



EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.11.2022 Bulletin 2022/46

(21) Application number: **22171958.6**

(22) Date of filing: **06.05.2022**

(51) International Patent Classification (IPC):
F25B 1/10 (2006.01) **F25B 25/00** (2006.01)
F25B 41/00 (2021.01) **F25B 40/00** (2006.01)
F25B 49/02 (2006.01) **F25B 1/04** (2006.01)
F25B 9/00 (2006.01)

(52) Cooperative Patent Classification (CPC):
F25B 1/10; F25B 1/04; F25B 9/008; F25B 25/005;
F25B 40/00; F25B 41/00; F25B 49/02;
F25B 2339/047; F25B 2600/025; F25B 2700/1931;
F25B 2700/1933; F25B 2700/2101;
F25B 2700/21161

(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
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **12.05.2021 JP 2021081277**

(71) Applicant: **Panasonic Intellectual Property Management Co., Ltd.**
Osaka-shi, Osaka 540-6207 (JP)

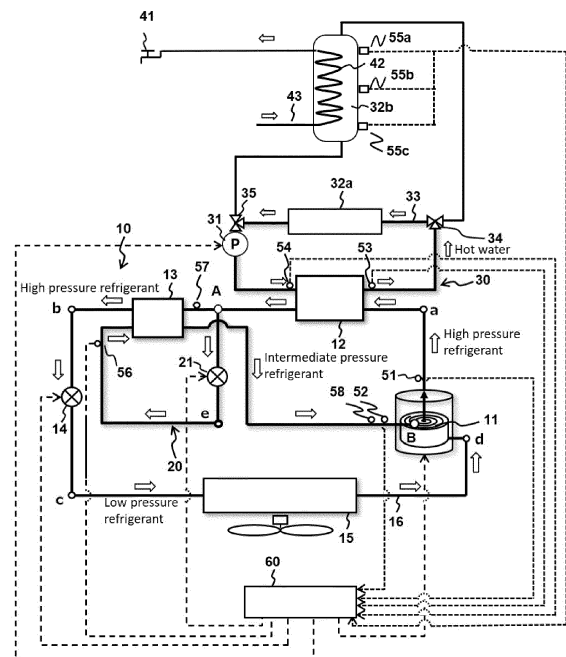
(72) Inventors:
• **IMAGAWA, Tsuneko**
Osaka, 540-6207 (JP)
• **YAMAOKA, Yuki**
Osaka, 540-6207 (JP)

(74) Representative: **Eisenführ Speiser**
Patentanwälte Rechtsanwälte PartGmbB
Arnulfstraße 27
80335 München (DE)

(54) **REFRIGERATION CYCLE DEVICE AND LIQUID HEATING DEVICE HAVING THE SAME**

(57) A refrigeration cycle device includes a main refrigerant circuit 10, a bypass refrigerant circuit 20, a pre-cooling temperature sensor for detecting temperature of refrigerant flowing through the bypass refrigerant circuit 20 located upstream of an intermediate heat exchanger 13, a post-cooling temperature sensor for detecting temperature of refrigerant flowing through the bypass refrigerant circuit 20 located downstream of the intermediate heat exchanger 13, and a control device 60, wherein the control device 60 calculates a degree of superheat of the refrigerant which merges with the compression rotating element based on temperature data acquired from the pre-cooling temperature sensor 56 and from the post-cooling temperature sensor 58, and when the calculated degree of superheat is lower than a predetermined value, the control device 60 operates to reduce a valve opening degree of the second expanding device 21, and the degree of superheat of refrigerant after it passes through the supercooling heat exchanger is made equal to or higher than the predetermined value. According to this, the present invention provides a reliably refrigeration cycle device and a liquid heating device having the same which prevents liquid back.

[Fig. 1]



Description

[PRIOR ART DOCUMENTS]

[TECHNICAL FIELD]

[PATENT DOCUMENTS]

[0001] The present invention relates to a refrigeration cycle device and a liquid heating device having the same.

5 **[0007]**

[BACKGROUND TECHNIQUE]

[Patent Document 1] Japanese Patent Application Laid-open No.2010-071643

[Patent Document 2] Japanese Patent Application Laid-open No.2009-192164

[0002] Patent document 1 discloses a supercritical steam compression type refrigeration cycle including a compressor which compresses refrigerant in two stages, and two expanding devices which expand refrigerant in two stages. Carbon dioxide is used as refrigerant.

10

[SUMMARY OF THE INVENTION]

[0003] The supercritical steam compression type refrigeration cycle of patent document 1 includes a gas-liquid separator. Refrigerant having gas phase in the gas-liquid separator as main component is intermediately injected into a refrigerant mixer located on the way to an intermediate connection circuit of the compressor from the injection circuit. The refrigerant is mixed into refrigerant discharged from a low-stage side rotation compression rotating element, and the mixed refrigerant is sucked into a high-stage side rotation compression rotating element.

15

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0004] In patent document 1, a ratio (displacement capacity ratio) of displacement capacity of the high-stage side rotation compression rotating element in comparison with displacement capacity of the low-stage side rotation compression rotating element is equal to or higher than isentropic index root of quotient obtained by dividing suction pressure of the compressor by refrigerant saturated liquid pressure in a first expanding device. According to this, discharge pressure of the low-stage side rotation compression rotating element is set equal to or lower than critical pressure of the refrigerant.

20

[0008] However, according to the above-described conventional configuration, the intermediate port is connected directly to a compression chamber of the compressor, and refrigerant which passes through the supercooling heat exchanger (intermediate heat exchanger) is injected into the compression chamber. In the case of the compressor having such a configuration that injected refrigerant and refrigerant which is on the way to be compressed are mixed in the compression chamber and again compressed in this way, if the injected refrigerant is liquid refrigerant, there is a problem that liquid back is generated, and reliability of the compressor is deteriorated. Further, it is difficult to directly measure a degree of superheat of refrigerant which is obtained after refrigerant injected in the compression chamber and refrigerant which is on the way to be compressed are mixed with each other.

25

[0005] Further, as refrigerant, patent document 2 uses refrigerant other than carbon dioxide. Patent document 2 discloses a refrigeration device including a compressor which compresses refrigerant in two stages, and two expanding devices which expand refrigerant in two stages.

30

[0009] The present invention is for solving the above problem, and it is an object of the invention to provide a reliable refrigeration cycle device which prevents liquid back by bringing, equal to or higher than a predetermined value, a degree of superheat of refrigerant after it passes through an intermediate heat exchanger. It is another object of the invention to provide a liquid heating device having the above-described refrigeration cycle device.

35

[0006] The refrigeration device of patent document 2 includes a supercooling heat exchanger and an injection circuit. The injection circuit decompresses a portion of refrigerant discharged from the compressor by a bypass expansion valve, and the decompressed refrigerant is heated by the supercooling heat exchanger. Thereafter, the heated decompressed refrigerant is injected into the intermediate port which is in communication with a low-stage side and a high-stage side of the compressor. Refrigerant from the injection circuit and refrigerant discharged from the low stage are mixed with each other in the intermediate port. The mixed refrigerant is sucked into the high-stage side rotating element. An opening degree of the bypass expansion valve is adjusted in accordance with a degree of superheat of the sucked refrigerant, thereby preventing liquid from returning to the compressor.

40

[MEANS FOR SOLVING THE PROBLEM]

[0010] To solve the conventional problem, a refrigeration cycle device of the present invention including: a main refrigerant circuit formed by sequentially connecting, to one another through a pipe, a compression mechanism composed of a compression rotating element, a use-side heat exchanger for heating use-side heat medium by refrigerant discharged from the compression rotating element, an intermediate heat exchanger, a first expanding device and a heat source-side heat exchanger; a bypass refrigerant circuit which branches off from the pipe between the use-side heat exchanger and the first expanding device, in which after the refrigerant which is branched is decompressed by a second expanding device, the branched refrigerant exchanges heat, in the intermediate heat exchanger, with the refrigerant flowing

45

50

55

through the main refrigerant circuit, and merges with refrigerant which is on the way of compression of the compression rotating element; a pre-cooling temperature sensor for detecting temperature of the refrigerant flowing through the bypass refrigerant circuit located upstream of the intermediate heat exchanger; a post-cooling temperature sensor for detecting temperature of the refrigerant flowing through the bypass refrigerant circuit located downstream of the intermediate heat exchanger; and a control device, wherein the control device calculates a degree of superheat of the refrigerant which merges with the compression rotating element based on temperature data acquired from the pre-cooling temperature sensor and from the post-cooling temperature sensor, and when the calculated degree of superheat is lower than a predetermined value, the control device operates to reduce a valve opening degree of the second expanding device.

[0011] According to this, it is possible to prevent the liquid back which is generated when liquid refrigerant is mixed into the compression chamber of the compression rotating element.

[EFFECT OF THE INVENTION]

[0012] According to the present invention, it is possible to prevent the increase of the vibration of a compression mechanism which is caused by generation of the liquid back, and it is possible to secure the reliability of the compression mechanism. Especially, when the second expansion valve is opened to a predetermined position at the time of actuation, it is possible to prevent refrigerant from being gasified and from being injected while keeping its liquid state. Hence, it is possible to provide a reliable refrigeration cycle device and a liquid heating device having the same.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0013]

Fig. 1 is a block diagram of a liquid heating device according to an embodiment of the present invention;

Figs. 2(a) and (b) are pressure-enthalpy diagrams (P-h diagrams) under an ideal condition concerning a refrigeration cycle device; and

Fig. 3 is a flowchart of control of a bypass expansion valve in the embodiment.

[MODE FOR CARRYING OUT THE INVENTION]

(Knowledge and the like which become a foundation of present disclosure)

[0014] In a refrigeration cycle in which refrigerant heated by an inter-cooler is injected into a compression chamber, an optimum injection amount differs depending upon

outside temperature and water temperature at the time of operation. Hence, it is a general control method to adjust the injection amount of refrigerant by a pressure reducing valve. However, when the injection amount is adjusted, the injection amount of refrigerant becomes too much, intermediate pressure-side refrigerant cannot entirely evaporate and flows into the compressor in its liquid state. Therefore, liquid compression is generated, and reliability of the compressor is deteriorated in some cases. Generally, to secure the reliability of the compressor, control is performed to prevent the liquid compression on the suction side. Not only that, in the case of a refrigeration cycle in which injection is carried out, it is necessary to also take the liquid compression in the injection. To solve this problem, the subject matter of the present disclosure is configured.

[0015] The present disclosure provides a reliable refrigeration cycle device which prevents liquid back of refrigerant which is injected after it passes through an intermediate heat exchanger, and also provides a liquid heating device having the same.

[0016] An embodiment will be described in detail below with reference to the drawings. However, description which is detail more than necessary will be omitted in some cases. For example, detailed description of already well known matters, or redundant description of substantially the same configuration will be omitted in some cases. This is for preventing the following description from becoming redundant more than necessary, and for making it easy for a person skilled in the art to understand the present disclosure.

[0017] The accompanying drawing and the following description are provided so that a person skilled in the art can sufficiently understand the present disclosure, and it is not intended that they limit the subject matter described in claims.

(Embodiment)

40 [1-1. Configuration]

[0018] Fig. 1 is a block diagram of a liquid heating device according to an embodiment. The liquid heating device is composed of a use-side heat medium circuit 30, and a refrigeration cycle device which is a supercritical steam compression type refrigeration cycle. The refrigeration cycle device is composed of a main refrigerant circuit 10 and a bypass refrigerant circuit 20.

[0019] The main refrigerant circuit 10 is formed by sequentially connecting, to one another through a pipe 16, a compression mechanism 11 which compresses refrigerant, a radiator 12 which is a use-side heat exchanger, an economizer 13 which is an intermediate heat exchanger, a main expansion valve 14 which is a first expanding device, and an evaporator 15 which is a heat source-side heat exchanger. Carbon dioxide (CO₂) is used as the refrigerant.

[0020] As the refrigerant, it is optimal to carbon dioxide,

but it is also possible to use zeotropic refrigerant mixture such as R407C, pseudo azeotropic refrigerant mixture such as R410A, single refrigerant such as R32, and flammable refrigerant such as propane.

[0021] The compression mechanism 11 injects refrigerant from the bypass refrigerant circuit 20 on the way of compression of refrigerant by the rotating element, the compression mechanism 11 makes the refrigerant from the bypass refrigerant circuit 20 and the refrigerant which is on the way of compression merge with each other, and the compression mechanism 11 again compresses them. The radiator 12 heats the use-side heat medium by the refrigerant discharged from the compression mechanism 11.

[0022] The bypass refrigerant circuit 20 branches off from the pipe 16 located between the radiator 12 and the main expansion valve 14, and the bypass refrigerant circuit 20 is connected to the compression chamber which is on the way of compression of the compression mechanism 11.

[0023] The bypass refrigerant circuit 20 is provided with a bypass expansion valve 21 which is a second expanding device. A portion of high pressure refrigerant after it passes through the radiator 12 or a portion of high pressure refrigerant after it passes through the economizer 13 is decompressed by the bypass expansion valve 21 and becomes intermediate pressure refrigerant. Thereafter, the intermediate pressure refrigerant exchanges, in the economizer 13, heat with high pressure refrigerant which flows through the main refrigerant circuit 10, the intermediate pressure refrigerant is injected into the rotating element of the compression mechanism 11, and the intermediate pressure refrigerant merges with refrigerant which is on the way of compression of the main refrigerant circuit 10.

[0024] The use-side heat medium circuit 30 is formed by sequentially connecting the radiator 12, a transfer pump 31 which is a transfer device and heating terminal 32a to one another through a heat medium pipe 33. Water or antifreeze liquid is used as the use-side heat medium.

[0025] The use-side heat medium circuit 30 in the embodiment includes a heating terminal 32a and a hot water tank 32b located in parallel thereto. By switching between a first switching valve 34 and a second switching valve 35, the use-side heat medium is circulated through the heating terminal 32a or the hot water tank 32b. It is only necessary that the use-side heat medium circuit 30 includes any one of the heating terminal 32a and the hot water tank 32b.

[0026] High temperature water produced by the radiator 12 radiates heat in the heating terminal 32a, the heat is used for heating homes, and low temperature water which radiates heat in the heating terminal 32a is again heated by the radiator 12.

[0027] The high temperature water produced by the radiator 12 is introduced into the hot water tank 32b from an upper portion of the hot water tank 32b, low temperature water is derived from a lower portion of the hot

water tank 32b and is heated by the radiator 12.

[0028] A hot water supply-heat exchanger 42 is placed in the hot water tank 32b, and exchanges heat between water supplied from the water supply pipe 43 and high temperature water in the hot water tank 32b. That is, if the hot water tap 41 is opened, water is supplied from the water supply pipe 43 into the hot water supply-heat exchanger 42. The water is heated by the hot water supply-heat exchanger 42, temperature of the water is adjusted to a predetermined value by the hot water tap 41, and hot water is supplied from the hot water tap 41. Water is supplied from the water supply pipe 43 and is heated by the hot water supply-heat exchanger 42. Hot water supplied from the hot water tap 41 and high temperature water in the hot water tank 32b are not mixed with each other and they are heated indirectly.

[0029] The hot water supply-heat exchanger 42 is a water heat exchanger using a copper pipe or a stainless pipe as a heattransfer pipe. As shown in Fig. 1, the hot water supply-heat exchanger 42 is connected to the water supply pipe 43 and the hot water tap 41 extending from a water-supply source (waterline). The water supply pipe 43 introduces ordinary temperature water to a lower end of the hot water supply-heat exchanger 42, i.e., to a lower portion in the hot water tank 32b. The ordinary temperature water introduced from the water supply pipe 43 into the hot water supply-heat exchanger 42 takes heat from high temperature water in the hot water tank 32b while moving upward from a lower portion in the hot water tank 32b. The ordinary temperature water becomes high temperature heated water and is supplied from the hot water tap 41.

[0030] In the hot water tank 32b, a plurality of hot water tank temperature thermistors measure temperature of hot water at a plurality of different height positions. For example, a first hot water tank temperature thermistor 55a, a second hot water tank temperature thermistor 55b and a third hot water tank temperature thermistor 55c are provided. The ordinary temperature Water which enters the hot water supply-heat exchanger 42 from the water supply pipe 43 takes heat from high temperature water in the hot water tank 32b while moving upward from a lower portion in the hot water tank 32b. Hence, temperature of the hot water in the hot water tank 32b naturally becomes high in its upper portion and lower in its lower portion.

[0031] The main refrigerant circuit 10 is provided with a high pressure-side pressure detecting device 51 in the pipe 16 on a discharge-side of the compression mechanism 11. The high pressure-side pressure detecting device 51 is provided in the main refrigerant circuit 10 from a discharge-side of the compression mechanism 11 to an upstream-side of the main expansion valve 14. It is only necessary that the high pressure-side pressure detecting device 51 can detect the pressure of the high pressure refrigerant of the main refrigerant circuit 10.

[0032] An intermediate heat exchanger main refrigerant inlet thermistor 57 is provided in the pipe 16 on a

downstream-side of the use-side heat exchanger 12 of the main refrigerant circuit 10, i.e., on an upstream-side of the economizer 13. The intermediate heat exchanger main refrigerant inlet thermistor 57 detects temperature of refrigerant which flows out from the use-side heat exchanger 12. Further, the bypass refrigerant circuit 20 is provided with an intermediate heat exchanger bypass inlet thermistor 56. The intermediate heat exchanger bypass inlet thermistor 56 detects temperature of refrigerant which flows out from a second expanding device 21 on a downstream-side of the second expanding device 21, i.e., on the upstream side of the economizer 13.

[0033] The use-side heat medium circuit 30 includes a heat medium outlet temperature thermistor 53 and a heat medium inlet temperature thermistor 54. The heat medium outlet temperature thermistor 53 detects temperature of use-side heat medium which flows out from the use-side heat exchanger 12. The heat medium inlet temperature thermistor 54 detects temperature of use-side heat medium which flows into the use-side heat exchanger 12.

[0034] Further, the bypass refrigerant circuit 20 includes the intermediate heat exchanger bypass inlet thermistor 56, an intermediate heat exchanger bypass outlet thermistor 58 and an intermediate pressure-side pressure detecting device 52. The intermediate heat exchanger bypass inlet thermistor 56 detects refrigerant temperature on the upstream side of the economizer 13. The intermediate heat exchanger bypass outlet thermistor 58 detects refrigerant temperature on the downstream-side of the economizer 13. The intermediate pressure-side pressure detecting device 52 directly or indirectly detects pressure on the downstream side of the second expanding device 21.

[0035] When the intermediate pressure-side pressure detecting device 52 directly detects the pressure, this pressure detecting device 52 directly, i.e., mechanically detects pressure of refrigerant.

[0036] When the intermediate pressure-side pressure detecting device 52 indirectly detects the pressure, a control device 60 calculates a value of pressure (intermediate pressure) of refrigerant after this pressure is reduced by the second expanding device 21 based on detection pressure detected by the high pressure-side pressure detecting device 51 and detection pressure detected by the intermediate heat exchanger main refrigerant inlet thermistor 57. Further, the control device 60 calculates a value of intermediate pressure based on detection temperature detected by the heat medium inlet temperature thermistor 54 and detection temperature detected by the intermediate heat exchanger bypass inlet thermistor 56. The control device 60 has arithmetic processing function.

[0037] That is, the control device 60 memorizes a pressure-enthalpy diagram (P-h diagram) as shown in Fig. 2.

[0038] The high pressure-side pressure detecting device 51 detects, every predetermined time, high pressure-side pressure (discharge pressure of high-stage side compression rotating element 11b), the intermediate

heat exchanger main refrigerant inlet thermistor 57 detects, every predetermined time, outlet temperature (point A) of the use-side heat exchanger 12, and the intermediate heat exchanger bypass inlet thermistor 56 detects, every predetermined time, inlet temperature (point e) of refrigerant of the bypass refrigerant circuit 20 of the intermediate heat exchanger 13.

[0039] Based on an ideal condition that enthalpies at the point A and the point e are substantially the same, the control device 60 calculates pressure and the enthalpy at the point e. According to this, it is possible to calculate a value of pressure (intermediate pressure) of refrigerant after the pressure is reduced by the second expanding device 21, and it is possible to determine whether the pressure is equal to or higher than critical pressure by the calculated value.

[0040] It is possible to use detection temperature which is detected by the heat medium inlet temperature thermistor 54 instead of using the detection value detected by the intermediate heat exchanger main refrigerant inlet thermistor 57 because these values are substantially the same.

[0041] That is, it is possible to determine that pressure (intermediate pressure) of refrigerant after this pressure is reduced by the second expanding device 21 is equal to or higher than the critical pressure based on the discharge pressure of the compression mechanism 11, based on the outlet temperature (point A) of refrigerant of the use-side heat exchanger 12, and based on the inlet temperature (point e) of refrigerant of the bypass refrigerant circuit 20 of the intermediate heat exchanger 13, or based on temperature of the use-side heat medium which flows into the use-side heat exchanger 12.

[0042] It is only necessary that the intermediate pressure-side pressure detecting device 52 includes any one of the pressure detecting devices which directly or indirectly detect pressure.

[0043] The control device 60 controls operating frequency of the compression mechanism 11, opening degrees of the main expansion valve 14 and the bypass expansion valve 21, and the transfer pump 31 based on detection pressures detected by the high pressure-side pressure detecting device 51 and the intermediate pressure-side pressure detecting device 52, and based on detection temperatures detected by the heat medium outlet temperature thermistor 53 and the heat medium inlet temperature thermistor 54.

[1-2. Action]

[0044] Figs. 2 are pressure-enthalpy diagrams (P-h diagrams) under an ideal condition concerning a refrigeration cycle device, wherein Fig. 2(a) shows a case in which high pressure is lower than predetermined pressure, and Fig. 2(b) shows a case in which high pressure is equal to or higher than the predetermined pressure. Points a to e and point A to B in Fig. 2 correspond to respective points of the liquid heating device shown in

Fig. 1.

[0045] Action of the refrigeration cycle device will be described using Figs. 2.

[0046] First, high pressure refrigerant (point a) discharged from the compression mechanism 11 radiates heat in the radiator 12 and then, the high pressure refrigerant branches off from the main refrigerant circuit 10 at a refrigerant branch point A. The high pressure refrigerant is reduced in pressure to intermediate pressure by the bypass expansion valve 21, the pressure becomes equal to the intermediate pressure refrigerant (point e), and the intermediate pressure refrigerant exchanges heat in the economizer 13.

[0047] The high pressure refrigerant which flows through the main refrigerant circuit 10 after it radiates heat in the radiator 12 is cooled by the intermediate pressure refrigerant (point e) which flows through the bypass refrigerant circuit 20, and the refrigerant is reduced in pressure by the main expansion valve 14 in a state where its enthalpy is reduced (point b).

[0048] According to this, after the pressure is reduced by the main expansion valve 14, refrigerant enthalpy of the refrigerant (point c) which flows into the evaporator 15 is also reduced. Dryness of the refrigerant when it flows into the evaporator 15 is lowered, and liquid component of the refrigerant is increased. Hence, this fact contributes to evaporation in the evaporator 15, a ratio of the refrigerant is increased, heat absorption from the outside air is increased, and the refrigerant returns to the suction side (point d) of the compression mechanism 11. The dryness of the refrigerant is a ratio of weight occupied by gas phase component with respect to the entire refrigerant.

[0049] On the other hand, refrigerant of an amount corresponding to an amount of gas phase component which does not contribute to evaporation in the evaporator 15 bypasses to the bypass refrigerant circuit 20 and becomes low temperature intermediate pressure refrigerant (point e). The intermediate pressure refrigerant is heated by high pressure refrigerant which flows through the main refrigerant circuit 10 in the economizer 13. In a state where refrigerant enthalpy becomes high, the intermediate pressure refrigerant reaches a merging point B of refrigerant which is on the way of compression of the compression mechanism 11.

[0050] Therefore, at the merging point (point B) of the compression mechanism 11, since the refrigerant pressure is higher than that on the suction side (point d) of the compression mechanism 11, refrigerant density is higher. At the same time, refrigerant which merges with refrigerant which is on the way of compression of the compression mechanism 11 is further compressed by the compression mechanism 11 and discharged. Hence, a flow rate of the refrigerant which flows into the radiator 12 is largely increased, and ability for heating water which is the use-side heat medium is largely enhanced.

[0051] Discharge pressure of the compression mechanism 11 rises and exceeds a predetermined value, the

control device 60 starts controlling a valve opening degree of the bypass expansion valve 21 such that pressure of refrigerant after it is reduced by the bypass expansion valve 21 exceeds the critical pressure as shown in Fig. 2(b).

[0052] More specifically, when it is determined that the detection pressure detected by the high pressure-side pressure detecting device 51 rises and exceeds a first predetermined high pressure value, if detection pressure detected by the intermediate pressure-side pressure detecting device 52 is equal to or lower than the critical pressure, the control device 60 starts the operation to increase the valve opening degree of the bypass expansion valve 21.

[0053] Then, the control device 60 operates to increase the valve opening degree of the bypass expansion valve 21 as shown in Fig. 2(b). At the same time, the control device 60 increases operating frequency of the compression mechanism 11, and increases a circulation amount of refrigerant which flows through the bypass refrigerant circuit 20. According to this, the control device 60 controls such that detection pressure detected by the high pressure-side pressure detecting device 51 becomes equal to a second predetermined high pressure value which is a target high pressure value. The second predetermined high pressure value is higher than the first predetermined high pressure value.

[0054] At the same time, as shown in Fig. 2(a), when pressure (intermediate pressure) of refrigerant after it is reduced by the second expanding device 21 is lower than the critical pressure, the control device 60 controls the valve opening degree of the bypass expansion valve 21 as shown in a control flow in Fig. 3. On the downstream side of the economizer 13 of the bypass refrigerant circuit 20, degrees of superheat SHm of refrigerant which is on the way of compression of the compression mechanism 11 and refrigerant before merging are acquired (S1). When it is determined that the degrees of superheat SHm are lower than a predetermined value SHt (YES in S2), the control device 60 operates to reduce the valve opening degree of the bypass expansion valve 21 and a flow rate of refrigerant is reduced (S3). According to this, a temperature rising width of refrigerant caused by heat exchange with the main refrigerant circuit 10 is increased and on the downstream side of the economizer 13, the degrees of superheat SHm of the refrigerant which is on the way of compression of the compression mechanism 11 and the refrigerant before merging rise. Hence, refrigerant which is injected to the compression mechanism 11 becomes gas. When it is determined that the acquired degree of superheat SHm of refrigerant on the downstream side of the economizer 13 exceeds the predetermined value SHt (NO in S2), the control device 60 operates to increase the valve opening degree of the bypass expansion valve 21, and the flow rate of refrigerant is increased (S4). According to this, the temperature rising width of refrigerant caused by heat exchange with the main refrigerant circuit 10 becomes small and on the

downstream side of the economizer 13, the degrees of superheat SHm of the refrigerant which is on the way of compression of the compression mechanism 11 and the refrigerant before the merging are reduced. Further, temperature of refrigerant which merges with the main refrigerant circuit 10 on the way of compression of the compression mechanism 11 is lowered, and discharge temperature which is temperature of refrigerant discharged from the compression mechanism 11 is lowered.

[0055] At that time, the degree of superheat SHm of refrigerant injected into the compression mechanism 11 can be calculated from a difference between temperature obtained from the intermediate heat exchanger bypass inlet thermistor 56 and temperature obtained from the intermediate heat exchanger bypass outlet thermistor 58 while taking pressure loss of the economizer 13 into account. This is because that when pressure (intermediate pressure) of refrigerant after it is reduced by the second expanding device 21 is lower than the critical pressure, temperature detected by the intermediate heat exchanger bypass inlet thermistor 56 becomes saturated temperature. The degree of superheat SHm can also be calculated from pressure information detected by the intermediate pressure-side pressure detecting device 52 and temperature information detected by the intermediate heat exchanger bypass outlet thermistor 58.

[0056] Action when the hot water tank 32b is used in the use-side heat medium circuit 30 will be described below.

[0057] Of the plurality of hot water tank temperature thermistors, the first hot water tank temperature thermistor 55a is positioned at the highest position in the hot water tank 32b. For example, when detection temperature detected by the first hot water tank temperature thermistor 55a is lower than the predetermined value, the control device 60 determines that high temperature water is insufficient in the hot water tank 32b.

[0058] Thus, the control device 60 operates the compression mechanism 11 and heats low temperature water by the radiator 12. According to this, the transfer pump 31 is operated such that detection temperature detected by the heat medium outlet temperature thermistor 53 which is heated produced temperature becomes equal to target temperature.

[0059] According to this, low temperature water derived from the lower portion in the hot water tank 32b is heated by the radiator 12. According to this, high temperature water is produced, and the produced high temperature water is introduced into the hot water tank 32b from the upper portion in the hot water tank 32b. At that time, since the detection temperature detected by the heat medium inlet temperature thermistor 54 is equal to or lower than third predetermined temperature, the transfer pump 31 is operated in the state shown in Fig. 2(a).

[0060] Since high temperature water is gradually stored in the hot water tank 32b from above, detection temperature detected by the heat medium inlet temperature thermistor 54 is gradually rising. Thereafter, when

the detection temperature detected by the heat medium inlet temperature thermistor 54 exceeds the third predetermined temperature, the transfer pump 31 is operated in the state shown in Fig. 2(b).

[0061] That is, the control device 60 controls such that the valve opening degree of the bypass expansion valve 21 is increased, and the operating frequency of the compression mechanism 11 is increased, thus the circulation amount of refrigerant flowing through the bypass refrigerant circuit 20 is increased, and detection pressure detected by the high pressure-side pressure detecting device 51 becomes equal to the second predetermined high pressure which is the target high pressure value. At the same time, the control device 60 operates such that detection pressure detected by the intermediate pressure-side pressure detecting device 52 becomes equal to predetermined intermediate pressure which is the target intermediate pressure value.

[0062] According to this, inlet temperature of heat medium entering the radiator 12 becomes high, and an enthalpy difference (a-A) of refrigerant in the radiator 12 becomes small. To compensate this reduced enthalpy difference, heating ability of refrigerant in the radiator 12 is enhanced. According to this, it is possible to keep supplying the high temperature water to the hot water tank 32b.

[0063] When the detection temperature detected by the heat medium inlet temperature thermistor 54 exceeds the first predetermined temperature which is higher than the third predetermined temperature, the control device 60 reduces the operating frequency of the compression mechanism 11. According to this, it is possible to store the high temperature water in the hot water tank 32b such that pressure of high pressure refrigerant in the radiator 12 does not exceeds the second predetermined high pressure value which is the target high pressure value while suppressing the pressure rise of the high pressure refrigerant in the radiator 12.

[0064] The same operating action may be executed respectively using the first predetermined high pressure value and the second predetermined high pressure value which are detection pressures detected by the high pressure-side pressure detecting device 51 as the threshold values instead of using the third predetermined temperature and the first predetermined temperature which are detection temperatures detected by the heat medium inlet temperature thermistor 54.

[0065] A case where the heating terminal 32a is used in the use-side heat medium circuit 30 will be described.

[0066] The control device 60 operates the compression mechanism 11 and heats circulating water by the radiator 12. The control device 60 operates the transfer pump 31 such that a temperature difference between the detection temperature detected by the heat medium outlet temperature thermistor 53 and the detection temperature detected by the heat medium inlet temperature thermistor 54 becomes equal to the target temperature difference.

[0067] According to this, high temperature water produced by the radiator 12 radiates heat in the heating terminal 32a, and the heat is used for heating homes, and low temperature water which radiates heat in the heating terminal 32a is again heated by the radiator 12. At that time, control is performed such that the temperature difference between the detection temperature detected by the heat medium outlet temperature thermistor 53 and the detection temperature detected by the heat medium inlet temperature thermistor 54 becomes equal to the target temperature difference. At the same time, since the detection temperature detected by the heat medium outlet temperature thermistor 53 is equal to or lower than fourth predetermined temperature, the transfer pump 31 is operated in the state shown in Fig. 2(a).

[0068] The home-heating load gradually becomes small. Therefore, since the control is performed such that the temperature difference between the detection temperature detected by the heat medium outlet temperature thermistor 53 and the detection temperature detected by the heat medium inlet temperature thermistor 54 becomes equal to the target temperature difference, the detection temperature detected by the heat medium outlet temperature thermistor 53 and the detection temperature detected by the heat medium inlet temperature thermistor 54 are gradually rising. Thereafter, when the detection temperature detected by the heat medium outlet temperature thermistor 53 exceeds the fourth predetermined temperature, the transfer pump 31 is operated in the state shown in Fig. 2(b).

[0069] That is, the control device 60 controls such that the valve opening degree of the bypass expansion valve 21 is increased, and the operating frequency of the compression mechanism 11 is increased, thus the circulation amount of refrigerant flowing through the bypass refrigerant circuit 20 is increased, and the detection pressure detected by the high pressure-side pressure detecting device 51 becomes equal to the second predetermined high pressure value which is the target high pressure value.

[0070] At the same time, when pressure (intermediate pressure) of refrigerant after it is reduced by the second expanding device 21 is lower than the critical pressure, the control device 60 controls the valve opening degree of the bypass expansion valve 21 as shown in the control flowchart shown in Fig. 3. On the downstream side of the economizer 13 of the bypass refrigerant circuit 20, the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and refrigerant before merging are acquired (S1). When it is determined that the degree of superheat SHm becomes lower than the predetermined value SHt (YES in S2), the control device 60 operates to reduce the valve opening degree of the bypass expansion valve 21, and the flow rate of refrigerant is reduced (S3). According to this, the temperature rising width of refrigerant caused by heat exchange with the main refrigerant circuit 10 becomes large, and the degrees of superheat SHm of refrigerant

on the way of compression of the compression mechanism 11 and the refrigerant before merging rise on the downstream side of the economizer 13. Therefore, refrigerant injected into the compression mechanism 11 becomes gas. When it is determined that the acquired degree of superheat SHm of refrigerant on the downstream side of the economizer 13 exceeds the predetermined value SHt (NO in S2), the control device 60 operates to increase the valve opening degree of the bypass expansion valve 21, and the flow rate of refrigerant is increased (S4). According to this, the temperature rising width of the refrigerant caused by the heat exchange with the main refrigerant circuit 10 becomes small, the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and the refrigerant before merging are lowered, temperature of refrigerant which merges with the main refrigerant circuit 10 on the way of compression of the compression mechanism 11 is lowered, and discharge temperature which is temperature of refrigerant discharged from the compression mechanism 11 is lowered.

[0071] At that time, the degree of superheat SHm of refrigerant injected into the compression mechanism 11 can be calculated from a difference between temperature obtained by the intermediate heat exchanger bypass inlet thermistor 56 and temperature obtained by the intermediate heat exchanger bypass outlet thermistor 58 while taking the pressure loss of the economizer 13 into account. This is because that when pressure (intermediate pressure) of refrigerant after it is reduced by the second expanding device 21 is lower than the critical pressure, temperature detected by the intermediate heat exchanger bypass inlet thermistor 56 becomes the saturated temperature. The degree of superheat SHm of refrigerant injected into the compression mechanism 11 can also be calculated from pressure information detected by the intermediate pressure-side pressure detecting device 52 and temperature information detected by the intermediate heat exchanger bypass outlet thermistor 58.

[0072] According to this, the home-heating load becomes small, and the enthalpy difference (a-A) of refrigerant in the radiator 12 becomes small. To compensate this reduced enthalpy difference, the heating ability of refrigerant in the radiator 12 is enhanced. According to this, it is possible to keep supplying high temperature water to the heating terminal 32a.

[0073] When detection temperature detected by the heat medium outlet temperature thermistor 53 exceeds the second predetermined temperature which is higher than the fourth predetermined temperature, the control device 60 reduces the operating frequency of the compression mechanism 11. According to this, it is possible to utilize the liquid heating device as a home-heating device using high temperature water while suppressing the pressure rise of high pressure refrigerant in the radiator 12 such that pressure of the high pressure refrigerant in the radiator 12 does not exceed the second predetermined high pressure value which is the target high pres-

sure value.

[1-3. Effect and the like]

[0074] When the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and the refrigerant before merging become lower than the predetermined value SHt on the downstream side of the economizer 13 of the bypass refrigerant circuit 20, operation is carried out such that the valve opening degree of the bypass expansion valve 21 becomes small. According to this, the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and the refrigerant before merging rise on the downstream side of the economizer 13. Hence, it is possible to prevent refrigerant injected into the compression mechanism 11 from being compressed in a liquid state.

[0075] When the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and the refrigerant before merging exceed the predetermined value SHt on the downstream side of the economizer 13, operation is carried out such that the valve opening degree of the bypass expansion valve 21 becomes large. According to this, the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and the refrigerant before merging are lowered on the downstream side of the economizer 13, and the discharge temperature which is temperature of refrigerant discharged from the compression mechanism 11 can also be lowered. Hence, excessive rise of discharge temperature exceeding a range of use can be suppressed.

[0076] From these facts, by controlling the degrees of superheat SHm of the refrigerant on the way of compression of the compression mechanism 11 and the refrigerant before merging on the downstream side of the economizer 13 using the bypass expansion valve 21, it is possible to secure the reliability of the compression mechanism 11. The predetermined value SHt which operates to increase the valve opening degree of the bypass expansion valve 21 and the predetermined value SHt which operates to reduce the valve opening degree of the bypass expansion valve 21 may be the same or different from each other. That is, the predetermined value SHt which operates to increase the valve opening degree of the bypass expansion valve 21 may be higher than the predetermined value SHt which operates to reduce the valve opening degree of the bypass expansion valve 21.

[0077] The same operating action may be executed using the first predetermined high pressure value and the second predetermined high pressure value which are detection pressures detected by the high pressure-side pressure detecting device 51 as the threshold values instead of using the fourth predetermined temperature and the second predetermined temperature which are detection temperatures detected by the heat medium outlet temperature thermistor 53.

[0078] It is preferable that in the refrigeration cycle device of the embodiment, carbon dioxide is used as the refrigerant. This is because that temperature of the use-side heat medium can be made high in the radiator 12 when the use-side heat medium is heated by the carbon dioxide which is the refrigerant.

[0079] If water or antifreeze liquid is used as the use-side heat medium, high temperature water can be used the heating terminal 32a or can be stored in the hot water tank 32b.

[INDUSTRIAL APPLICABILITY]

[0080] As described above, the refrigeration cycle device of the present invention includes the main refrigerant circuit having the intermediate heat exchanger and the bypass refrigerant circuit. By making the degree of superheat of refrigerant injected from the bypass refrigerant circuit into the compression mechanism equal to or higher than the predetermined value, it is possible to prevent liquid compression from being generated in the compression mechanism. Hence, the present invention is useful for a liquid heating device of a refrigerator, an air conditioner, hot water supply system and a home-heating device using the refrigeration cycle device.

[EXPLANATION OF SYMBOLS]

[0081]

10 main refrigerant circuit
11 compression mechanism
12 radiator (use-side heat exchanger)
13 economizer (intermediate heat exchanger)
14 main expansion valve (first expanding device)
15 evaporator (heat source-side heat exchanger)
16 pipe
20 bypass refrigerant circuit
21 bypass expansion valve (second expanding device)
30 use-side heat medium circuit
31 transfer pump (transfer device)
32a heating terminal
32b hot water tank
33 heat medium pipe
34 first switching valve
35 second switching valve
41 hot water tap
42 hot water supply-heat exchanger
43 water supply pipe
51 high pressure-side pressure detecting device
52 intermediate pressure-side pressure detecting device
53 heat medium outlet temperature thermistor
54 heat medium inlet temperature thermistor
55a first hot water tank temperature thermistor
55b second hot water tank temperature thermistor
55c third hot water tank temperature thermistor

56 intermediate heat exchanger bypass inlet thermistor (pre-cooling temperature sensor)
 57 intermediate heat exchanger main refrigerant inlet thermistor
 58 intermediate heat exchanger bypass outlet thermistor (post-cooling temperature sensor)
 60 control device

Claims

1. A refrigeration cycle device comprising:

a main refrigerant circuit (10) formed by sequentially connecting, to one another through a pipe (16), a compression mechanism (11) composed of a compression rotating element, a use-side heat exchanger (12) for heating use-side heat medium by refrigerant discharged from the compression rotating element, an intermediate heat exchanger (13), a first expanding device (14) and a heat source-side heat exchanger (15);
 a bypass refrigerant circuit (20) which branches off from the pipe (16) between the use-side heat exchanger (12) and the first expanding device (14), in which after the refrigerant which is branched is decompressed by a second expanding device (21), the branched refrigerant exchanges heat, in the intermediate heat exchanger (13), with the refrigerant flowing through the main refrigerant circuit (10), and merges with the refrigerant which is on the way of compression of the compression rotating element;
 a pre-cooling temperature sensor (56) for detecting temperature of the refrigerant flowing through the bypass refrigerant circuit (20) located upstream of the intermediate heat exchanger (13);
 a post-cooling temperature sensor (58) for detecting temperature of the refrigerant flowing through the bypass refrigerant circuit (20) located downstream of the intermediate heat exchanger (13); and
 a control device (60), wherein
 the control device (60) calculates a degree of superheat of the refrigerant which merges with the compression rotating element based on temperature data acquired from the pre-cooling temperature sensor (56) and from the post-cooling temperature sensor (58), and when the calculated degree of superheat is lower than a predetermined value, the control device (60) operates to reduce a valve opening degree of the second expanding device (21).

2. The refrigeration cycle device according to claim 1, wherein

the control device (60) calculates the degree of superheat of the refrigerant which merges with the compression rotating element based on the temperature data acquired from the pre-cooling temperature sensor (56) and from the post-cooling temperature sensor (58), and when the calculated degree of superheat is equal to or higher than the predetermined value, the control device (60) operates to increase the valve opening degree of the second expanding device (21).

3. The refrigeration cycle device according to claim 2, further comprising an intermediate pressure-side pressure detecting device (52) for detecting pressure of the refrigerant flowing through the bypass refrigerant circuit (20) located downstream of the second expanding device (21), wherein when detection pressure detected by the intermediate pressure-side pressure detecting device (52) is equal to or lower than a critical pressure, the control device (60) operates to increase the valve opening degree of the second expanding device (21).

4. The refrigeration cycle device according to claim 3, wherein the control device (60) increases operating frequency of the compression rotating element.

5. The refrigeration cycle device according to claim 4, further comprising a high pressure-side pressure detecting device (51) for detecting high pressure-side pressure of the main refrigerant circuit (10), wherein when detection pressure detected by the high pressure-side pressure detecting device (51) exceeds a predetermined value, the control device (60) reduces the operating frequency of the compression rotating element.

6. The refrigeration cycle device according to any one of claims 1 to 5, wherein the refrigerant is carbon dioxide.

7. A liquid heating device comprising the refrigeration cycle device according to any one of claims 1 to 5, and a use-side heat medium circuit (30) for circulating the use-side heat medium by a transfer device (31).

8. The liquid heating device according to claim 7, comprising

a heat medium outlet temperature thermistor (53) for detecting temperature of the use-side heat medium which flows out from the use-side heat exchanger (12), and
 a heat medium inlet temperature thermistor (54) for detecting temperature of the use-side heat medium which flows into the use-side heat ex-

changer (12), wherein
the control device (60) operates the transfer de-
vice (31) such that detection temperature de-
tected by the heat medium outlet temperature
thermistor (53) becomes equal to a target tem- 5
perature, and when the detection temperature
detected by the heat medium inlet temperature
thermistor (54) exceeds first predetermined
temperature, the control device (60) reduces op-
erating frequency of the compression rotating 10
element.

9. The liquid heating device according to claim 7, com-
prising

15
a heat medium outlet temperature thermistor
(53) for detecting temperature of the use-side
heat medium which flows out from the use-side
heat exchanger (12), and
a heat medium inlet temperature thermistor (54) 20
for detecting temperature of the use-side heat
medium which flows into the use-side heat ex-
changer (12), wherein
the control device (60) operates the transfer de-
vice (31) such that a temperature difference be- 25
tween detection temperature detected by the
heat medium outlet temperature thermistor (53)
and detection temperature detected by the heat
medium inlet temperature thermistor (54) be-
comes equal to a target temperature difference, 30
and when the detection temperature of the heat
medium outlet temperature thermistor (53) ex-
ceeds second predetermined temperature, the
control device (60) reduces operating frequency
of the compression rotating element. 35

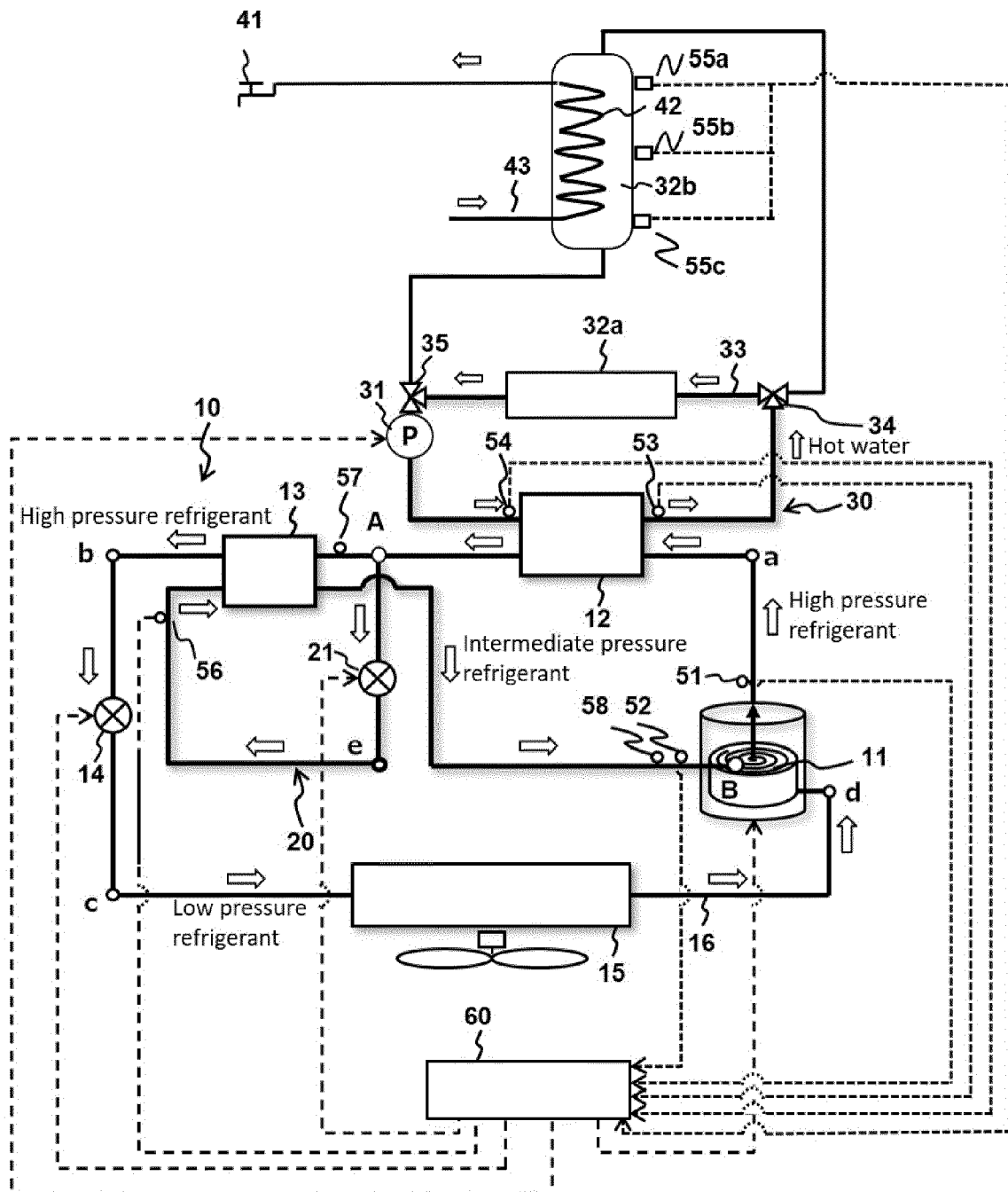
10. The liquid heating device according to any one of
claims 7 to 9, wherein
the use-side heat medium is water or antifreeze liq-
uid. 40

45

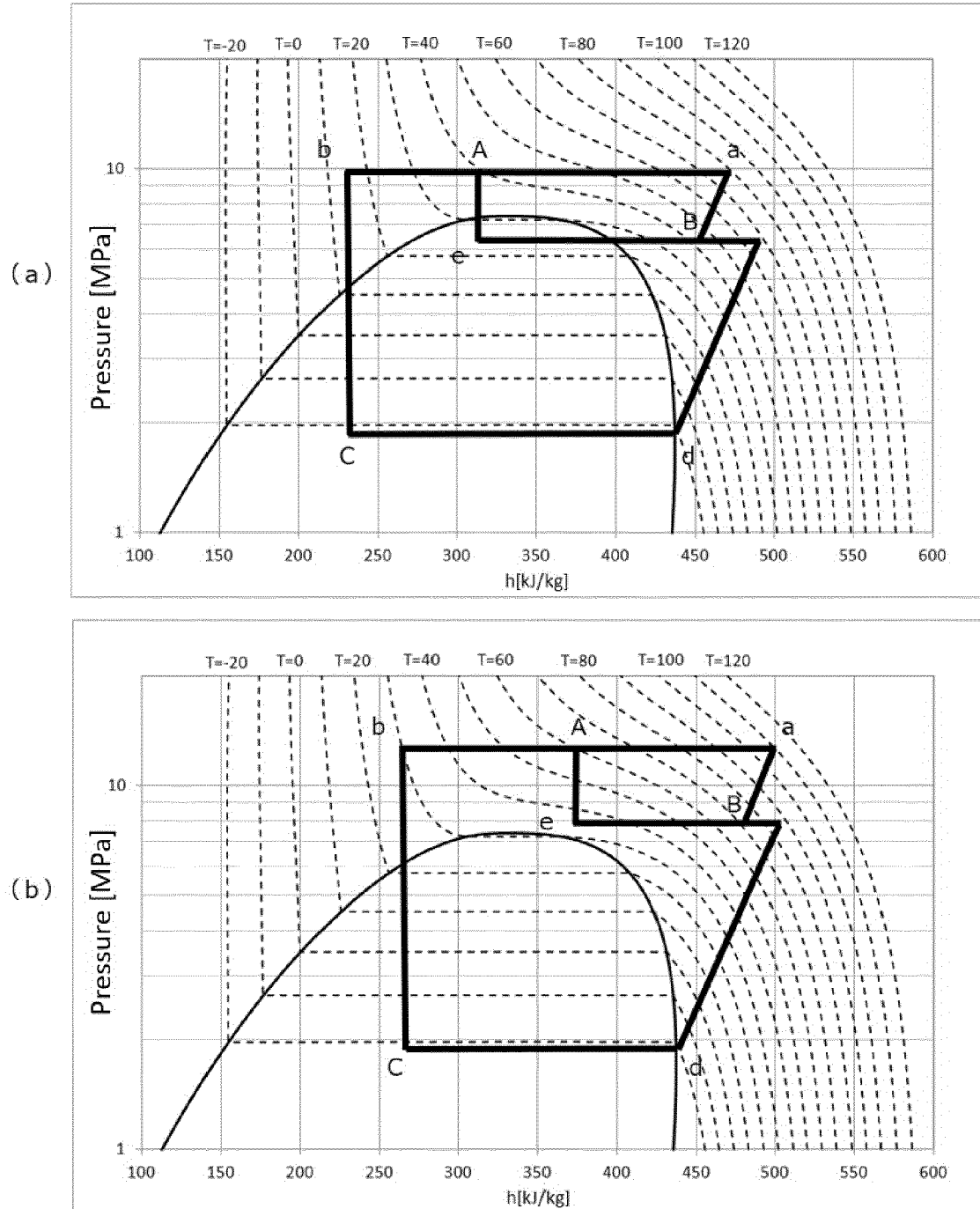
50

55

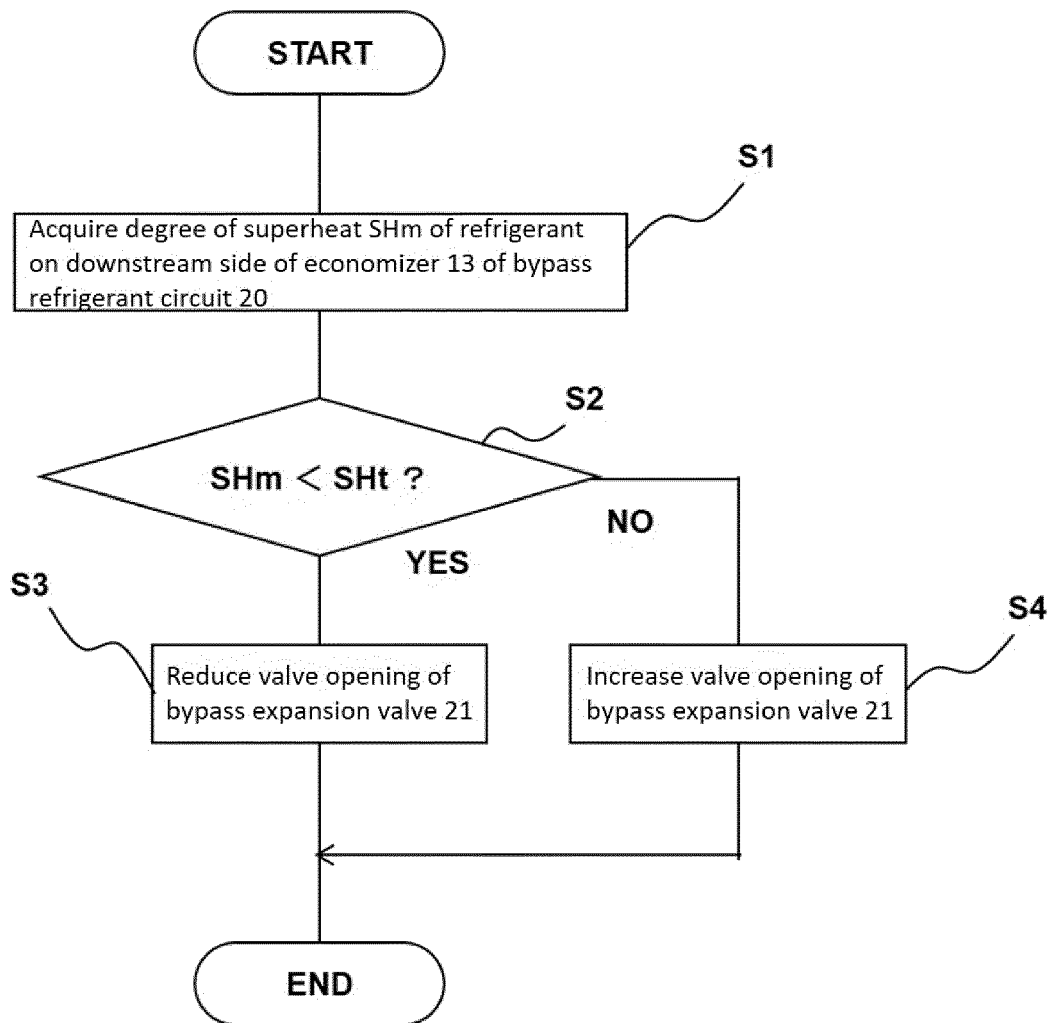
[Fig. 1]



[Fig. 2]



[Fig. 3]





EUROPEAN SEARCH REPORT

Application Number

EP 22 17 1958

5

10

15

20

25

30

35

40

45

50

55

1

EPO FORM 1503 03.82 (P04C01)

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	DE 11 2016 004544 T5 (DENSO CORP [JP]) 21 June 2018 (2018-06-21)	1, 2	INV. F25B1/10
Y	* paragraphs [0084] - [0091]; figures 1, 14, 15 *	3-10	F25B25/00 F25B41/00 F25B40/00
X	KR 2020 0009765 A (LG ELECTRONICS INC [KR]) 30 January 2020 (2020-01-30)	1, 2	F25B49/02 F25B1/04
Y	* paragraphs [0053], [0061], [0062], [0070], [0087], [0095], [0096], [0097], [0025]; figures *	3-10	F25B9/00
Y	EP 3 683 520 A1 (PANASONIC IP MAN CO LTD [JP]) 22 July 2020 (2020-07-22) * paragraphs [0058], [0069], [0-71], [0082], [0091] - [0095], [0097], [0099], [0111] - [0115]; figures 1, 3, 5 *	3-10	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 28 September 2022	Examiner Ritter, Christoph
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 22 17 1958

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

28-09-2022

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 112016004544 T5	21-06-2018	DE 112016004544 T5	21-06-2018
		JP 6477908 B2	06-03-2019
		JP WO2017061233 A1	22-02-2018
		WO 2017061233 A1	13-04-2017

KR 20200009765 A	30-01-2020	NONE	

EP 3683520 A1	22-07-2020	DK 3683520 T3	20-12-2021
		EP 3683520 A1	22-07-2020
		ES 2904478 T3	05-04-2022
		JP 7012208 B2	28-01-2022
		JP 2020115068 A	30-07-2020

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

- JP 2010071643 A [0007]
- JP 2009192164 A [0007]