} is 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 refrigerant supercooling degree Sc at the outlet of the radiator 22 calculated by the refrigerant supercooling degree calculating means 46 becomes equal to the target supercooling degree S_{ct} at the outlet of the radiator 22 calculated by the target supercooling degree calculating means 48 based on a result of comparison carried out by the supercooling de-

gree comparing means 49, and the bypass valve operation determining means 44 outputs an operation amount determined for the bypass expansion valve 31.

[0056] In the embodiment, the control device 4 operates the main expansion valve 24 such that the discharge temperature T_d becomes equal to a preset predetermined target temperature T_{dt} at the time of the normal operation.

[0057] At the time of the normal operation, the control device 4 operates the bypass expansion valve 31 such that the bypass passage outlet temperature T_{bo} becomes equal to the suction saturation temperature T_s calculated based on the suction pressure P_s . When the bypass passage outlet temperature T_{bo} is substantially equal to the suction saturation temperature T_s , the control device 4 operates the bypass expansion valve 31 such that the refrigerant supercooling degree Sc at the outlet of the radiator 22 which is obtained by a difference between the radiator outlet temperature T_{co} and the radiator saturation temperature T_c calculated based on the radiator outlet pressure P_c becomes equal to the target supercooling degree S_{ct} at the outlet of the radiator 22 which is determined based on the evaporator outlet superheating degree Sh obtained by a difference between the suction saturation temperature T_s and the evaporator outlet temperature T_{eo} .

[0058] Next, control of the control device 4 at the time of the normal operation will be explained in detail with reference to the flowchart shown in Fig. 4.

[0059] First, the control device 4 detects the discharge temperature T_d by the fourth temperature sensor 64 (step 1), and operates the main expansion valve 24 such that the discharge temperature T_d becomes equal to the preset target discharge temperature T_{dm} (step 2).

[0060] Next, the control device 4 detects the suction pressure P_s by the first 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 first pressure sensor 51 (step 4). The suction saturation temperature T_s is calculated using a refrigerant-properties equation.

[0061] 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). 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, and 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 returns to step 1.

[0062] 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, and the procedure is shifted to a control step where the bypass amount is optimized.

[0063] The second pressure sensor 52 detects the radiator outlet pressure P_c , the second temperature sensor 62 detects the radiator outlet temperature T_{co} and the third temperature sensor 63 detects the evaporator outlet temperature T_{eo} (step 7). Then, the radiator saturation temperature T_c under a pressure of a refrigerant flowing out from the radiator 22 is calculated from the radiator outlet pressure P_c detected by the second pressure sensor 52 (step 8). The radiator saturation temperature T_c is also calculated using the refrigerant-properties equation.

[0064] Thereafter, the control device 4 calculates the refrigerant supercooling degree Sc at the outlet of the radiator 22 by $Sc = T_c - T_{co}$, calculates the refrigerant superheating degree Sh at the outlet of the evaporator 25 by $Sh = T_{eo} - T_s$ (step 9), and calculates the target supercooling degree S_{ct} at the outlet of the radiator 22 by an equation such as $S_{ct} = axSh + b$ (step 10). Here, a and b are coefficients, and a is a positive real number.

[0065] The control device 4 adjusts the opening degree of the bypass expansion valve 31 such that the refrigerant supercooling degree Sc at the outlet of the radiator 22 becomes equal to the target supercooling degree S_{ct} at the outlet of the radiator 22 (step 11), and the procedure returns to step 1.

[0066] As described above, according to this embodiment, the refrigerant circuit 2 includes the first pressure sensor 51 which detects a pressure of a refrigerant sucked into the compressor 21, the second pressure sensor 52 which detects a pressure of a refrigerant flowing out from the radiator 22, the second temperature sensor 62 which detects a temperature of the refrigerant flowing out from the radiator 22, the third temperature sensor 63 which detects a temperature of a refrigerant flowing out from the evaporator 25, the fourth temperature sensor 64 which detects a temperature of a refrigerant discharged from the compressor 21, and the first temperature sensor 61 which detects a temperature of a refrigerant flowing out from the supercooling heat exchanger 23 in the bypass passage 3.

[0067] The control device 4 operates the main expansion valve 24 such that the discharge temperature T_d detected by the fourth temperature sensor 64 becomes equal to the predetermined target temperature T_{dt} , and if the bypass passage outlet temperature T_{bo} detected by the first temperature sensor 61 is not equal to the suction saturation temperature T_s calculated based on the suction pressure P_s detected by the first pressure sensor 51, the control device 4 operates the bypass expansion valve 31 such that the bypass passage outlet temperature T_{bo} becomes equal to the suction saturation temperature T_s .

[0068] When the bypass passage outlet temperature

Tbo is substantially equal to the suction saturation temperature Ts, the control device 4 operates the bypass expansion valve 31 such that the refrigerant supercooling degree Sc at the outlet of the radiator 22 obtained by a difference between the radiator outlet temperature Tco and the radiator saturation temperature Tc which is calculated based on the radiator outlet pressure Pc detected by the second pressure sensor 52 becomes equal to the target supercooling degree Sct at the outlet of the radiator 22 determined based on the evaporator outlet superheating degree Sh obtained by a difference between the suction saturation temperature Ts and the evaporator outlet temperature Teo.

[0069] According to this, control is performed such that the refrigerant at the outlet of the bypass passage 3 is always brought into the saturated state and when the refrigerant at the outlet of the bypass passage 3 is in the saturated state, a supercooling degree at the outlet of a radiator 22 is appropriately controlled. Hence, excessive opening or closing of the bypass expansion valve 31 is suppressed, and a bypass amount can be optimized.

[0070] Therefore, it is possible to maximize an enthalpy difference increasing effect in the evaporator 25 obtained by heat exchange between the mainstream refrigerant and the bypassing refrigerant carried out by the supercooling heat exchanger 23, and a pressure loss reducing effect in the low pressure side refrigerant path caused by bypassing of a refrigerant, and even when an outside air temperature is extremely low as low as -20°C, it is possible to obtain higher operation efficiency and sufficient heating ability while suppressing abnormal rise in the discharge temperature Td.

[0071] Further, also when a refrigerant connection pipe between the radiator 22 and the evaporator 25 becomes long, a gas amount insufficient state is detected, and it is possible to maintain efficient heating operation while preventing reduction in the suction pressure Ps caused by excessive closing of the bypass expansion valve 31. Therefore, installation flexibility of the device is also enhanced.

[0072] Although the first pressure sensor 51 is provided between the main accumulator 27 and the position of the refrigerant circuit 2 to which the bypass passage 3 is connected in Fig. 1, the first pressure sensor 51 may be provided at any position of the refrigerant circuit 2 only if the first pressure sensor 51 is provided between the evaporator 25 and the compressor 21. Alternatively, the first pressure sensor 51 may be provided at the bypass passage 3 at a location downstream of the supercooling heat exchanger 23.

[0073] Although the first pressure sensor 51 calculates the suction saturation temperature Ts 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 Ts.

[0074] Although the second pressure sensor 52 is pro-

vided at a position of the outlet of the radiator 22 in the refrigerant circuit 2, but the second pressure sensor 52 may be provided at any position of the refrigerant circuit 2 only if the position is between the compressor 21 and the main expansion valve 24. It is more preferable if a pressure loss between the position of the outlet of the radiator 22 and the position of the second pressure sensor 52 is calculated from a flow rate of a refrigerant and the loss is corrected.

[0075] Although the radiator saturation temperature Tc is calculated by the second pressure sensor 52, a temperature of a portion where a high pressure two-phase refrigerant in the radiator 22 flows may be detected and a result thereof may be used instead of the radiator saturation temperature Tc.

[0076] 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.

[0077] 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.

[0078] 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 controlled by varying a load by means of a power generator connected to the expansion device.

[Industrial Applicability]

[0079] 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 (1A) comprising a refrigerant circuit (2) in which a compressor (21), a radiator (22), a supercooling heat exchanger (23), main expansion means (24) and an evaporator (25) are annularly connected to one another in this order, a bypass passage (3) which branches off from the refrigerant circuit between the radiator and the main expansion means, and which is connected to the refrigerant circuit between the evaporator and the compressor or is connected to a compression chamber of the compressor through the supercooling heat exchanger, bypass expansion means (31) provided in the by-

pass passage at a location upstream of the supercooling heat exchanger,
 a first temperature sensor (61) which detects a temperature of a refrigerant flowing out from the supercooling heat exchanger, 5
 first saturation temperature detecting means (51) which detects a saturation temperature of a refrigerant sucked into the compressor,
 a second temperature sensor (62) which detects a temperature of a refrigerant flowing out from the radiator, and 10
 second saturation temperature detecting means (52) which detects a saturation temperature of refrigerant in the radiator, **characterized in that**
 a control device (4) operates the bypass expansion means such that a temperature detected by the first temperature sensor comes close to a temperature detected by the first saturation temperature detecting means when the temperature detected by the first temperature sensor is higher than the temperature detected by the first saturation temperature detecting means, and the control device operates the bypass expansion means such that a temperature detected by the second temperature sensor becomes lower than a temperature detected by the second saturation temperature detecting means by a predetermined temperature when the temperature detected by the first temperature sensor is substantially equal to the temperature detected by the first saturation temperature detecting means. 30

2. The refrigeration cycle apparatus according to claim 1, further comprising
 a third temperature sensor which detects a temperature of a refrigerant flowing out from the evaporator, **characterized in that**
 the control device controls such that as a temperature difference between a temperature detected by the third temperature sensor and the temperature detected by the first saturation temperature detecting means is greater, a value of the predetermined temperature becomes smaller. 40
3. A hydronic heater including the refrigeration cycle apparatus according to claim 1 or 2. 45

Patentansprüche

1. Kühlkreislaufvorrichtung (1A), enthaltend: 50
 einen Kühlkreislauf (2), in welchem ein Kompressor (21), ein Radiator (22), ein Unterkühlungs-Wärmetauscher (23), Hauptexpansionsmittel (24) und ein Verdampfer (25) in dieser Reihenfolge ringförmig miteinander verbunden sind, 55
 einen Bypasskanal (3), welcher von dem Kühl-

kreislauf zwischen dem Radiator und den Hauptexpansionsmitteln abzweigt und welcher mit dem Kühlkreislauf zwischen dem Verdampfer und dem Kompressor oder mit einer Kompressionskammer des Kompressors über den Unterkühlungs-Wärmetauscher verbunden ist, Bypassexpansionsmittel (31), die in dem Bypasskanal an einem Ort stromaufwärts des Unterkühlungs-Wärmetauscher vorgesehen sind, einen ersten Temperatursensor (61), welcher eine Temperatur eines Kühlmittels erfasst, das aus dem Unterkühlungs-Wärmetauscher (23) austritt,
 erste Sättigungstemperatur-Erfassungsmittel (51), welche eine Sättigungstemperatur eines Kühlmittels erfassen, das in den Kompressor eingesaugt wird,
 einen zweiten Temperatursensor (62), welcher eine Temperatur eines Kühlmittels erfasst, das aus dem Radiator austritt, und
 zweite Sättigungstemperatur-Erfassungsmittel (52), welche eine Sättigungstemperatur des Kühlmittels in dem Radiator erfassen, **dadurch gekennzeichnet, dass** eine Steuereinrichtung (4) die Bypassexpansionsmittel in der Weise betreibt, dass sich eine Temperatur, die durch den ersten Temperatursensor erfasst wird, einer Temperatur, welche durch die ersten Sättigungstemperatur-Erfassungsmittel erfasst wird, annähert, wenn die Temperatur, die durch den ersten Temperatursensor erfasst wird, höher ist als die Temperatur, die durch die ersten Sättigungstemperatur-Erfassungsmittel erfasst wird, und die Steuereinrichtung die Bypassexpansionsmittel in der Weise betreibt, dass eine Temperatur, die durch den zweiten Temperatursensor erfasst wird, um eine vorbestimmte Temperatur kleiner wird als eine Temperatur, die durch die zweiten Sättigungstemperatur-Erfassungsmittel erfasst wird, wenn die Temperatur, die durch den ersten Temperatursensor erfasst wird, im Wesentlichen gleich ist der Temperatur, die durch die ersten Sättigungstemperatur-Erfassungsmittel erfasst wird.

2. Kühlkreislaufvorrichtung nach Anspruch 1, weiterhin enthaltend:

einen dritten Temperatursensor, der eine Temperatur eines Kühlmittels erfasst, welches aus dem Verdampfer austritt, **dadurch gekennzeichnet, dass** die Steuereinrichtung in der Weise steuert, dass, wenn eine Temperaturdifferenz zwischen einer Temperatur, die durch den dritten Temperatursensor erfasst wird, und der Temperatur, die durch die ersten Sättigungstemperatur-Erfassungsmittel erfasst wird, größer wird, ein Wert der vorbe-

stimmten Temperatur kleiner wird.

3. Hydraulikeinrichtung, enthaltend die Kühlkreislaufvorrichtung nach Anspruch 1 oder 2.

5

Revendications

1. Dispositif à cycle frigorifique (1A) comprenant:

10

un circuit frigorifique (2) dans lequel un compresseur (21), un radiateur (22), un échangeur de chaleur de super-réfrigération (23), des moyens principaux de détente (24) et un évaporateur (25) sont reliés, dans cet ordre, de façon annulaire les uns aux autres,

15

un canal de dérivation (3) qui est en dérivation du circuit frigorifique entre ledit radiateur et lesdits moyens principaux de détente et qui est relié au circuit frigorifique entre l'évaporateur et le compresseur ou est relié à une chambre de compression du compresseur par ledit échangeur de chaleur de super-réfrigération, des moyens de détente de dérivation (31) prévus dans le canal de dérivation à un endroit situé en amont de l'échangeur de chaleur de super-réfrigération,

20

25

un premier capteur de température (61) qui détecte une température d'un réfrigérant sortant de l'échangeur de chaleur de super-réfrigération (23),

30

des premiers moyens de détection de température de saturation (51) qui détectent une température de saturation d'un réfrigérant aspiré dans le compresseur,

35

un deuxième capteur de température (62) qui détecte une température d'un réfrigérant sortant du radiateur, et

des deuxièmes moyens de détection de température de saturation (52) qui détectent une température de saturation du réfrigérant dans le radiateur,

40

caractérisé par le fait qu'un dispositif de commande (4) actionne les moyens de détente de dérivation de telle sorte qu'une température détectée par le premier capteur de température se rapproche d'une température détectée par les premiers moyens de détection de température de saturation, lorsque la température détectée par le premier capteur de température est supérieure à la température détectée par les premiers moyens de détection de température de saturation, et le dispositif de commande actionne les moyens de détente de dérivation de telle sorte qu'une température détectée par le deuxième capteur de température devient inférieure d'une température prédéterminée à une température détectée par les deuxièmes

45

50

55

moyens de détection de température de saturation, lorsque la température détectée par le premier capteur de température est pour l'essentiel égale à la température détectée par les premiers moyens de détection de température de saturation.

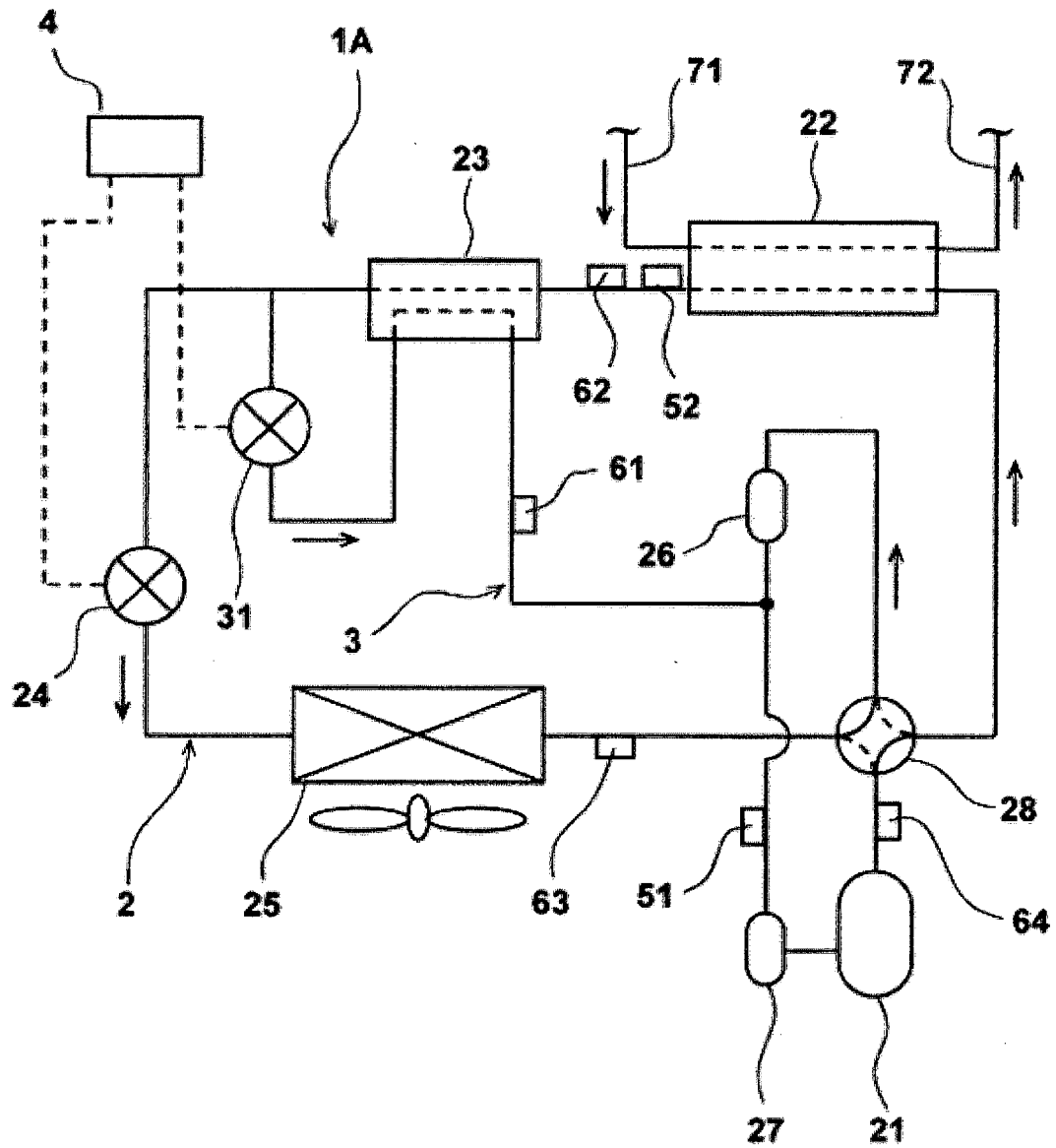
2. Dispositif à cycle frigorifique selon la revendication 1, comprenant en outre:

un troisième capteur de température qui détecte une température d'un réfrigérant sortant de l'évaporateur,

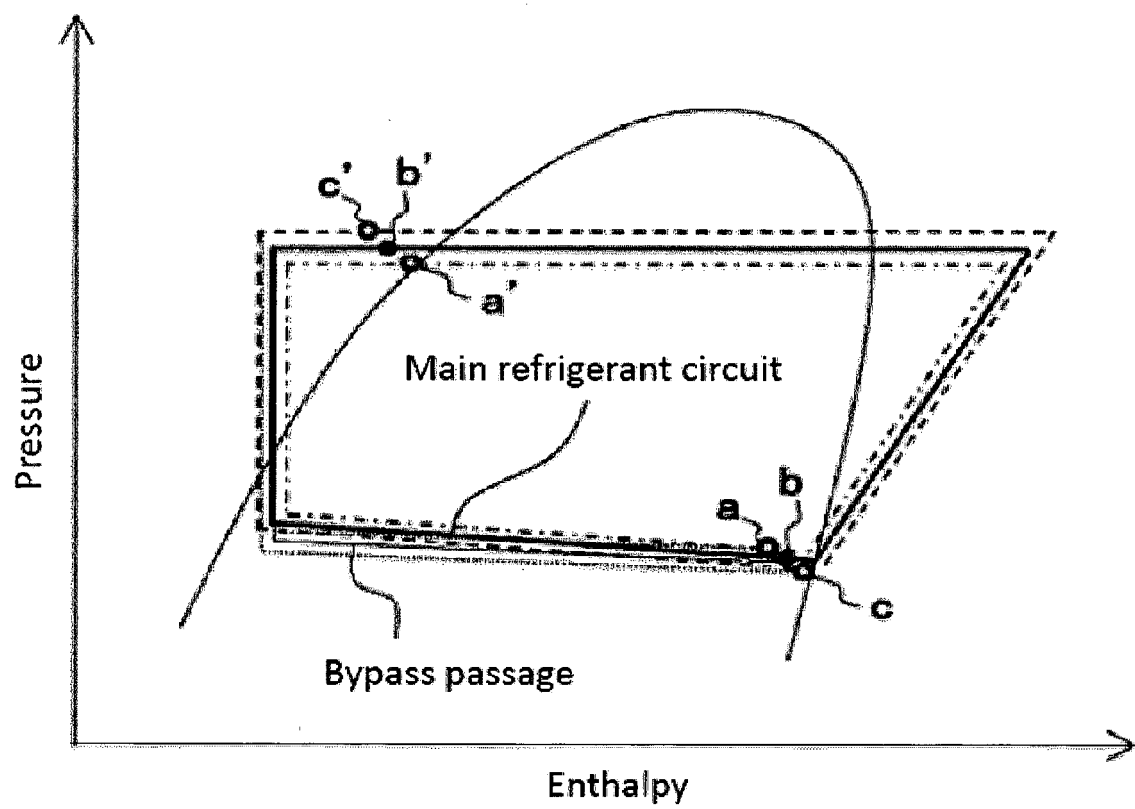
caractérisé par le fait que le dispositif de commande commande de telle sorte que, lorsqu'une différence de température entre une température détectée par le troisième capteur de température et la température détectée par les premiers moyens de détection de température de saturation devient plus grande, une valeur de la température prédéterminée devient plus petite.

3. Dispositif de chauffage hydraulique comprenant le dispositif à cycle frigorifique selon la revendication 1 ou 2.

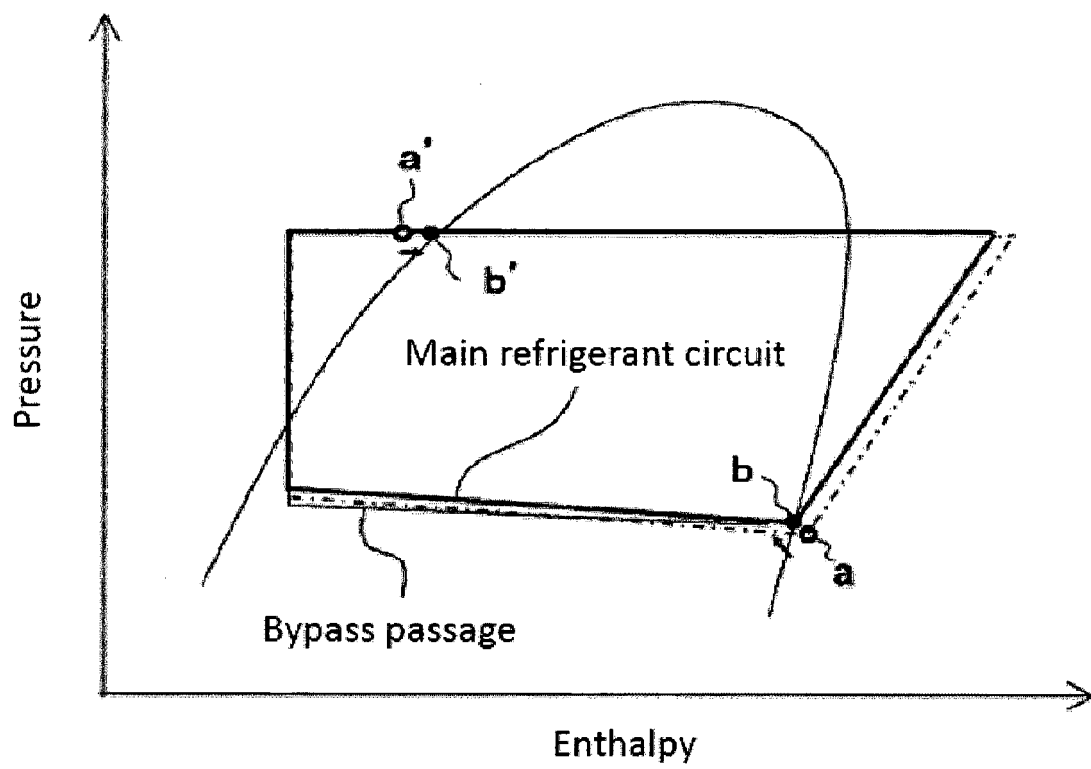
[Fig. 1]



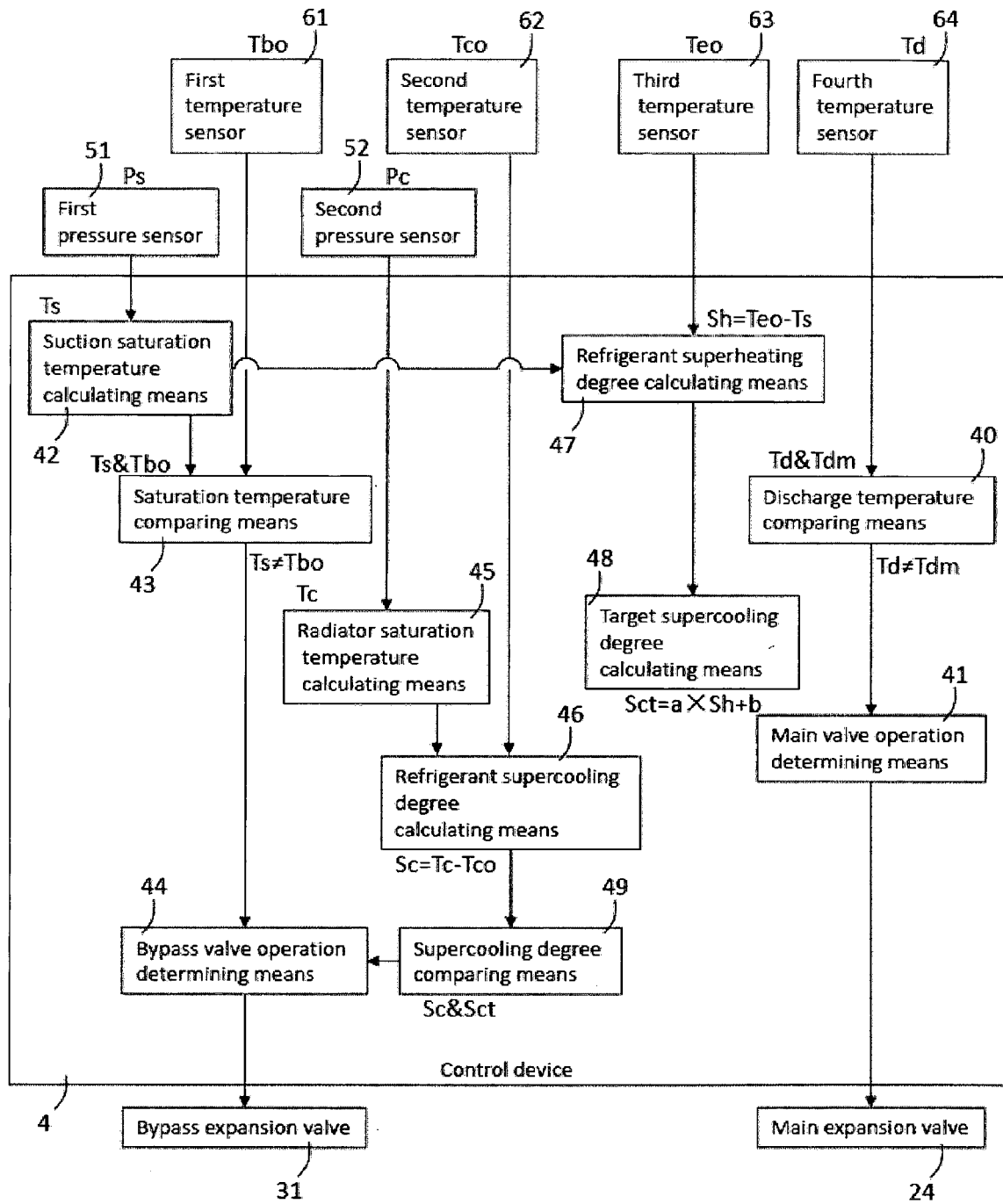
[Fig. 2]



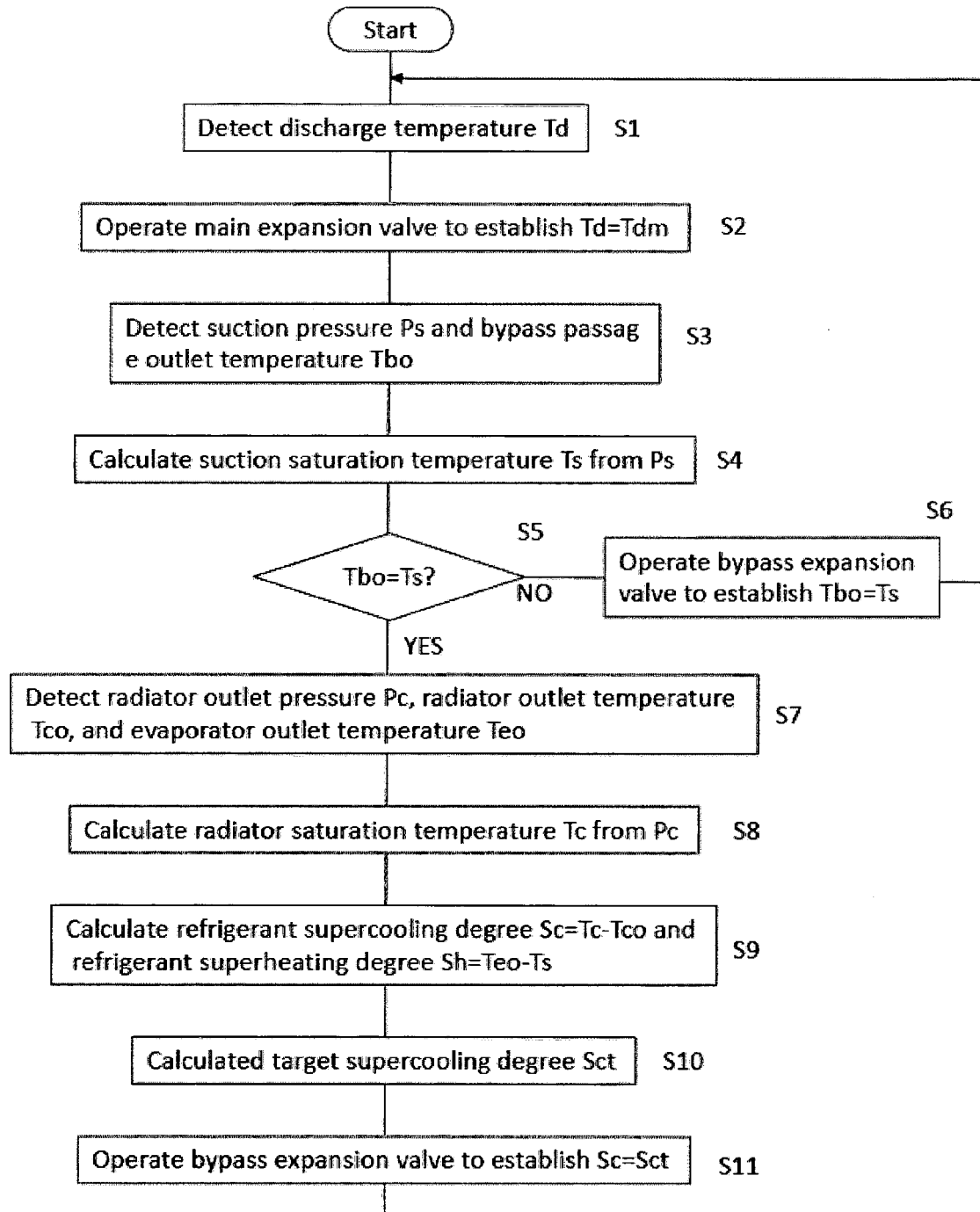
[Fig. 3]



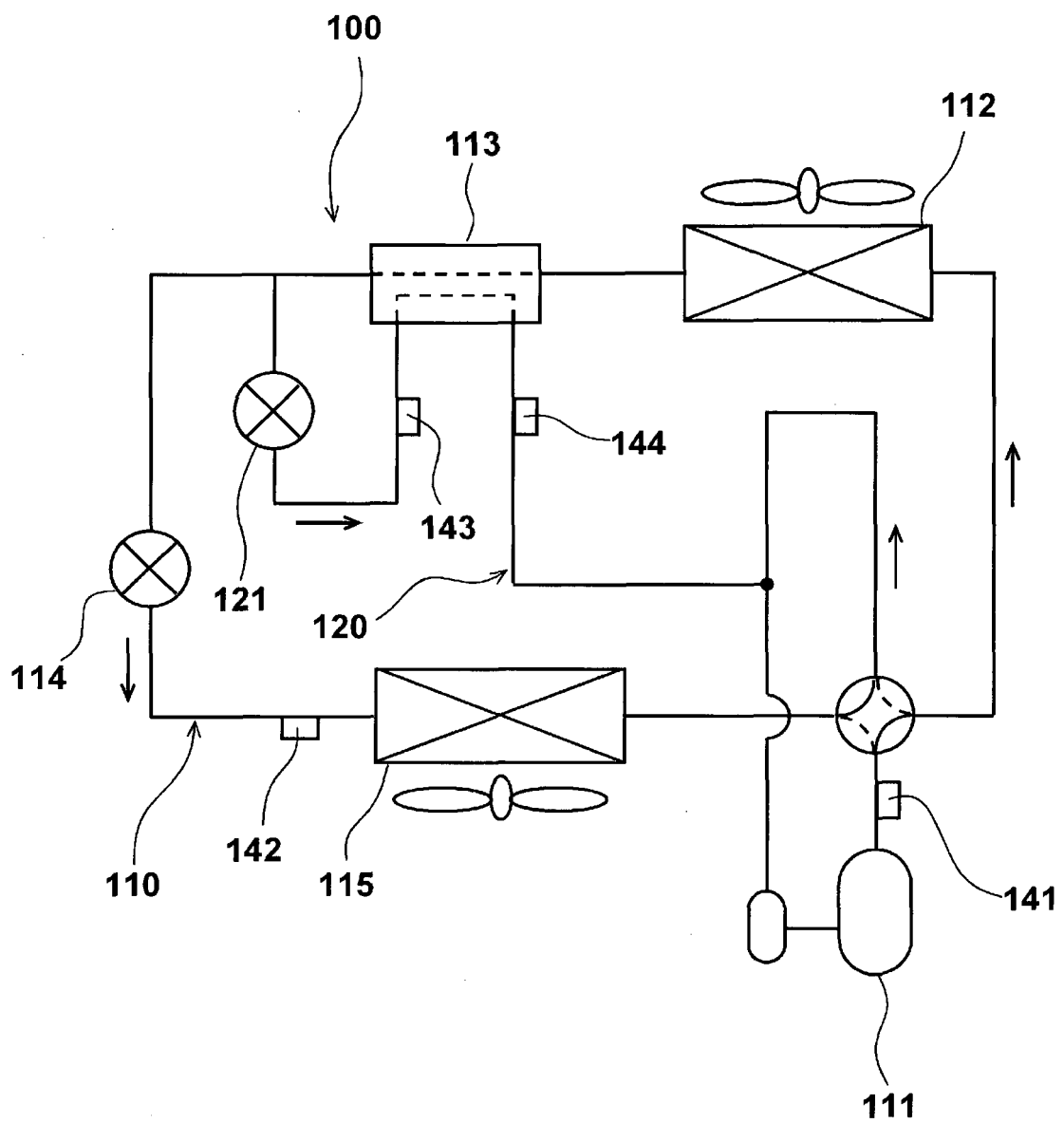
[Fig. 4]



[Fig. 5]



[Fig. 6]



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 20060048539 A1 [0002]
- JP H1068553 A [0007]