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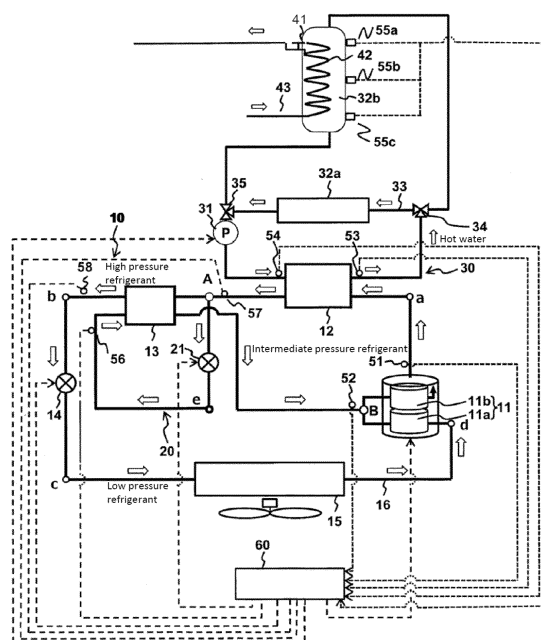
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(54) REFRIGERATION CYCLE DEVICE AND LIQUID HEATING DEVICE HAVING THE SAME

(57) The present invention provides a refrigeration cycle device and a liquid heating device having the refrigeration cycle device. The refrigeration cycle device includes: a main refrigerant circuit 10 formed by sequentially connecting, to one another through a pipe 16, a compressing mechanism 11, a utilization-side heat exchanger 12, an intermediate heat exchanger 13, a first expansion device 14 and a heat source-side heat exchanger 15; a bypass refrigerant circuit 20 in which the refrigerant branches off from the pipe 16 between the utilization-side heat exchanger 12 and the first expansion device 14, the branched refrigerant is decompressed by a second expansion device 21 and thereafter, the refrigerant heat-exchanges, in the intermediate heat exchanger 13, with the former refrigerant which flows through the main refrigerant circuit 10, and the refrigerant joins up with the refrigerant which is on an intermediate stage of compression of a compression rotary element; and a control device 60. The control device 60 controls a valve opening of the second expansion device 21 such that a state where pressure of refrigerant after it is decompressed by the second expansion device 21 exceeds critical pressure is maintained. Therefore, even when high pressure is further increased, COP is not deteriorated by appropriately performing control.

[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.2010-054194

[0002] As a conventional refrigeration cycle device, there is a supercritical vapor compression type refrigeration cycle which includes a two-stage compressor for compressing refrigerant in two stages, and two expansion devices for expanding refrigerant in two stages, and which uses carbon dioxide as the refrigerant (see patent document 1 for example).

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[SUMMARY OF THE INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0003] The supercritical vapor compression type refrigeration cycle of patent document 1 includes a gas-liquid separator. Refrigerant composed of gaseous phase in the gas-liquid separator as main ingredient is immediately injected into a refrigerant mixer located between an injection circuit and an intermediate connection circuit of the two-stage compressor, the refrigerant is mixed with refrigerant discharged from a low stage-side rotary compression rotary element, and is sucked into a high stage-side rotary compression rotary element.

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[0008] According to the configuration of patent document 1, however, in the supercritical vapor compression type refrigeration cycle, when high pressure is further increased for producing high temperature water, since intermediate pressure of refrigerant in the injection circuit is equal to or lower than critical pressure, there is a problem that a pressure difference between the high pressure and the intermediate pressure becomes large, and COP of the supercritical vapor compression type refrigeration cycle is deteriorated.

[0004] In patent document 1, by setting a ratio (excluded volume ratio) of excluded volume of the high stage-side rotary compression rotary element with respect to excluded volume of low stage-side rotary compression rotary element equal to or larger than isentropic exponential square root of the quotient obtained by dividing suction pressure of the two-stage compressor by refrigerant saturated liquid pressure in a first expansion device, discharged pressure of the low stage-side rotary compression rotary element is made equal to or smaller than critical pressure of the refrigerant.

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[0009] According to the configuration of patent document 2, since control is performed based on the degree of overheat of the outlet of the supercooling heat exchanger, control cannot be performed when pressure of refrigerant which is discharged from the two-stage compressor and expanded is equal to or higher than critical pressure.

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[0010] The present invention has been accomplished to solve the problems, and it is an object of the invention to provide a refrigeration cycle device and a liquid heating device having the same which do not deteriorate COP by appropriately performing the control even when high pressure is further increased.

[0005] Further, there is another conventional refrigeration cycle device of this kind which does not use carbon dioxide as the refrigerant and which includes a two-stage compressor for compressing the refrigerant in two stages and two expansion devices for expanding the refrigerant in two stages (see patent document 2 for example).

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[MEANS FOR SOLVING THE PROBLEM]

[0006] The refrigeration device of patent document 2 includes a supercooling heat exchanger and an injection circuit. In the injection circuit, a portion of refrigerant discharged from the two-stage compressor is expanded, and the refrigerant is heat-exchanged with refrigerant discharged from the supercooling heat exchanger and thereafter, the refrigerant is injected into an intermediate port. In the refrigeration device, by setting a target degree of overheat in accordance of a degree of overheat of an outlet of the supercooling heat exchanger, an opening of an expansion valve is controlled.

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[0011] To solve the conventional problems, the present invention provides a refrigeration cycle device including: a main refrigerant circuit formed by sequentially connecting, to one another through a pipe, a compressing mechanism composed of a compression rotary element, a utilization-side heat exchanger for heating utilization-side heating medium by refrigerant discharged from the compression rotary element, an intermediate heat exchanger, a first expansion device and a heat source-side heat exchanger; a bypass refrigerant circuit in which the refrigerant branches off from the pipe between the utilization-side heat exchanger and the first expansion device, the branched refrigerant is decompressed by a second expansion device and thereafter, the refrigerant heat-exchanges, in the intermediate heat exchanger, with the former refrigerant which flows through the main refrigerant circuit, and the refrigerant

joins up with the refrigerant which is on an intermediate stage of compression of the compression rotary element; and a control device, wherein the control device controls a valve opening of the second expansion device such that a temperature difference between outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger becomes larger than a temperature difference when the refrigerant flows through the intermediate heat exchanger in a gas-liquid two-phase state, and such that a temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and inlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger becomes larger than a temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and outlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger, and pressure of the refrigerant after it is decompressed by the second expansion device is maintained in a state where the pressure exceeds a critical pressure.

[0012] According to this, even if pressure of refrigerant after it is decompressed by the second expansion device exceeds critical pressure, an enthalpy difference between refrigerant of an outlet and refrigerant of an inlet of the intermediate heat exchanger flowing through the bypass refrigerant circuit can be made large, and it is possible to increase a flow rate of refrigerant flowing through the intermediate heat exchanger of the bypass refrigerant circuit. Therefore, it is possible to provide a refrigeration cycle device which realizes high COP.

[EFFECT OF THE INVENTION]

[0013] According to the present invention, it is possible to provide a refrigeration cycle device and a liquid heating device having the same which do not deteriorate COP by appropriately performing the control even when high pressure is further increased.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0014]

Fig. 1 is a block diagram of a liquid heating device in a first embodiment of the present invention;

Fig. 2(a) is a pressure-enthalpy diagram (P-h diagram) when intermediate pressure of a refrigeration cycle device in the first embodiment of the invention is lower than critical pressure, and Fig. 2(b) is a pressure-enthalpy diagram (P-h diagram) when intermediate pressure of the refrigeration cycle device is higher than critical pressure;

Fig. 3 is a diagram showing a temperature relation

between refrigerant of a main refrigerant circuit and refrigerant of a bypass refrigerant circuit flowing through an intermediate heat exchanger of the refrigeration cycle device of the first embodiment of the invention;

Fig. 4(a) is a diagram showing a relation between ΔT_M and a circulation amount of refrigerant of the bypass refrigerant circuit flowing through an intermediate heat exchanger in the first embodiment of the invention, Fig. 4(b) is a diagram showing a relation between a heat exchanging amount of the intermediate heat exchanger and a circulation amount of refrigerant of the bypass refrigerant circuit flowing through the intermediate heat exchanger, and Fig. 4(c) is a diagram showing a relation between ΔT which is a temperature difference between ΔT_H and ΔT_L and a circulation amount of refrigerant of the bypass refrigerant circuit flowing through the intermediate heat exchanger; and

Fig. 5 is a pressure-enthalpy diagram (P-h diagram) of the refrigeration cycle device when inlet temperature of utilization-side medium of a utilization-side heat exchanger is varied in the liquid heating device of the first embodiment of the invention.

[MODE FOR CARRYING OUT THE INVENTION]

[0015] A first aspect of the present invention provides a refrigeration cycle device including: a main refrigerant circuit formed by sequentially connecting, to one another through a pipe, a compressing mechanism composed of a compression rotary element, a utilization-side heat exchanger for heating utilization-side heating medium by refrigerant discharged from the compression rotary element, an intermediate heat exchanger, a first expansion device and a heat source-side heat exchanger; a bypass refrigerant circuit in which the refrigerant branches off from the pipe between the utilization-side heat exchanger and the first expansion device, the branched refrigerant is decompressed by a second expansion device and thereafter, the refrigerant heat-exchanges, in the intermediate heat exchanger, with the former refrigerant which flows through the main refrigerant circuit, and the refrigerant joins up with the refrigerant which is on an intermediate stage of compression of the compression rotary element; and a control device, wherein the control device controls a valve opening of the second expansion device such that a temperature difference between outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger becomes larger than a temperature difference when the refrigerant flows through the intermediate heat exchanger in a gas-liquid two-phase state, and such that a temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and inlet tem-

perature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger becomes larger than a temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and outlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger, and pressure of the refrigerant after it is decompressed by the second expansion device is maintained in a state where the pressure exceeds a critical pressure.

[0016] According to this, even when pressure of refrigerant after it is decompressed by the second expansion device exceeds the critical pressure, an enthalpy difference between the refrigerant of the outlet and the refrigerant of the inlet of the intermediate heat exchanger flowing through the bypass refrigerant circuit can be made large, and it is possible to increase the flow rate of refrigerant flowing through the intermediate heat exchanger of the bypass refrigerant circuit. Therefore, it is possible to provide a refrigeration cycle device which realizes high COP.

[0017] According to a second aspect of the invention, in the first aspect, the control device controls the valve opening of the second expansion device such that the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger becomes large as the pressure of the refrigerant after it is decompressed by the second expansion device is high.

[0018] With this configuration, inlet temperature of the utilization-side heating medium to the utilization-side heat exchanger, outlet temperature of the utilization-side heating medium from the utilization-side heat exchanger, and heat source-side heating medium (air) to the heat source-side heat exchanger rise. According to this, pressure of the refrigerant flowing through the bypass refrigerant circuit in the intermediate heat exchanger also rises. However, to secure an enthalpy difference which is required at this time, the control device controls the valve opening of the second expansion device such that the higher the pressure of refrigerant after it is decompressed by the second expansion device becomes, the larger the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger becomes. Therefore, since the enthalpy difference between refrigerant of the outlet and refrigerant of the inlet in the intermediate heat exchanger flowing through the bypass refrigerant circuit can be secured even if intermediate pressure rises, it is possible to provide a refrigeration cycle device which realizes high COP.

[0019] According to a third aspect of the invention, in the first or second aspect, the control device determines

whether the pressure of the refrigerant after it is decompressed by the second expansion device is equal to or higher than the critical pressure from a pressure value of the refrigerant discharged from the compressing mechanism, from outlet temperature of the refrigerant at the utilization-side heat exchanger, and from the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger.

[0020] According to this, even if a pressure detection device is not provided, it is possible to determine whether pressure of refrigerant after it is decompressed by the second expansion device is equal to or higher than the critical pressure. Therefore, it is possible to provide a refrigeration cycle device which can reduce costs.

[0021] According to a fourth aspect of the invention, especially in any one of the first to third aspects, the refrigerant is carbon dioxide.

[0022] According to this, in the utilization-side heat exchanger, when utilization-side heating medium is heated by refrigerant, it is possible to rise the temperature of the utilization-side heating medium.

[0023] Using the refrigeration cycle device of especially in any one of the first to fourth aspects, the fifth aspect of the invention provides a liquid heating device including a utilization-side heating medium circuit which circulates the utilization-side heating medium by a transfer device.

[0024] According to this, it is possible to provide a liquid heating device capable of utilizing high temperature utilization-side heating medium without deteriorating COP of the refrigeration cycle device.

[0025] According to a sixth aspect of the invention, especially in the fifth aspect, the liquid heating device further includes: a heating medium outlet temperature thermistor for detecting temperature of the utilization-side heating medium which flows out from the utilization-side heat exchanger; and a heating medium inlet temperature thermistor for detecting the temperature of the utilization-side heating medium which flows into the utilization-side heat exchanger, wherein the control device operates the transfer device such that detected temperature of the heating medium outlet temperature thermistor becomes equal to target temperature, and the control device controls the valve opening of the second expansion device such that when detected temperature of the heating medium inlet temperature thermistor exceeds first predetermined temperature, the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger becomes larger than the temperature difference when the refrigerant flows through the intermediate heat exchanger in the gas-liquid two-phase state, and such that the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the inlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate

heat exchanger becomes larger than the temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the outlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger.

[0026] According to this, it is possible to provide a liquid heating device capable of storing high temperature water in a hot water storage tank for example without deteriorating COP also when high pressure of the refrigeration cycle device is further increased.

[0027] According to a seventh aspect of the invention, especially in the fifth aspect, the liquid heating device further includes: a heating medium outlet temperature thermistor for detecting temperature of the utilization-side heating medium which flows out from the utilization-side heat exchanger; and a heating medium inlet temperature thermistor for detecting the temperature of the utilization-side heating medium which flows into the utilization-side heat exchanger, wherein the control device operates the transfer device such that a temperature difference between detected temperature of the heating medium outlet temperature thermistor and detected temperature of the heating medium inlet temperature thermistor becomes equal to a target temperature difference, and the control device controls the valve opening of the second expansion device such that when the detected temperature of the heating medium outlet temperature thermistor exceeds second predetermined temperature, the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger becomes larger than the temperature difference when the refrigerant flows through the intermediate heat exchanger in the gas-liquid two-phase state, and such that the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the inlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger becomes larger than the temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger and the outlet temperature of the refrigerant flowing through the main refrigerant circuit at the intermediate heat exchanger.

[0028] According to this, it is possible to provide a liquid heating device which heats a room using high temperature water for example without deteriorating COP also when high pressure of the refrigeration cycle device is further increased.

[0029] According to an eighth aspect of the invention, especially in any one of the fifth to seventh aspects, the control device determines whether the pressure of the refrigerant after it is decompressed by the second expansion device is equal to or higher than the critical pres-

sure from a pressure value of the refrigerant discharged from the compressing mechanism, from the temperature of the utilization-side heating medium which flows into the utilization-side heat exchanger, and from the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit at the intermediate heat exchanger.

[0030] According to this, even if a pressure detection device is not provided, since it is possible to determine whether pressure of the refrigerant after it is decompressed by the second expansion device is equal to or higher than the critical pressure, it is possible to provide a refrigeration cycle device which reduces costs.

[0031] According to a ninth aspect of the invention, especially in any one of the fifth to eighth aspects, the utilization-side heating medium is water or antifreeze liquid.

[0032] According to this, high temperature water can be stored in a hot water storage tank for example without deteriorating COP, and it is possible to provide a liquid heating device for heating a room using high temperature water.

[0033] An embodiment of the present invention will be described below with reference to the drawings. The invention is not limited to the embodiment.

(First Embodiment)

[0034] Fig. 1 is a block diagram of a liquid heating device in a first embodiment of the present invention. The liquid heating device is composed of a refrigeration cycle device which is a supercritical vapor compression type refrigeration cycle and a utilization-side heating medium circuit 30. The refrigeration cycle device is composed of a main refrigerant circuit 10 and a bypass refrigerant circuit 20.

[0035] The main refrigerant circuit 10 is formed by sequentially connecting, to one another through a pipe 16, a compressing mechanism 11 for compressing refrigerant, a utilization-side heat exchanger 12 which is a radiator, an intermediate heat exchanger 13, a first expansion device 14 and a heat source-side heat exchanger 15 which is an evaporator. Carbon dioxide (CO₂) is used as the refrigerant.

[0036] As the refrigerant, it is optimal to use carbon dioxide, but it is also possible to use non-azeotropic mixture refrigerant such as R407C, pseudoazeotropic mixture refrigerant such as R410A and single refrigerant such as R32.

[0037] The compressing mechanism 11 is composed of a low stage-side compression rotary element 11a and a high stage-side compression rotary element 11b. The utilization-side heat exchanger 12 heats utilization-side heating medium by refrigerant discharged from the high stage-side compression rotary element 11b.

[0038] A volume ratio of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b constituting the compressing mechanism 11 is constant, the rotary elements 11a, 11b use a common driving shaft (not shown), and are

composed of one compressor placed in one container.

[0039] The embodiment will be described using the two-stage compressing mechanism 11 in which the compression rotary element is composed of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, but the compression rotary element may not be divided into the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, and the invention can be applied also in a single compression rotary element.

[0040] Here, when the compressing mechanism 11 is the single compression rotary element, the invention can be applied based on such a configuration that refrigerant from the bypass refrigerant circuit 20 joins up with refrigerant at a position where the compression rotary element is on an intermediate stage of compression, a compression rotary element to a position where refrigerant from the bypass refrigerant circuit 20 joins up is the low stage-side compression rotary element 11a, and a compression rotary element after the position where refrigerant from the bypass refrigerant circuit 20 joins up is the high stage-side compression rotary element 11b.

[0041] The two-stage compressing mechanism 11 may be composed of two compressors in which the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are independent from each other.

[0042] The bypass refrigerant circuit 20 branches off from a pipe 16 extending from the utilization-side heat exchanger 12 to the first expansion device 14, and the bypass refrigerant circuit 20 is connected to the pipe 16 between the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b.

[0043] The bypass refrigerant circuit 20 is provided with a second expansion device 21. A portion of high pressure refrigerant after it passes through the utilization-side heat exchanger 12 or a portion of high pressure refrigerant after it passes through the intermediate heat exchanger 13 is decompressed by the second expansion device 21, and becomes intermediate pressure refrigerant. Thereafter, the intermediate pressure refrigerant heat-exchanges with high pressure refrigerant flowing through the main refrigerant circuit 10 in the intermediate heat exchanger 13, and joins up with refrigerant between the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b.

[0044] The utilization-side heating medium circuit 30 is formed by sequentially connecting, to one another through a heating medium pipe 33, the utilization-side heat exchanger 12, a transfer device 31 which is a transfer pump, and a heating terminal 32a. As the utilization-side heating medium, water or antifreeze liquid is used.

[0045] The utilization-side heating medium circuit 30 of this embodiment includes the heating terminal 32a and a hot water storage tank 32b in parallel. By switching between a first switching valve 34 and a second switching

valve 35, utilization-side heating medium is circulated through the heating terminal 32a or the hot water storage tank 32b. It is only necessary that the utilization-side heating medium circuit 30 includes any one of the heating terminal 32a or the hot water storage tank 32b.

[0046] High temperature water produced by the utilization-side heat exchanger 12 radiates heat by the heating terminal 32a and is utilized for heating a room, and low temperature water which radiates heat by the heating terminal 32a is again heated by the utilization-side heat exchanger 12.

[0047] High temperature water produced by the utilization-side heat exchanger 12 is introduced into the hot water storage tank 32b from an upper portion of the hot water storage tank 32b, and low temperature water is taken out from a lower portion of the hot water storage tank 32b and heated by the utilization-side heat exchanger 12.

[0048] A hot water supply-heat exchanger 42 is placed in the hot water storage tank 32b, and makes water supplied from a water supply-pipe 43 and high temperature water in the hot water storage tank 32b heat-exchange with each other. That is, when a hot water supply plug hot water supply plug 41 is opened, water is supplied from the water supply-pipe 43 to the hot water supply-heat exchanger 42, the water is heated by the hot water supply-heat exchanger 42, and adjusted to predetermined temperature by the hot water supply plug hot water supply plug 41, and hot water is supplied from the hot water supply plug hot water supply plug 41.

[0049] Water is supplied from the water supply-pipe 43, and heated by the hot water supply-heat exchanger 42. Hot water supplied from the hot water supply plug hot water supply plug 41 and high temperature water in the hot water storage tank 32b are indirectly heated so that they are not mixed with each other.

[0050] The hot water supply-heat exchanger 42 is a water heat exchanger using a copper pipe or a stainless pipe as a heat transfer pipe. As shown in Fig. 1, the hot water supply plug 41 and the water supply-pipe 43 extending from a water supply source (waterline) are connected to the hot water supply-heat exchanger 42. The water supply-pipe 43 introduces normal temperature water to a lower end of the hot water supply-heat exchanger 42, i.e., to a lower location in the hot water storage tank 32b.

[0051] The normal temperature water which enters the hot water supply-heat exchanger 42 from the water supply-pipe 43 moves from downward to upward in the hot water storage tank 32b, draws heat from high temperature water in the hot water storage tank 32b, and becomes high temperature heated water, and is supplied from the hot water supply plug hot water supply plug 41.

[0052] For measuring temperature of hot water at a plurality of different height locations, the hot water storage tank 32b is provided with a first hot water storage tank temperature thermistor 55a, a second hot water storage tank temperature thermistor 55b and a third hot water

storage tank temperature thermistor 55c.

[0053] The normal temperature water which flows into the hot water supply-heat exchanger 42 from the water supply-pipe 43 draws heat from high temperature water in the hot water storage tank 32b while moving from downward to upward in the hot water storage tank 32b. Therefore, temperature of an upper portion of hot water in the hot water storage tank 32b naturally becomes high and temperature of a lower portion thereof naturally becomes low.

[0054] A discharge-side pipe 16 of the high stage-side compression rotary element 11b of the main refrigerant circuit 10 is provided with a high pressure-pressure detection device 51. The high pressure-pressure detection device 51 is provided in the main refrigerant circuit 10 between a discharge side of the high stage-side compression rotary element 11b and an upstream side of the first expansion device 14. It is only necessary that the high pressure-pressure detection device 51 can detect pressure of high pressure refrigerant of the main refrigerant circuit 10.

[0055] The pipe 16 located downstream of the utilization-side heat exchanger 12 of the main refrigerant circuit 10 and upstream of the intermediate heat exchanger 13 is provided with an intermediate heat exchanger main refrigerant inlet thermistor 57. The intermediate heat exchanger main refrigerant inlet thermistor 57 detects temperature of refrigerant which flows out from the utilization-side heat exchanger 12. The pipe 16 located downstream of the intermediate heat exchanger 13 of the main refrigerant circuit 10 and upstream of the first expansion device 14 is provided with an intermediate heat exchanger main refrigerant outlet thermistor 58.

[0056] The bypass refrigerant circuit 20 is provided with an intermediate heat exchanger bypass inlet thermistor 56 downstream of the second expansion device 21 and upstream of the intermediate heat exchanger 13. Further, the bypass refrigerant circuit 20 is provided with an intermediate heat exchanger bypass outlet thermistor 52 downstream of the intermediate heat exchanger 13.

[0057] The utilization-side heating medium circuit 30 is provided with a heating medium outlet temperature thermistor 53 for detecting temperature of utilization-side heating medium flowing out from the utilization-side heat exchanger 12 and a heating medium inlet temperature thermistor 54 for detecting temperature of utilization-side heating medium flowing into the utilization-side heat exchanger 12.

[0058] A control device 60 controls operation frequencies of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, valve openings of the first expansion device 14 and the second expansion device 21, and a transfer amount of utilization-side heating medium by the transfer device 31. The control device 60 controls these elements by pressure detected by the high pressure-pressure detection device 51, calculated intermediate pressure, a temperature difference (ΔTM) between detected tempera-

ture of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature of the intermediate heat exchanger bypass inlet thermistor 56, a temperature difference (ΔTH) between detected temperature of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature of the intermediate heat exchanger main refrigerant inlet thermistor 57, a temperature difference (ΔTL) between detected temperature of the intermediate heat exchanger bypass inlet thermistor 56 and detected temperature of the intermediate heat exchanger main refrigerant outlet thermistor 58, detected temperature of the heating medium outlet temperature thermistor 53 and detected temperature of the heating medium inlet temperature thermistor 54.

[0059] A method, by the control device 60, for calculating pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 in the bypass refrigerant circuit 20 will be described later.

[0060] Figs. 2 are pressure-enthalpy diagrams (P-h diagram) under ideal conditions concerning the refrigeration cycle device in this embodiment, wherein Figs. 2(a) shows a case where high pressure is lower than predetermined pressure, and Fig. 2(b) shows a case where high pressure is equal to or higher than the predetermined pressure.

[0061] Points a to e and points A and B in Figs. 2 correspond to points in the refrigeration cycle device shown in Fig. 1.

[0062] First, high pressure refrigerant (point a) discharged from the high stage-side compression rotary element 11b radiates heat in the utilization-side heat exchanger 12 and then, the refrigerant branches off from the main refrigerant circuit 10 at a refrigerant branch A, the refrigerant is decompressed to intermediate pressure by the second expansion device 21 and becomes intermediate pressure refrigerant (point e), and heat-exchanges by the intermediate heat exchanger 13.

[0063] High pressure refrigerant flowing through the main refrigerant circuit 10 after it radiates heat in the utilization-side heat exchanger 12 is cooled by intermediate pressure refrigerant (point e) flowing through the bypass refrigerant circuit 20 and the high pressure refrigerant is decompressed by the first expansion device 14 in a state where enthalpy is reduced (point b).

[0064] According to this, after the refrigerant is decompressed in the first expansion device 14, refrigerant enthalpy of refrigerant (point c) which flows into the heat source-side heat exchanger 15 is also reduced. A refrigerant dryness fraction (ratio of weight occupied by gaseous phase component with respect to entire refrigerant) when the refrigerant flows into the heat source-side heat exchanger 15 is reduced and liquid component of refrigerant is increased. Therefore, this contributes to evaporation in the heat source-side heat exchanger 15, a ratio of refrigerant is increased, a heat absorption amount from outside air is increased, and the refrigerant returns to a suction side (point d) of the low stage-side compression

rotary element 11a.

[0065] On the other hand, refrigerant of an amount corresponding to gaseous phase component which does not contribute to evaporation in the heat source-side heat exchanger 15 bypasses to the bypass refrigerant circuit 20 and becomes intermediate pressure refrigerant (point e), the refrigerant is heated by high pressure refrigerant flowing through the main refrigerant circuit 10 in the intermediate heat exchanger 13, and the refrigerant reaches a refrigerant junction B located between the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b in a state where refrigerant enthalpy is increased.

[0066] Therefore, on the suction side (point B) of the high stage-side compression rotary element 11b, since refrigerant pressure is higher than the suction side (point d) of the low stage-side compression rotary element 11a, density of the refrigerant is also higher, and refrigerant which joins up with refrigerant discharged from the low stage-side compression rotary element 11a is sucked, the refrigerant is further compresses by the high stage-side compression rotary element 11b and is discharged. Thus, a flow rate of refrigerant flowing into the utilization-side heat exchanger 12 is largely increased, and ability of heating water which is utilization-side heating medium is largely enhanced.

[0067] If discharged pressure of the high stage-side compression rotary element 11b rises and exceeds a predetermined value, the control device 60 starts controlling the valve opening of the second expansion device 21 such that pressure of refrigerant after it is decompressed by the second expansion device 21 exceeds critical pressure.

[0068] More specifically, when the control device 60 determines that detected pressure of the high pressure-pressure detection device 51 rises and exceeds a first predetermined high pressure value, if intermediate pressure is equal to or lower than critical pressure, the control device 60 starts operation to increase the valve opening of the second expansion device 21 so that the intermediate pressure exceeds the critical pressure.

[0069] As shown in Fig. 2(b), the control device 60 operates the second expansion device 21 to increase the valve opening thereof, rises operation frequencies of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, increases a circulation amount of refrigerant flowing between the utilization-side heat exchanger 12 and the bypass refrigerant circuit 20, and brings the detected pressure from the high pressure-pressure detection device 51 into 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.

[0070] That is, by increasing the valve opening of the second expansion device 21, a flow rate of refrigerant flowing through the bypass refrigerant circuit 20 can be increased. Therefore, suction pressure of the high stage-

side compression rotary element 11b can be maintained in a state where the suction pressure exceeds the critical pressure which is a predetermined intermediate pressure value. According to this, suction pressure of the high stage-side compression rotary element 11b, i.e., pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 can be maintained in a state where the pressure exceeds the critical pressure which is the predetermined intermediate pressure value, and heating ability of refrigerant in the utilization-side heat exchanger 12 can also be enhanced.

[0071] The compressing mechanism 11 may be composed of two compressors in which the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are independent from each other, and it is only necessary to rise operation frequency of at least the high stage-side compression rotary element 11b.

[0072] Here, a method, by the control device 60, for calculating pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 in the bypass refrigerant circuit 20 will be described.

[0073] The pressure-enthalpy diagram (P-h diagram) as shown in Figs. 2 is stored in the control device 60.

[0074] Per predetermined time, high pressure-side pressure (discharged pressure of high stage-side compression rotary element 11b) is detected by the high pressure-pressure detection device 51, outlet temperature (point A) of refrigerant of the utilization-side heat exchanger 12 is detected by the intermediate heat exchanger main refrigerant inlet thermistor 57, and inlet temperature (point e) of refrigerant of the bypass refrigerant circuit 20 of the intermediate heat exchanger 13 is detected by the intermediate heat exchanger bypass inlet thermistor 56.

[0075] Under an ideal condition that enthalpies at points A and e are substantially the same values, the control device 60 calculates pressure and enthalpy at the point e, thereby calculating a value of pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21, and it is possible to determine whether the pressure is equal to or higher than the critical pressure based on the calculated value.

[0076] It is also possible to use detected temperature of the heating medium inlet temperature thermistor 54 instead of detected temperature of the intermediate heat exchanger main refrigerant inlet thermistor 57 because these values are substantially equal to each other.

[0077] That is, it is possible to determine that pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 is equal to or higher than the critical pressure from discharged pressure of the high stage-side compression rotary element 11b, inlet temperature (point e) of refrigerant of the bypass refrigerant circuit 20 of the intermediate heat exchanger 13, and temperature of utilization-side heating medium which flows into the utilization-side heat ex-

changer 12.

[0078] According to this, it is possible to determine whether a state where pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure is maintained.

[0079] In this embodiment, the control device 60 controls the valve opening of the second expansion device 21 such that a state where suction pressure p_f of the high stage-side compression rotary element 11b, i.e., pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure is maintained, and such that a heat exchanging amount between refrigerant of the bypass refrigerant circuit 20 and refrigerant of the main refrigerant circuit 10 in the intermediate heat exchanger 13 becomes the maximum.

[0080] The reason is that when the heat exchanging amount in the intermediate heat exchanger 13 becomes the maximum, since enthalpy at the point b in Fig. 2(b) is reduced, enthalpy at the point c is also reduced and therefore, refrigerant dryness fraction in the heat source-side heat exchanger 15 is reduced, a heat absorption amount is increased and thus, COP can be maximized.

[0081] A concrete controlling method of the valve opening will be described below. Fig. 3 shows a relation between refrigerant of the main refrigerant circuit 10 and temperature of refrigerant of the bypass refrigerant circuit 20 which flow through the intermediate heat exchanger 13.

[0082] In Fig. 3, the control device 60 controls the valve opening of the second expansion device 21 based on a temperature difference (ΔTM) between detected temperature (point B) of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature (e) of the intermediate heat exchanger bypass inlet thermistor 56, a temperature difference (ΔTH) between detected temperature (point B) of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature (point A) of the intermediate heat exchanger main refrigerant inlet thermistor 57, and a temperature difference (ΔTL) between detected temperature (e) of the intermediate heat exchanger bypass inlet thermistor 56 and detected temperature (b) of the intermediate heat exchanger main refrigerant outlet thermistor 58.

[0083] Fig. 4(a) is a diagram showing a relation between ΔTM and a circulation amount of refrigerant of the bypass refrigerant circuit 20 flowing through the intermediate heat exchanger 13. Fig. 4(b) is a diagram showing a relation between a heat exchanging amount of the intermediate heat exchanger 13 and a circulation amount of refrigerant of the bypass refrigerant circuit 20 flowing through the intermediate heat exchanger 13. Fig. 4(c) is a diagram showing a relation between ΔTH , ΔTL and a circulation amount of refrigerant of the bypass refrigerant circuit 20 flowing through the intermediate heat exchanger 13.

[0084] First, in Fig. 4(a), a solid line shows variation

when intermediate pressure is supercritical, and a dash line shows variation when intermediate pressure is in a gas-liquid two-phase area.

[0085] When a circulation amount of bypass refrigerant flowing through the bypass refrigerant circuit 20 is small, since a circulation amount of refrigerant of the main refrigerant circuit 10 is larger than a circulation amount of bypass refrigerant flowing through the bypass refrigerant circuit 20, refrigerant flowing through the bypass refrigerant circuit 20 is sufficiently heated, outlet temperature (point B) of refrigerant of the bypass refrigerant circuit 20 of the intermediate heat exchanger 13 easily rises and ΔTM becomes large.

[0086] On the other hand, as a circulation amount of bypass refrigerant is increased, a flow rate difference between a circulation amount of bypass refrigerant flowing through the bypass refrigerant circuit 20 and a circulation amount of refrigerant flowing through the main refrigerant circuit 10 becomes small. Therefore, temperature rise of outlet temperature (point B) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 is suppressed, and ΔTM becomes small.

[0087] That is, when intermediate pressure is in the gas-liquid two-phase area, if a circulation amount of bypass refrigerant exceeds a given amount, liquid component which occupies refrigerant is increased, heat obtained by the heat exchange with respect to refrigerant circulating through the main refrigerant circuit 10 becomes latent heat, and temperature of refrigerant flowing through the bypass refrigerant circuit 20 does not rise. Therefore, ΔTM becomes substantially zero. When the intermediate pressure exceeds critical pressure on the other hand, since there is no liquid component, temperature of refrigerant rises and ΔTM does not become substantially zero.

[0088] Next, in Fig. 4(b), a solid line shows variation when intermediate pressure is supercritical, and a dash line shows variation when intermediate pressure is in the gas-liquid two-phase area.

[0089] When intermediate pressure is in the gas-liquid two-phase area and when the intermediate pressure exceeds the critical pressure, a size of ΔTM when a heat exchanging amount of the intermediate heat exchanger 13 is set to the maximum is different, and when the intermediate pressure exceeds the critical pressure, it can be found that ΔTM is larger than that when the intermediate pressure is in the gas-liquid two-phase area.

[0090] Next, in Fig. 4(c), since inlet temperature (point A) of refrigerant in the intermediate heat exchanger 13 flowing through the main refrigerant circuit 10 is not varied because inlet temperature of utilization-side heating medium to the utilization-side heat exchanger 12 is constant.

[0091] At this time, if the valve opening of the second expansion device 21 is small, when a circulation amount of bypass refrigerant flowing through the bypass refrigerant circuit 20 is small, a circulation amount of refrigerant flowing through the main refrigerant circuit 10 is larger than that of bypass refrigerant flowing through the bypass

refrigerant circuit 20. Therefore, refrigerant flowing through the bypass refrigerant circuit 20 is sufficiently heated, outlet temperature (point B) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 becomes close to inlet temperature (point A) of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13. Therefore, ΔT_H which is a temperature difference is small.

[0092] On the other hand, outlet temperature (point e) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 is temperature of refrigerant after it is decompressed by the second expansion device 21, but if the valve opening of the second expansion device 21 is small and if an amount of bypass refrigerant flowing through the bypass refrigerant circuit 20 is small, intermediate pressure also becomes low and therefore, temperature of the refrigerant is also low. Hence, ΔT_L which is a temperature difference with respect to outlet temperature (point b) of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13 becomes large.

[0093] However, if the control device 60 operates to increase the valve opening of the second expansion device 21 and to increase the circulation amount of bypass refrigerant, since a heat exchanging amount at the intermediate heat exchanger 13 is increased, rise of outlet temperature (point B) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 is suppressed, and ΔT_H is increased.

[0094] As the control device 60 operates to increase the valve opening of the second expansion device 21 and a circulation amount of bypass refrigerant is increased, intermediate pressure is increased. Therefore, outlet temperature (point e) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 rises, and ΔT_L which is a temperature difference with respect to outlet temperature (point b) of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13 becomes small.

[0095] In this embodiment, the control device 60 executes the following intermediate pressure supercritical operation mode.

(Intermediate pressure supercritical operation mode)

[0096] When the control device 60 determines that detected pressure of the high pressure-pressure detection device 51 rises and exceeds the first predetermined high pressure value, if the intermediate pressure is equal to or lower than the critical pressure, the control device 60 starts the operation to increase the valve opening of the second expansion device 21 so that intermediate pressure exceeds critical pressure. Then, the control device 60 controls the valve opening of the second expansion device 21 such that a temperature difference (ΔT_M) between outlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat

exchanger 13 and inlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 becomes larger than a temperature difference (ΔT_M) when refrigerant flows through the intermediate heat exchanger 13 in the gas-liquid two-phase state so that a state where pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure is maintained.

[0097] That is, the control device 60 controls the valve opening of the second expansion device 21 such that a temperature difference (ΔT_M) between detected temperature (point B) of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature (e) of the intermediate heat exchanger bypass inlet thermistor 56 becomes larger than a temperature difference (ΔT_M) when refrigerant flows through the intermediate heat exchanger 13 in the gas-liquid two-phase state so that a state where pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure is maintained.

[0098] Further, in this embodiment, the control device 60 controls the valve opening of the second expansion device 21 such that when it is determined that detected pressure of the high pressure-pressure detection device 51 rises and exceeds the first predetermined high pressure value, if intermediate pressure is equal to or lower than the critical pressure, the control device 60 starts the operation to increase the valve opening of the second expansion device 21 so that the intermediate pressure exceeds the critical pressure, and so that a state where pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure is maintained, a temperature difference (ΔT_H) between outlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and inlet temperature of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13 becomes larger than a temperature difference (ΔT_H) when refrigerant flows through the intermediate heat exchanger 13 in the gas-liquid two-phase state and larger than a temperature difference (ΔT_L) between inlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and outlet temperature of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13.

[0099] That is, the control device 60 controls the valve opening of the second expansion device 21 such that a temperature difference (ΔT_H) between detected temperature (point B) of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature (point A) of the intermediate heat exchanger main refrigerant inlet thermistor 57 becomes larger than a temperature difference (ΔT_H) when refrigerant flows through the intermediate heat exchanger 13 in the gas-liquid two-phase state and larger than a temperature difference (ΔT_L) between detected temperature (e) of the intermediate heat ex-

changer bypass inlet thermistor 56 and detected temperature (b) of the intermediate heat exchanger main refrigerant outlet thermistor 58 so that a state where pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure is maintained.

[0100] While performing the above-described control, the control device 60 controls such that a temperature difference (ΔTM) between outlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and inlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 becomes larger than a temperature difference when refrigerant flows through the intermediate heat exchanger 13 in the gas-liquid two-phase state as shown in Figs. 4.

[0101] Further, the control device 60 controls such that a temperature difference (ΔTH) between outlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and inlet temperature of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13 becomes larger than a temperature difference (ΔTL) between inlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and outlet temperature of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13.

[0102] Further, the control device 60 adjusts the valve opening of the second expansion device 21 such that a heat exchanging amount at the intermediate heat exchanger 13 becomes the maximum value, and sets a circulation amount of bypass refrigerant flowing through the bypass refrigerant circuit 20.

[0103] Relations between ΔTM , ΔT and a heat exchanging amount of the intermediate heat exchanger 13 are previously set in the control device 60. The control device 60 adjusts the valve opening of the second expansion device 21 such that ΔTM , ΔT and the heat exchanging amount of the intermediate heat exchanger 13 become the maximum values, and sets a circulation amount of bypass refrigerant flowing through the bypass refrigerant circuit 20.

[0104] The above-described matters are control contents of the intermediate pressure supercritical operation mode.

[0105] According to this, it is possible to provide a refrigeration cycle device which realizes high COP.

[0106] A case where the hot water storage tank 32b is used in the utilization-side heating medium circuit 30 will be described below.

[0107] Among the plurality of hot water storage tank temperature thermistors, when detected temperature of the first hot water storage tank temperature thermistor 55a placed at the highest position of the hot water storage tank 32b is lower than a predetermined value for example, the control device 60 determines that high temperature water is insufficient in the hot water storage tank

32b.

[0108] The control device 60 operates the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, heats low temperature water by the utilization-side heat exchanger 12, and operates the transfer device 31 such that detected temperature of the heating medium outlet temperature thermistor 53 which is its heating temperature becomes target temperature.

[0109] According to this, low temperature water is taken out from a lower portion of the hot water storage tank 32b and heated by the utilization-side heat exchanger 12 and then, high temperature water is produced. The high temperature water is introduced into the hot water storage tank 32b from an upper portion of the hot water storage tank 32b. At this time, since the detected temperature of the heating medium inlet temperature thermistor 54 is equal to or lower than first predetermined temperature, the refrigeration cycle device operates in a state described in Fig. 2(a).

[0110] Since high temperature water is gradually stored in the hot water storage tank 32b from the upper portion, detected temperature of the heating medium inlet temperature thermistor 54 gradually rises, but if the detected temperature of the heating medium inlet temperature thermistor 54 exceeds the first predetermined temperature, the refrigeration cycle device operates in a state described in Fig. 2(b).

[0111] That is, operation is carried out to increase the valve opening of the second expansion device 21, operation frequencies of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are made to rise, a circulation amount of refrigerant flowing between the utilization-side heat exchanger 12 and the bypass refrigerant circuit 20 is increased, and detected pressure from the high pressure-pressure detection device 51 is made equal to a second predetermined high pressure value which is a target high pressure value. At the same time, the intermediate pressure supercritical operation mode is executed.

[0112] According to this, inlet temperature at the utilization-side heat exchanger 12 of heating medium becomes high, and an enthalpy difference (a-A) of refrigerant at the utilization-side heat exchanger 12 becomes small. By increasing the heating ability of refrigerant at the utilization-side heat exchanger 12, supply of high temperature water to the hot water storage tank 32b can be maintained.

[0113] If detected temperature of the heating medium inlet temperature thermistor 54 exceeds third predetermined temperature which is higher than the first predetermined temperature, operation frequencies of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are lowered. According to this, high temperature water can be stored in the hot water storage tank 32b while suppressing the rise of pressure of the high pressure refrigerant in the utilization-side heat exchanger 12 so that pressure of the

high pressure refrigerant in the utilization-side heat exchanger 12 does not exceed a second predetermined high pressure value which is a target high pressure value.

[0114] The same operation action may be executed using, as a threshold value, the first predetermined high pressure value and the second predetermined high pressure value which are detected pressure of the high pressure-pressure detection device 51 instead of the first predetermined temperature and the third predetermined temperature which are detected temperature of the heating medium inlet temperature thermistor 54.

[0115] The compressing mechanism 11 may be composed of the two compressors in which the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are independent from each other, and it is only necessary that operation frequency of at least the high stage-side compression rotary element 11b is lowered.

[0116] A case where the heating terminal 32a is used in the utilization-side heating medium circuit 30 will be described.

[0117] The control device 60 operates the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, and heats circulation water by the utilization-side heat exchanger 12, but the control device 60 operates the transfer device 31 such that a temperature difference between detected temperature of the heating medium outlet temperature thermistor 53 which is a temperature difference of the circulation water and detected temperature of the heating medium inlet temperature thermistor 54 becomes equal to a target temperature difference.

[0118] According to this, high temperature water produced by the utilization-side heat exchanger 12 radiates heat in the heating terminal 32a and is utilized for heating a room, and low temperature water which radiates heat in the heating terminal 32a is again heated by the utilization-side heat exchanger 12. At this time, control is performed such that a temperature difference between detected temperature of the heating medium outlet temperature thermistor 53 and detected temperature of the heating medium inlet temperature thermistor 54 becomes equal to the target temperature difference. Since detected temperature of the heating medium outlet temperature thermistor 53 is equal to or lower than the second predetermined temperature, the refrigeration cycle device is operated in the state described in Fig. 2(a).

[0119] Since a heating load gradually becomes small, control is performed such that a temperature difference between the detected temperature of the heating medium outlet temperature thermistor 53 and detected temperature of the heating medium inlet temperature thermistor 54 becomes equal to the target temperature difference. Therefore, although the detected temperature of the heating medium outlet temperature thermistor 53 and the detected temperature of the heating medium inlet temperature thermistor 54 gradually rise, if the detected temperature of the heating medium outlet temperature ther-

mistor 53 exceeds the second predetermined temperature, the refrigeration cycle device is operated in the state described in Fig. 2(b).

[0120] That is, operation is carried out to increase the valve opening of the second expansion device 21, operation frequencies of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are made to rise, a circulation amount of refrigerant flowing between the utilization-side heat exchanger 12 and the bypass refrigerant circuit 20 is increased, and detected pressure from the high pressure-pressure detection device 51 is made equal to a second predetermined high pressure value which is a target high pressure value. At the same time, the intermediate pressure supercritical operation mode is executed.

[0121] According to this, the heating load becomes small, and an enthalpy difference (a-A) of refrigerant at the utilization-side heat exchanger 12 becomes small. By increasing the heating ability of refrigerant at the utilization-side heat exchanger 12, the supply of high temperature water to the heating terminal 32a can be maintained.

[0122] If detected temperature of the heating medium outlet temperature thermistor 53 exceeds fourth predetermined temperature which is higher than the second predetermined temperature, operation frequencies of the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are lowered. According to this, the present invention can be utilized as a heating device using high temperature water while suppressing the rise of pressure of the high pressure refrigerant in the utilization-side heat exchanger 12 so that pressure of the high pressure refrigerant in the utilization-side heat exchanger 12 does not exceed a second predetermined high pressure value which is a target high pressure value.

[0123] The same operation action may be executed using, as a threshold value, the first predetermined high pressure value and the second predetermined high pressure value which are detected pressure of the high pressure-pressure detection device 51 instead of the second predetermined temperature and the fourth predetermined temperature.

[0124] The intermediate pressure supercritical operation mode will be described below using Fig. 5. This mode is executed by the control device 60 in a case where detected temperature of the heating medium inlet temperature thermistor 54 exceeds the first predetermined temperature when the hot water storage tank 32b is used in the utilization-side heating medium circuit 30, or in a case where detected temperature of the heating medium outlet temperature thermistor 53 exceeds the second predetermined temperature when the heating terminal 32a is used in the utilization-side heating medium circuit 30.

[0125] In Fig. 5, a solid line shows the case where detected temperature of the heating medium inlet temperature thermistor 54 exceeds the first predetermined tem-

perature when the hot water storage tank 32b is used in the utilization-side heating medium circuit 30, or the case where detected temperature of the heating medium outlet temperature thermistor 53 exceeds the second predetermined temperature when the heating terminal 32a is used in the utilization-side heating medium circuit 30.

[0126] A broken line shows the case where detected temperature of the heating medium inlet temperature thermistor 54 is equal to or lower than the first predetermined temperature when the hot water storage tank 32b is used in the utilization-side heating medium circuit 30, or the case where detected temperature of the heating medium outlet temperature thermistor 53 is equal to or lower than the second predetermined temperature when the heating terminal 32a is used in the utilization-side heating medium circuit 30.

[0127] That is, in Fig. 5, in a state where pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 exceeds the critical pressure, if the intermediate pressure rises, inlet temperature (point A) of refrigerant flowing through the main refrigerant circuit 10 at the intermediate heat exchanger 13 moves to increase the enthalpy and similarly, outlet temperature (point e) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and outlet temperature (point B) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 also move to increase the enthalpy.

[0128] In the state where the pressure exceeds the critical pressure, as the enthalpy increases, inclination of an isothermal line with respect to pressure also becomes steep.

[0129] Therefore, in the intermediate heat exchanger 13, to obtain the same heat exchanging amount even if the intermediate pressure rises, the control device 60 must control the valve opening of the second expansion device 21 such that a temperature difference (ΔT_M) between outlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 and inlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 becomes large.

[0130] That is, the control device 60 must control the valve opening of the second expansion device 21 such that as the intermediate pressure becomes high, a temperature difference (ΔT_M) between detected temperature (point B) of the intermediate heat exchanger bypass outlet thermistor 52 and detected temperature (e) of the intermediate heat exchanger bypass inlet thermistor 56 becomes large.

[0131] A value of pressure (intermediate pressure) of refrigerant after it is decompressed by the second expansion device 21 is calculated from discharged pressure of the high stage-side compression rotary element 11b, outlet temperature (point A) of refrigerant of the utilization-side heat exchanger 12 or temperature of utilization-side heating medium which flows into the utilization-

side heat exchanger 12, inlet temperature (point e) of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13.

[0132] When this value is equal to or higher than the critical pressure, the control device 60 may control the valve opening of the second expansion device 21 such that the temperature difference between the outlet temperature and inlet temperature of refrigerant flowing through the bypass refrigerant circuit 20 at the intermediate heat exchanger 13 becomes large as pressure of refrigerant after it is decompressed by the second expansion device 21 becomes high based on the value of the calculated intermediate pressure.

[0133] Here, ΔT_M is previously set in the control device 60 such that as the intermediate pressure becomes high, the value of ΔT_M also becomes large.

[0134] When the heating medium inlet temperature thermistor 54 exceeds the first predetermined temperature, or when the heating medium outlet temperature thermistor 53 exceeds the second predetermined temperature, the control device 60 may control the valve opening of the second expansion device 21 such that the intermediate pressure rises and the value of ΔT_M also becomes large by reducing the valve opening of the first expansion device 14 and increasing the valve opening of the second expansion device 21 as detected temperature of the heating medium inlet temperature thermistor 54 or detected temperature of the heating medium outlet temperature thermistor 53 rises.

[0135] Here, ΔT_M is previously set in the control device 60 such that the value of ΔT_M also becomes large as inlet temperature of the utilization-side heating medium to the utilization-side heat exchanger 12 or outlet temperature of utilization-side heating medium from the utilization-side heat exchanger 12 becomes high.

[0136] The compressing mechanism 11 may be configured such that the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b are composed of two independent compressors, and it is only necessary that operation frequency of at least the high stage-side compression rotary element 11b is lowered.

[0137] The compressing mechanism 11 may not be divided into the low stage-side compression rotary element 11a and the high stage-side compression rotary element 11b, and may be a single compression rotary element. When the compressing mechanism 11 is a single compression rotary element, refrigerant from the bypass refrigerant circuit 20 joins up with refrigerant at a position where the compression rotary element is on an intermediate stage of compression.

[0138] In the refrigeration cycle device of the embodiment, it is preferable that refrigerant is carbon dioxide. This is because temperature of utilization-side heating medium when it is heated by carbon dioxide which is refrigerant can be made high in the utilization-side heat exchanger 12.

[0139] If the utilization-side heating medium is water

or antifreeze liquid, the utilization-side heating medium can be used to the heating terminal 32a or high temperature water can be stored in the hot water storage tank 32b.

[INDUSTRIAL APPLICABILITY]

[0140] As described above, the refrigeration cycle device of the present invention is composed of the main refrigerant circuit having the intermediate heat exchanger and the bypass refrigerant circuit, and a pressure difference between high pressure and intermediate pressure is not made large. According to this, since COP is not deteriorated, the refrigeration cycle device of the present invention is useful for liquid heating devices of refrigerant, air conditioning, hot water supply and a heating device.

[EXPLANATION OF SYMBOLS]

[0141]

10	main refrigerant circuit	
11	compressing mechanism	
11a	low stage-side compression rotary element	
11b	high stage-side compression rotary element	
12	utilization-side heat exchanger	
13	intermediate heat exchanger	
14	first expansion device	
15	heat source-side heat exchanger	
16	pipe	
20	bypass refrigerant circuit	
21	second expansion device	
30	utilization-side heating medium circuit	
31	transfer device	
32a	heating terminal	
32b	hot water storage tank	
33	heating medium pipe	
34	first switching valve	
35	second switching valve	
41	hot water supply plug	
42	hot water supply-heat exchanger	
43	water supply-pipe	
51	high pressure-side pressure detection device	
52	intermediate heat exchanger bypass outlet thermistor	
53	heating medium outlet temperature thermistor	
54	heating medium inlet temperature thermistor	
55a	first hot water storage tank temperature thermistor	
55b	second hot water storage tank temperature thermistor	
55c	third hot water storage tank temperature thermistor	
56	intermediate heat exchanger bypass inlet thermistor	
57	intermediate heat exchanger main refrigerant inlet thermistor	

58	intermediate heat exchanger main refrigerant outlet thermistor
60	control device

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Claims

1. A refrigeration cycle device comprising: a main refrigerant circuit (10) formed by sequentially connecting, to one another through a pipe (16), a compressing mechanism (11) composed of a compression rotary element, a utilization-side heat exchanger (12) for heating utilization-side heating medium by refrigerant discharged from the compression rotary element, an intermediate heat exchanger (13), a first expansion device (14) and a heat source-side heat exchanger (15);
a bypass refrigerant circuit (20) in which the refrigerant branches off from the pipe (16) between the utilization-side heat exchanger (12) and the first expansion device (14), the branched refrigerant is decompressed by a second expansion device (21) and thereafter, the refrigerant heat-exchanges, in the intermediate heat exchanger (13), with the former refrigerant which flows through the main refrigerant circuit (10), and the refrigerant joins up with the refrigerant which is on an intermediate stage of compression of the compression rotary element; and
a control device (60), wherein
the control device (60) controls a valve opening of the second expansion device (21)
such that a temperature difference between outlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) becomes larger than a temperature difference when the refrigerant flows through the intermediate heat exchanger (13) in a gas-liquid two-phase state, and
such that a temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and inlet temperature of the refrigerant flowing through the main refrigerant circuit (10) at the intermediate heat exchanger (13) becomes larger than a temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and outlet temperature of the refrigerant flowing through the main refrigerant circuit (10) at the intermediate heat exchanger (13), and
pressure of the refrigerant after it is decompressed by the second expansion device (21) is maintained in a state where the pressure exceeds a critical pressure.

2. The refrigeration cycle device according to claim 1, wherein
the control device (60) controls the valve opening of the second expansion device (21) such that the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) becomes large as the pressure of the refrigerant after it is decompressed by the second expansion device (21) is high. 5
3. The refrigeration cycle device according to claim 1 or 2, wherein 10
the control device (60) determines whether the pressure of the refrigerant after it is decompressed by the second expansion device (21) is equal to or higher than the critical pressure from a pressure value of the refrigerant discharged from the compressing mechanism (11), from outlet temperature of the refrigerant at the utilization-side heat exchanger (12), and from the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13). 15
4. The refrigeration cycle device according to any one of claims 1 to 3, wherein the refrigerant is carbon dioxide. 20
5. A liquid heating device comprising a utilization-side heating medium circuit (30) which circulates the utilization-side heating medium by a transfer device (31) using the refrigeration cycle device according to any one of claims 1 to 4. 25
6. The liquid heating device according to claim 5, further comprising: 30
a heating medium outlet temperature thermistor (53) for detecting temperature of the utilization-side heating medium which flows out from the utilization-side heat exchanger (12); and
a heating medium inlet temperature thermistor (54) for detecting the temperature of the utilization-side heating medium which flows into the utilization-side heat exchanger (12), wherein the control device (60) operates the transfer device (31) such that detected temperature of the heating medium outlet temperature thermistor (53) becomes equal to target temperature, and the control device (60) controls the valve opening of the second expansion device (21) such that when detected temperature of the heating medium inlet temperature thermistor (54) exceeds first predetermined temperature, the temperature difference between the outlet temperature of the refrigerant flowing through 35
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the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) becomes larger than the temperature difference when the refrigerant flows through the intermediate heat exchanger (13) in the gas-liquid two-phase state, and such that the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the inlet temperature of the refrigerant flowing through the main refrigerant circuit (10) at the intermediate heat exchanger (13) becomes larger than the temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the outlet temperature of the refrigerant flowing through the main refrigerant circuit (10) at the intermediate heat exchanger (13).

7. The liquid heating device according to claim 5, further comprising:

a heating medium outlet temperature thermistor (53) for detecting temperature of the utilization-side heating medium which flows out from the utilization-side heat exchanger (12); and
a heating medium inlet temperature thermistor (54) for detecting the temperature of the utilization-side heating medium which flows into the utilization-side heat exchanger (12), wherein the control device (60) operates the transfer device (31) such that a temperature difference between detected temperature of the heating medium outlet temperature thermistor (53) and detected temperature of the heating medium inlet temperature thermistor (54) becomes equal to a target temperature difference, and the control device (60) controls the valve opening of the second expansion device (21) such that when the detected temperature of the heating medium outlet temperature thermistor (53) exceeds second predetermined temperature, the temperature difference between the outlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) becomes larger than the temperature difference when the refrigerant flows through the intermediate heat exchanger (13) in the gas-liquid two-phase state, and such that the temperature difference between the outlet temperature of the refrigerant flowing

through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the inlet temperature of the refrigerant flowing through the main refrigerant circuit (10) at the intermediate heat exchanger (13) becomes larger than the temperature difference between the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13) and the outlet temperature of the refrigerant flowing through the main refrigerant circuit (10) at the intermediate heat exchanger (13).

8. The liquid heating device according to any one of claims 5 to 7, wherein the control device (60) determines whether the pressure of the refrigerant after it is decompressed by the second expansion device (21) is equal to or higher than the critical pressure from a pressure value of the refrigerant discharged from the compressing mechanism (11), from the temperature of the utilization-side heating medium which flows into the utilization-side heat exchanger (12), and from the inlet temperature of the refrigerant flowing through the bypass refrigerant circuit (20) at the intermediate heat exchanger (13).
9. The liquid heating device according to any one of claims 5 to 8, wherein the utilization-side heating medium is water or anti-freeze liquid.

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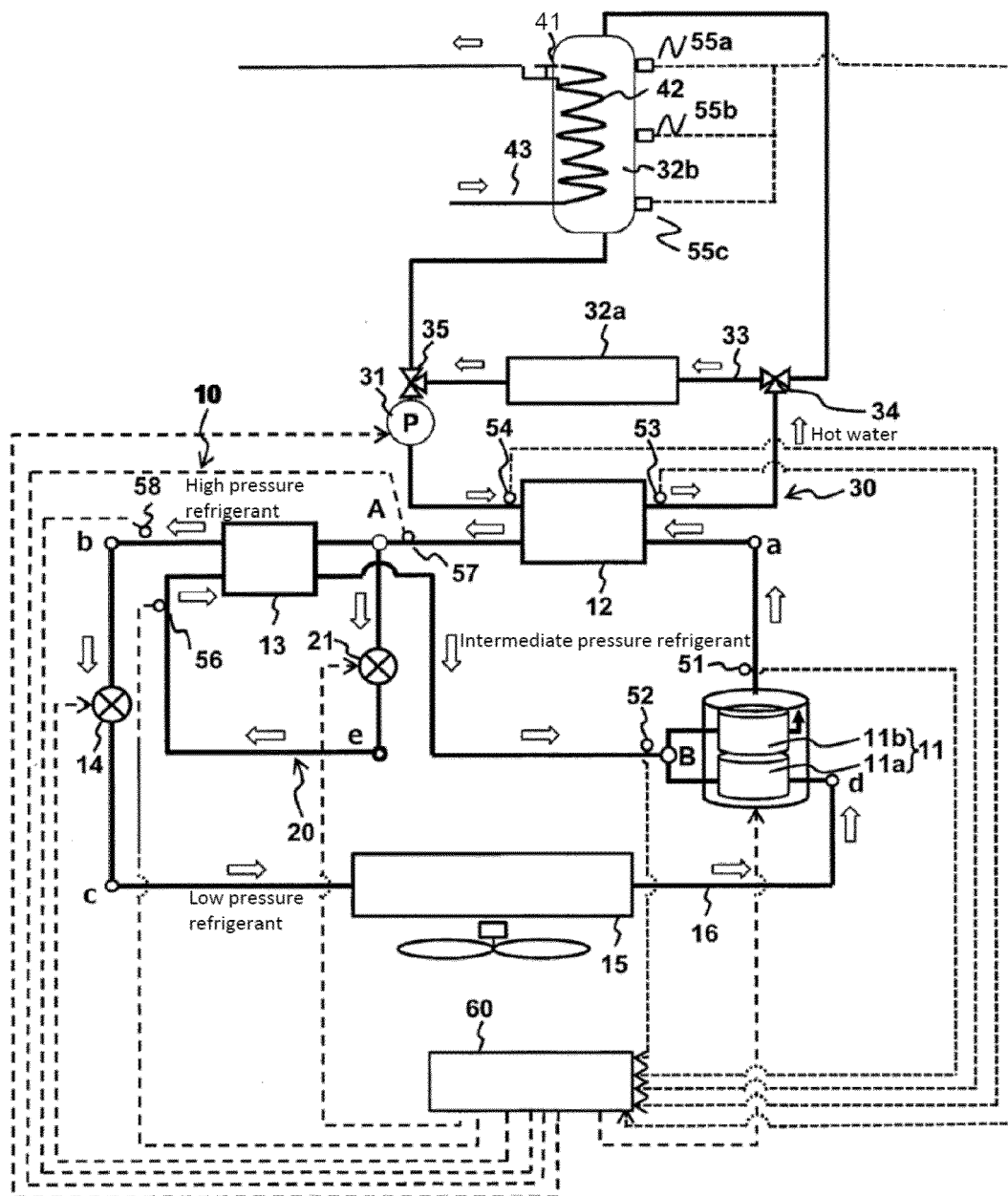
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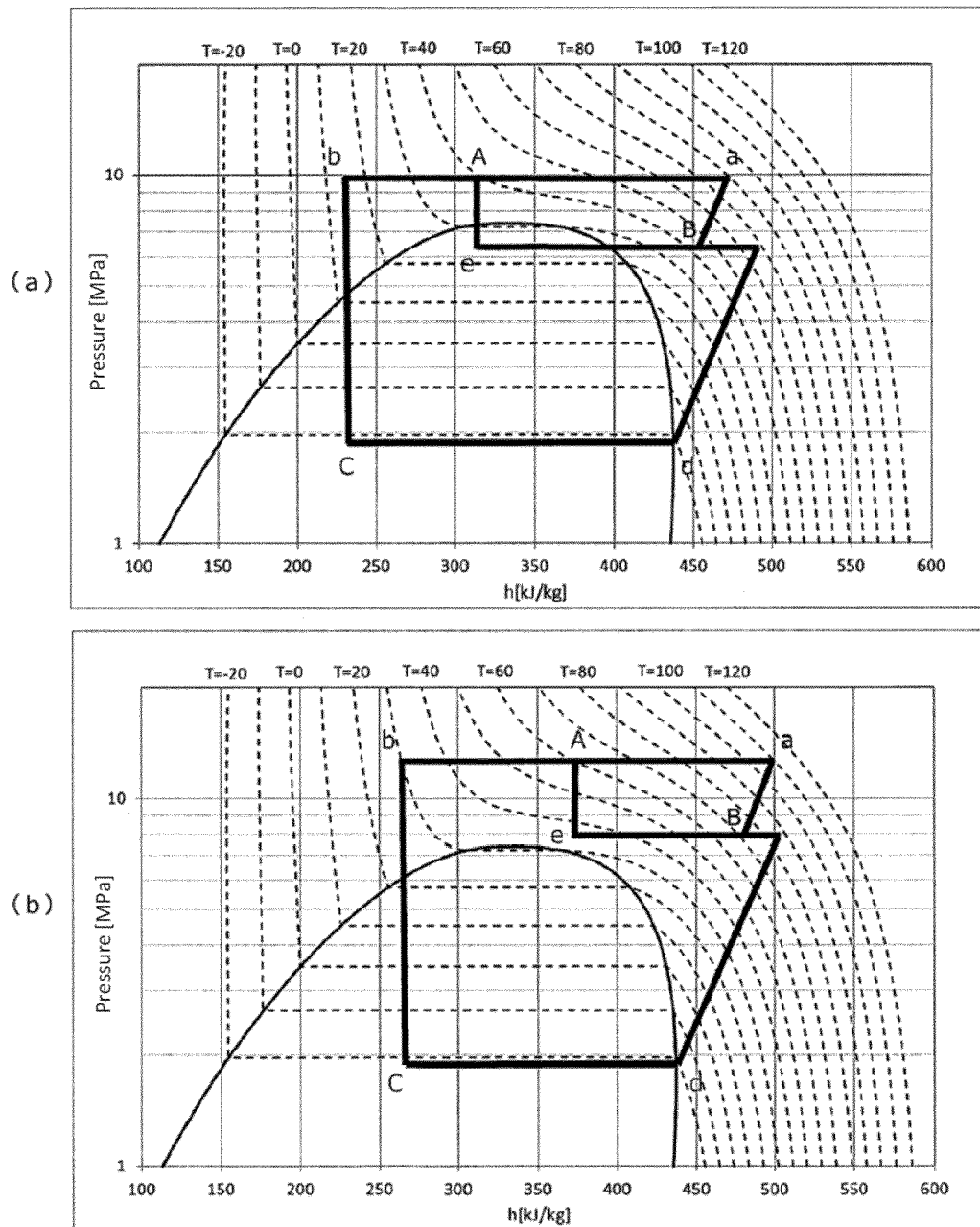
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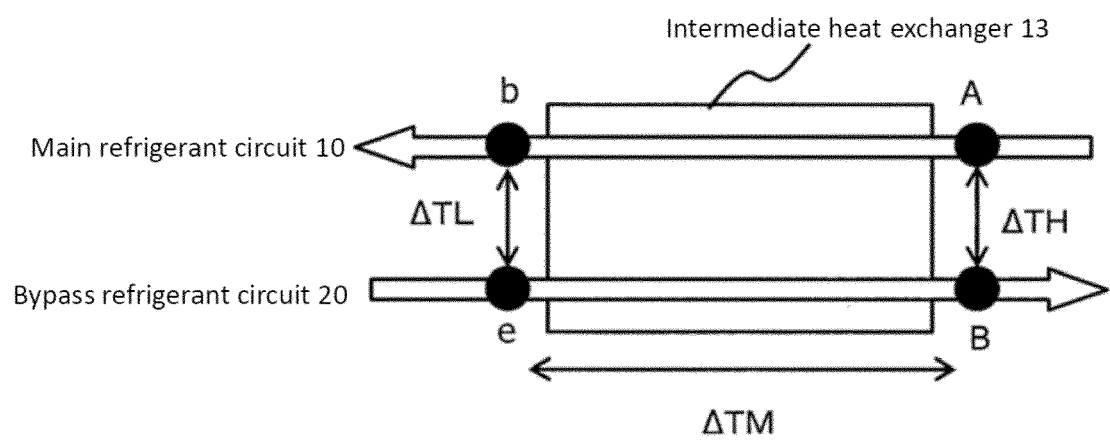
[Fig. 1]



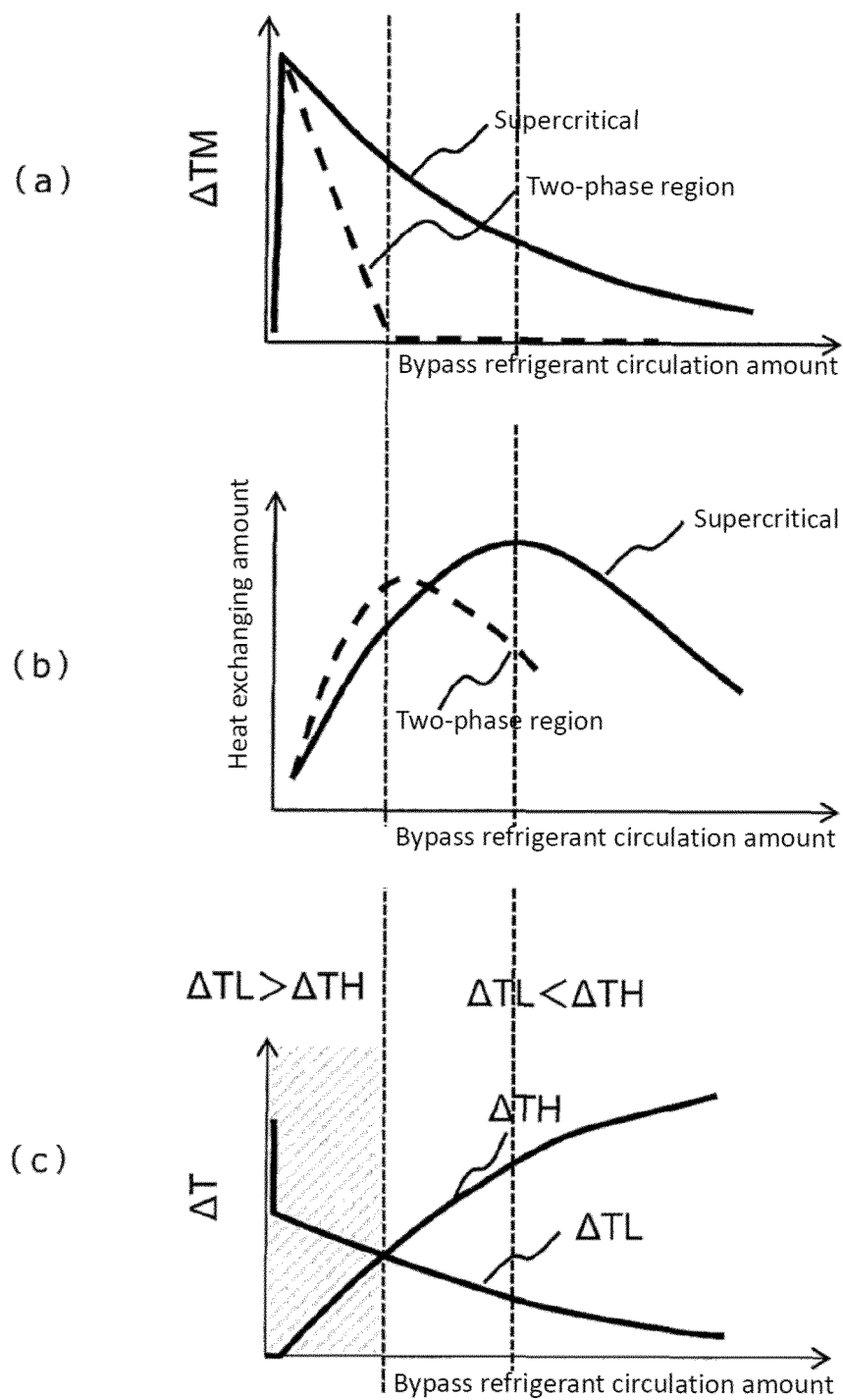
[Fig. 2]



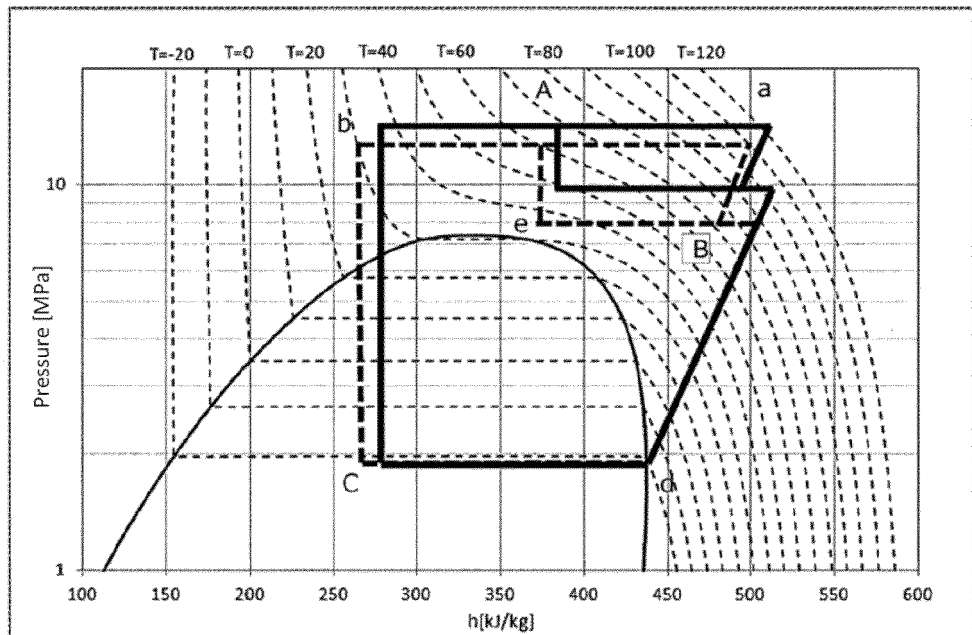
[Fig. 3]



[Fig. 4]



[Fig. 5]





EUROPEAN SEARCH REPORT

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Place of search Munich		Date of completion of the search 4 December 2019	Examiner Gaspar, Ralf
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