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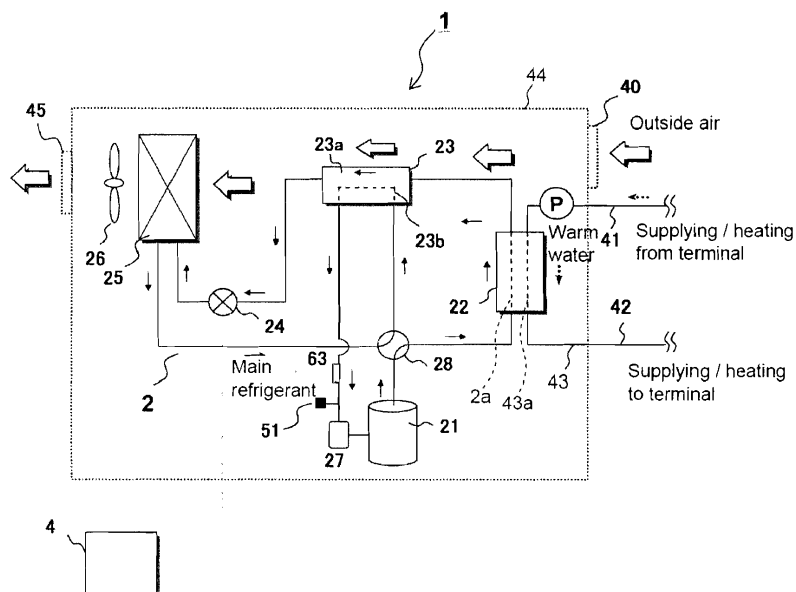
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(54) **Refrigeration cycle apparatus and warm water producing apparatus having refrigeration cycle apparatus**

(57) The refrigeration cycle apparatus includes a refrigerant circuit 2, a refrigerant/refrigerant heat exchanger 23 and a control device 4. The refrigerant/refrigerant heat exchanger 23 includes an outer pipe 23a through which high pressure refrigerant flows, and an inner pipe 23b which is disposed in the outer pipe 23a and through which low pressure refrigerant flows. At least a portion of air flowing through the evaporator 25 is induced by the

refrigerant/refrigerant heat exchanger 23. Therefore, the high pressure refrigerant is cooled by the air, a super-cooling degree of refrigerant is increased, temperature of air flowing into the evaporator 25 is made to rise, and a heat exchanging amount in the evaporator 25 is increased. Therefore, it is possible to enhance energy efficiency.

[Fig. 6]



Description

[TECHNICAL FIELD]

[0001] The present invention relates to a refrigeration cycle apparatus for supercooling refrigerant, and a warm water producing apparatus having the refrigeration cycle.

[BACKGROUND TECHNIQUE]

[0002] In conventional refrigeration cycle apparatuses, a supercooling heat exchanger is provided downstream of a condenser, this supercooling heat exchanger is formed as a refrigerant/refrigerant heat exchanger which exchanges heat between refrigerant flowing out from the condenser and expanded refrigerant, thereby supercooling the refrigerant which flows out from the condenser. This refrigeration cycle apparatus is applied to a refrigerating apparatus and an air conditioner (see patent document 1 for example).

[0003] As the supercooling heat exchanger, there exists a double pipe-type heat exchanger which exchanges heat between refrigerant flowing through an inner pipe and refrigerant flowing through an outer pipe (see patent document 2 for example).

[0004] Fig. 7 shows a schematic configuration of a conventional refrigerant circuit of an air conditioner described in patent document 1. The air conditioner 100 is composed of an outdoor unit 200 and an indoor unit 300, and the refrigerant circuit includes a main refrigerant circuit 110 through which refrigerant circulates, and a bypass circuit 120.

[0005] The outdoor unit 200 is composed of a compressor 111, a four-way valve 112, a refrigerant/refrigerant heat exchanger (supercooling heat exchanger) 114, a main expansion valve 115, an outdoor heat exchanger 116, an outdoor fan 117 and a bypass circuit 120.

[0006] The indoor unit 300 is composed of an indoor heat exchanger 113 and an indoor fan 118.

[0007] The main refrigerant circuit 110 is configured by annularly connecting the compressor 111, the four-way valve 112, the indoor heat exchanger 113, the supercooling heat exchanger 114, the main expansion valve 115, the outdoor heat exchanger 116 and a gas/liquid separator 119 to one another through refrigerant pipes.

[0008] The bypass circuit 120 branches off from the refrigerant circuit 110 upstream of the supercooling heat exchanger 114, and is connected to the refrigerant circuit 110 between an evaporator 116 and a compressor 112 through the supercooling heat exchanger 114. The bypass circuit 120 is provided with a bypass expansion valve 121 upstream of the indoor heat exchanger 113.

[0009] An effect of the refrigeration cycle apparatus will be described based on a heating operation using a refrigerant circuit diagram shown in Fig. 7 and a schematic diagram of the supercooling heat exchanger 114 shown in Fig. 8.

[0010] In the heating operation, a flow path of the four-way valve 112 is set such that refrigerant flows in directions of solid lines in Fig. 7. High temperature and high pressure gas refrigerant discharged from the compressor 111 flows into the indoor heat exchanger 113 which becomes the condenser through the four-way valve 112. Refrigerant which flows through the indoor heat exchanger 113 exchanges heat with air existing around the indoor unit 300 sucked by the indoor fan 118, and the refrigerant is condensed and liquefied. The condensed and liquefied refrigerant flows into the outdoor unit 200, and the refrigerant is separated, upstream of the supercooling heat exchanger 114, into main refrigerant flowing through the main refrigerant circuit 110 and bypass refrigerant flowing through the bypass circuit 120.

[0011] Fig. 8 is a schematic diagram showing a configuration of the supercooling heat exchanger 114 described in patent document 2.

[0012] The supercooling heat exchanger 114 is composed of a double pipe-type heat exchanger including an outer pipe 114a and an inner pipe 114b. In this double pipe-type heat exchanger, the bypass refrigerant flows in the inner pipe 114b, and the main refrigerant flows in the outer pipe 114a. The bypass refrigerant and the main refrigerant flow in opposite directions.

[0013] In the supercooling heat exchanger 114 shown in Fig. 8, the bypass refrigerant which flows into the bypass circuit 120 and is decompressed in the bypass expansion valve 121 and pressure of the bypass refrigerant becomes low, the main refrigerant flows through the main refrigerant circuit 110, and the bypass refrigerant and the main refrigerant exchange heat with each other. The main refrigerant is supercooled by the supercooling heat exchanger 114 and then is decompressed by the main expansion valve 115.

[0014] The main refrigerant flows into the outdoor heat exchanger 116 which is an evaporator. The main refrigerant flowing through the outdoor heat exchanger 116 absorbs heat from air existing around the outdoor unit 200 sucked by the outdoor fan 117, and evaporates and then, and the main refrigerant is sucked by the compressor 111 through the four-way valve 112 and the gas/liquid separator 119 which separates gas and liquid from each other.

[0015] The bypass refrigerant passes through the bypass expansion valve 121 and is decompressed and then, the bypass refrigerant cools the main refrigerant in the supercooling heat exchanger 114 and evaporates. Thereafter, the bypass refrigerant merges with the main refrigerant between the four-way valve 112 and the gas/liquid separator 119.

[0016] As a result, the main refrigerant is supercooled by the supercooling heat exchanger 114. The main refrigerant includes more liquid component as compared with a case where main refrigerant is not supercooled. The main refrigerant flows into the evaporator (outdoor heat exchanger 116). Therefore, an enthalpy difference in the evaporator increases. According to this, a heat-

absorbing amount in the evaporator is increased.

[0017] Gas-phase refrigerant which does not contribute to evaporation in the evaporator 116 is made to branch off as bypass refrigerant, and the refrigerant is made to bypass the evaporator 116. According to this, it is possible to reduce a pressure loss generated in the refrigerant circuit 110 of the gas/liquid separator 119 from the evaporator 116. Therefore, suction pressure of the compressor 111 is increased, i.e., density of refrigerant is increased, and freezing performance as a system is enhanced.

[PRIOR ART DOCUMENTS]

[PATENT DOCUMENTS]

[0018]

[Patent Document 1] Japanese Patent Publication No.4036288

[Patent Document 2] Japanese Patent Application Laid-open No.H10-54616

[SUMMARY OF THE INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0019] According to the conventional configuration, however, in the supercooling heat exchanger 114 which is the refrigerant/refrigerant heat exchanger, main refrigerant flowing through the outer pipe 114b is supercooled only with bypass refrigerant (low pressure refrigerant) flowing in the inner pipe 114a. Therefore, this conventional configuration has a problem that a sufficient supercooling degree of main refrigerant can not be secured.

[0020] The present invention has been accomplished to solve the conventional problem, and it is an object of the invention to provide a refrigeration cycle apparatus in which a supercooling degree of refrigerant is sufficiently secured, and heat energy of high pressure refrigerant in a refrigerant/refrigerant heat exchanger is effectively utilized, thereby enhancing energy efficiency.

[MEANS FOR SOLVING THE PROBLEM]

[0021] To achieve the above object, the present invention provides a refrigeration cycle apparatus including: a refrigerant circuit formed by annularly connecting a compressor which compresses refrigerant, a radiator which exchanges heat between a heat medium and the refrigerant compressed by the compressor, an expansion device which decompresses the refrigerant, and an evaporator which exchanges heat between the refrigerant and air, to one another in this order through refrigerant pipes; a refrigerant/refrigerant heat exchanger which is disposed in the refrigerant circuit between the radiator and the expansion device, and which cools high pressure refrigerant flowing out from the radiator by low pressure

refrigerant flowing through the refrigerant circuit; and a control device, wherein the refrigerant/refrigerant heat exchanger includes an outer pipe through which the high pressure refrigerant flows, and an inner pipe which is disposed in the outer pipe and through which the low pressure refrigerant flows, and at least a portion of air flowing through the evaporator is induced into the refrigerant/refrigerant heat exchanger.

[0022] According to this, in a heating operation of the heat medium, high pressure refrigerant flowing through the outer pipe of the refrigerant/refrigerant heat exchanger is cooled by air induced by the evaporator, a supercooling degree of the refrigerant increases, and air which absorbs heat from the high pressure refrigerant is induced to the evaporator. Therefore, a temperature difference between the refrigerant flowing through the evaporator and air increases.

[EFFECT OF THE INVENTION]

[0023] According to the present invention, an enthalpy difference can be increased by increase in the supercooling degree of refrigerant, and a compression ratio of the compressor can be reduced by the rise of evaporating pressure. Therefore, it is possible to provide a refrigeration cycle apparatus in which energy efficiency is enhanced.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0024]

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

Fig. 2(a) is a schematic diagram showing a configuration of a refrigerant/refrigerant heat exchanger of the refrigeration cycle apparatus, and Fig. 2(b) is a sectional view of the refrigerant/refrigerant heat exchanger of the refrigeration cycle apparatus;

Fig. 3 is a P-h diagram (Mollier diagram) for explaining variation in the refrigeration cycle of the refrigeration cycle apparatus;

Fig. 4 is a flowchart of control of a flow rate of bypass refrigerant of the refrigeration cycle apparatus;

Fig. 5 is a flowchart of control of a flow rate of main refrigerant of the refrigeration cycle apparatus;

Fig. 6 is a schematic diagram showing a configuration of a refrigeration cycle apparatus in a second embodiment of the invention;

Fig. 7 is a schematic diagram showing a configuration of a conventional air conditioner; and

Fig. 8 is a schematic diagram showing a configuration of conventional refrigerant/refrigerant heat exchanger.

[MODE FOR CARRYING OUT THE INVENTION]

[0025] A first aspect of the present invention provides a refrigeration cycle apparatus including: a refrigerant circuit formed by annularly connecting a compressor which compresses refrigerant, a radiator which exchanges heat between a heat medium and the refrigerant compressed by the compressor, an expansion device which decompresses the refrigerant, and an evaporator which exchanges heat between the refrigerant and air, to one another in this order through refrigerant pipes; a refrigerant/refrigerant heat exchanger which is disposed in the refrigerant circuit between the radiator and the expansion device, and which cools high pressure refrigerant flowing out from the radiator by low pressure refrigerant flowing through the refrigerant circuit; and a control device, wherein the refrigerant/refrigerant heat exchanger includes an outer pipe through which the high pressure refrigerant flows, and an inner pipe which is disposed in the outer pipe and through which the low pressure refrigerant flows, and at least a portion of air flowing through the evaporator is induced into the refrigerant/refrigerant heat exchanger.

[0026] According to this, in the heating operation of the heat medium, air (low temperature outside air) induced by the evaporator passes through the outer surface of the outer pipe of a double pipe-type heat exchanger which is the refrigerant/refrigerant heat exchanger, thereby cooling the high temperature and high pressure refrigerant which flows through the outer pipe, and a supercooling degree of refrigerant is increased.

[0027] Air absorbs heat from the high temperature and high pressure refrigerant through the outer pipe of the refrigerant/refrigerant heat exchanger. As a result, temperature of the air rises, and the air is induced by the evaporator. Therefore, a temperature difference between the air and the low temperature refrigerant which flows in the evaporator increases, and a heat exchanging amount in the evaporator increases.

[0028] As a result, an enthalpy difference can be increased by increase in the refrigerant supercooling degree in the refrigerant/refrigerant heat exchanger, and evaporating pressure can be increased by increase in a heat exchanging amount of the evaporator. Therefore, a compression ratio of the compressor is reduced, compressor power is reduced, and energy can be saved.

[0029] According to a second aspect of the invention, especially in the first aspect, an outer surface of the outer pipe includes a heat transfer facilitating portion for increasing a contact area with respect to the air.

[0030] According to this, in the double pipe-type refrigerant/refrigerant heat exchanger, a surface area of the outer pipe in which the high temperature and high pressure refrigerant flows increases, and a heat radiation amount from the outer pipe to air increases.

[0031] As a result, the refrigerant supercooling degree in the refrigerant/refrigerant heat exchanger increases, liquid component of refrigerant which flows into the evaporator

increases, and a freezing effect in the evaporator can further be increased.

[0032] According to a third aspect of the invention, especially in the first or second aspect, the refrigeration cycle apparatus further includes a bypass circuit which branches off from the refrigerant circuit between the radiator and the expansion device, the bypass circuit includes a bypass expansion device and the refrigerant/refrigerant heat exchanger, the bypass circuit is connected to a compression chamber of the compressor or to the refrigerant circuit between the evaporator and the compressor, and in the refrigerant/refrigerant heat exchanger, the high pressure refrigerant flowing out from the radiator and flowing through the outer pipe is cooled by the low pressure refrigerant flowing out from the bypass expansion device and flowing through the inner pipe.

[0033] According to this, the high pressure refrigerant which flows out from the radiator is cooled by the low pressure refrigerant which is decompressed by the bypass expansion device, the supercooling degree of the refrigerant can be increased, and condensation pressure can be reduced. Gas-phase refrigerant having a large pressure loss flows into the bypass circuit, and a pressure loss of the refrigerant in the evaporator is reduced. Therefore, energy can be saved.

[0034] According to a fourth aspect of the invention, especially in the third aspect, the refrigeration cycle apparatus further includes a first superheating degree detector which detects a refrigerant superheating degree on an outlet side of the bypass circuit, and the control device controls the bypass expansion device so that a detection value of the first superheating degree detector becomes equal to a predetermined value.

[0035] According to this, a degree of excess or deficiency of a flow rate of bypass refrigerant which branches off from the refrigerant circuit to the bypass circuit can be determined based on a refrigerant superheating degree SH at the outlet of the bypass circuit. That is, when the bypass flow rate is insufficient, since ability possessed by the refrigerant/refrigerant heat exchanger is relatively high, the refrigerant superheating degree SH at the outlet of the bypass circuit becomes excessively large, and when the bypass flow rate is excessively large on the other hand, the ability possessed by the refrigerant/refrigerant heat exchanger becomes relatively becomes small. Therefore, the refrigerant superheating degree SH can not be secured.

[0036] Hence, the bypass expansion device is controlled such that the refrigerant superheating degree becomes about 0 to 1 K. According to this, it is possible to exert ability of the refrigerant/refrigerant heat exchanger to the maximum extent possible in just proportion.

[0037] According to a fifth aspect of the invention, especially in the third or fourth aspect, the refrigeration cycle apparatus further includes a second superheating degree detector which detects a refrigerant superheating degree on an outlet side of the evaporator, and the control device controls the expansion device so that a detection

value of the second superheating degree detector becomes equal to a predetermined value.

[0038] According to this, a degree of excess or deficiency of a flow rate of refrigerant which flows through the refrigerant circuit can be determined based on an outlet-side refrigerant superheating degree SHe of the evaporator. That is, when a flow rate of refrigerant is insufficient with respect to ability possessed by the evaporator, since the ability possessed by the evaporator becomes relatively large, refrigerant excessively evaporates in the evaporator, and the superheating degree at the evaporator outlet increases.

[0039] When the flow rate of refrigerant is excessively large on the other hand, since the ability possessed by the evaporator becomes relatively small, refrigerant can not sufficiently evaporate in the evaporator, the refrigerant flows out from the evaporator in its moisture state, a superheating degree can not be secured sufficiently.

[0040] Hence, by controlling the opening degree of the expansion device by the control device so that the outlet superheating degree of the evaporator becomes 0 K to a predetermined value, it is possible to exert the ability of the evaporator to a maximum extent.

[0041] According to a sixth aspect of the invention, especially in the first or second aspect, in the refrigerant/refrigerant heat exchanger, the high pressure refrigerant flowing out from the radiator and flowing through the outer pipe is cooled by the low pressure refrigerant flowing out from the evaporator and flowing through the inner pipe.

[0042] According to this, high temperature and high pressure liquid refrigerant which flows out from the condenser and low temperature and low pressure gas/liquid two phase refrigerant which flows out from the evaporator exchange heat with each other, the liquid refrigerant is supercooled and a supercooling degree of the refrigerant increased, and the gas/liquid two phase refrigerant is heated and the superheating degree of the refrigerant increases.

[0043] As a result, it is possible to cool the refrigerant by the refrigerant/refrigerant heat exchanger to reduce the condensation pressure by the easy configuration having no bypass circuit. Therefore, it is possible to reduce the compression ratio of the compressor, to reduce the compressor power and to inexpensively save energy.

[0044] A seventh aspect of the invention provides a warm water producing apparatus which includes the refrigeration cycle apparatus according to any one of the first to sixth aspects, the heat medium is water or antifreeze liquid, and the heat medium heated by the radiator is utilized for supplying hot water or heating a house.

[0045] According to this, the present invention can be applied not only to a heat exchanger in which the radiator is for refrigerant/air but also to a heat exchanger for refrigerant/water and a heat exchanger for refrigerant/antifreeze liquid, and it is unnecessary to limit.

[0046] As a result, it is possible to widely apply a heat medium (air, water, antifreeze liquid and the like) heated by a radiator to a convection type, a radiant type, a heat

conduction type heating devices and water heaters.

[0047] Embodiments of the present invention will be described below with reference to the drawings. The invention is not limited to the embodiments.

(First Embodiment)

[0048] Fig. 1 shows a refrigeration cycle apparatus 1 according to a first embodiment of the present invention. This refrigeration cycle apparatus 1 is configured as a warm water producing apparatus including a refrigerant circuit 2 through which refrigerant is circulated, a heat medium flow path 43 through which warm water heated and produced by high temperature and high pressure refrigerant is circulated, and a control device 4. As the refrigerant, it is possible to use zeotropic refrigerant mixture such as R407C, pseudo azeotropic refrigerant mixture such as R410A, and single refrigerant such as R32 and R290.

[0049] In this embodiment, the refrigeration cycle apparatus 1 includes a refrigerant circuit 2 through main refrigerant flows, a bypass circuit 3 through bypass refrigerant flows, and a casing 44 forming an outline. The refrigerant circuit 2 is formed by annularly and sequentially connecting a compressor 21, a condenser (radiator) 22, a refrigerant/refrigerant heat exchanger 23, a main expansion valve (main expansion device) 24 and an evaporator 25 to one another through refrigerant pipes.

[0050] The condenser 22 is a refrigerant/water heat exchanger, and includes a refrigerant pipe 2a through which refrigerant flows, and a heat medium pipe 43a through which heat medium such as water flows.

[0051] An evaporator 25 is a fine tube heat exchanger. A blower 26 introduces outside air in the casing 44 from an air suction port 40 formed in the casing 44. The air introduced from the air suction port 40 is heated by refrigerant which flows through the refrigerant/refrigerant heat exchanger 23, and heat of the air is absorbed by refrigerant which flows through the evaporator 25. The refrigerant/refrigerant heat exchanger 23 is disposed on an air flow path which extends from the air suction port 40 to the evaporator 25. Air sucked from the air suction port 40 into the casing 44 is discharged from an air discharge port 45 formed in the casing 44.

[0052] The refrigerant circuit 2 is provided with a four-way valve 28 which switches flowing directions of refrigerant to switch between a cooling operation and a heating operation. The refrigerant circuit 2 is provided with a suction pressure sensor 51 (first superheating degree detector, second superheating degree detector) which detects suction-side refrigerant pressure Ps of the compressor 21, and a temperature sensor 61 (second superheating degree detector) which detects outlet-side refrigerant temperature Teo of the evaporator 25. The bypass circuit 3 is provided with a bypass circuit outlet temperature sensor 62 (first superheating degree detector) which detects outlet-side refrigerant temperature of the bypass circuit 3 for detecting outlet-side refrigerant superheating de-

gree SHby of the bypass circuit 3.

[0053] The bypass circuit 3 branches off from the refrigerant circuit 2 between the refrigerant/refrigerant heat exchanger 23 and the evaporator 25. The bypass circuit 3 is connected to the refrigerant circuit 2 between the four-way valve 28 and the gas/liquid separator 27 disposed on the suction side of the compressor 21 through a bypass expansion valve (bypass expansion device) 31 and the refrigerant/refrigerant heat exchanger 23.

[0054] The control device 4 controls opening degrees of the main expansion valve 24 and the bypass expansion valve 31 based on detection values detected by various sensors 51, 61 and 62.

[0055] A supply pipe 41 and a collection pipe 42 are connected to the heat medium flow path 43. Water supplied to the heat medium pipe 43a through the supply pipe 41 exchanges heat with refrigerant which flows through the refrigerant pipe 2a, the water is heated and becomes warm water, and the water is collected through the collection pipe 42.

[0056] Figs. 2 are a schematic diagram and a sectional view of the refrigerant/refrigerant heat exchanger 23 of this embodiment. The refrigerant/refrigerant heat exchanger 23 is a double pipe-type heat exchanger, and includes an outer pipe 23a and an inner pipe 23b. Cross sections of the outer pipe 23a and the inner pipe 23b are formed into cylindrical shapes. Bypass refrigerant which is low temperature and low pressure gas/liquid two phase refrigerant which flowed out from the bypass expansion valve 31 flows into the inner pipe 23b. Main refrigerant which is high temperature and high pressure liquid refrigerant which flowed out from the condenser 22 flows into an annular portion between the outer pipe 23a and the inner pipe 23b. The main refrigerant and the bypass refrigerant flow in opposite directions, and exchange heat with each other. That is, the refrigerant/refrigerant heat exchanger 23 functions such that high pressure refrigerant which flowed out from the condenser 22 and low pressure refrigerant produced by decompressing high pressure refrigerant by the expansion valve (bypass expansion valve 31) exchange heat with each other.

[0057] A circular heat exchanging fin which is coaxial with a pipe axis is disposed on an outer surface of the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23 as a heat transfer facilitating portion 30 for facilitating the heat transfer with respect to air. Here, the heat transfer facilitating portion 30 is not especially limited only if a surface area of the outer pipe 23a can be increased, and the heat transfer facilitating portion 30 may be a dimple formed by denting a portion of the outer pipe 23a for example.

[0058] Action and an effect of the refrigeration cycle apparatus having the above-described configuration will be described below. Fig. 3 is a P-h diagram (Mollier diagram) showing a relation between refrigerant pressure P and a refrigerant enthalpy h of the refrigerant circuit.

[0059] In the heating operation of a heat medium for supplying hot water or heating a house, refrigerant in a

saturated state or a superheated state sucked by the compressor 21 is compressed by the compressor 21 and brought into high temperature and high pressure gas, the gas refrigerant is sent to the condenser 22 through the four-way valve 28, the high temperature refrigerant and water (heat medium) exchange heat with each other in the condenser 22, warm water is produced, and the warm water is utilized for supplying or heating a house. In Fig. 1, arrows show flowing directions of refrigerant and warm water (heat medium) at the time of the heating operation.

[0060] Warm water collected by the collection pipe 42 is sent to a heat exchanging unit (not shown) such as a radiator or a hot water tank (not shown), and the warm water is utilized for supplying or heating a house.

[0061] That is, high temperature and high pressure gas refrigerant discharged from the compressor 21 flows into the condenser 22, heats water which was supplied to the condenser 22 through the supply pipe 41, dissipates heat to the water, the gas refrigerant is liquefied and condensed, and is brought into a saturated state or a supercooled liquid state. High temperature and high pressure liquid refrigerant (main refrigerant) which flowed out from the condenser 22 flows into an interior (annular portion) of the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23, and the liquid refrigerant is cooled by bypass refrigerant which flows through the inner pipe 23b.

[0062] Further, since the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23 is disposed on an air flow path through which low temperature outside air flowing from the air suction port 40 to the evaporator 25 passes, the outside air and refrigerant which flows through the interior (annular portion) of the outer pipe 23a exchange heat with each other through the heat transfer facilitating portion (heat exchanging fin) 30 provided on the outer surface of the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23, and the refrigerant flowing through the interior (annular portion) of the outer pipe 23a is further cooled.

[0063] As a result, a refrigerant enthalpy after the refrigerant passes through the refrigerant/refrigerant heat exchanger 23 is reduced from a point c (enthalpy hsc1) to a point C (enthalpy hsc2) as compared with the conventional technique as shown in Fig. 3.

[0064] Air which passed through the outer surface of the outer pipe 23a is heated by the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23, temperature of the air rises and the air is induced by the evaporator 25. Therefore, a temperature difference between the air and the low temperature refrigerant which flows in the evaporator 25 increases. As a result, evaporating pressure P_e on the side of refrigerant in the evaporator 25 rises as compared with the conventional technique.

[0065] Next, after main refrigerant passes through the refrigerant/refrigerant heat exchanger 23, the main refrigerant branches off into the refrigerant circuit 2 and the bypass circuit 3 on the outlet side of the refrigerant/refrigerant heat exchanger 23.

[0066] High pressure refrigerant which flowed into the

main expansion valve 24 is decompressed by the main expansion valve 24 and is expanded. Thereafter, the high pressure refrigerant flows into the evaporator 25, but an enthalpy of the refrigerant which flows into the evaporator 25 is reduced from a point d (enthalpy hsc1) to a point D (enthalpy hsc2) in Fig. 3 as compared with the conventional technique and a dry degree of refrigerant which flows into the evaporator 25 becomes small. That is, a ratio of liquid refrigerant whose phase is changed from liquid phase to gas phase in the evaporator 25 and in which evaporative latent heat is generated increases.

[0067] Here, generally, low pressure gas/liquid two phase refrigerant which flowed into the evaporator 25 (fin tube heat exchanger) branches into a plurality of refrigerant flow paths (refrigerant paths) by a shunt.

[0068] When the refrigerant branches into the plurality of refrigerant flow paths (refrigerant paths), as a dry degree of the inflow refrigerant is higher, i.e., as an amount of gas phase component of the refrigerant is greater, variation in flow rates of branched refrigerants into the refrigerant paths increases, and distribution characteristics are deteriorated. On the other hand, as the dry degree of the inflow refrigerant is lower, i.e., as an amount of liquid phase component of refrigerant is greater, variation in flow rates of branched refrigerants into the refrigerant paths reduces, and distribution characteristics becomes excellent.

[0069] Therefore, in this embodiment, since the dry degree of refrigerant which flows into the evaporator 25 becomes low as compared with the conventional technique, it is possible to suppress such a phenomenon that a flow rate of refrigerant in one or some of a plurality of refrigerant paths becomes excessively large, branch flowing performance in the evaporator 25 is improved, and a pressure loss of refrigerant in the entire evaporator 25 is reduced. In this evaporator 25, heat is absorbed from air (low temperature outside air), refrigerant itself is heated and evaporates, and the refrigerant is brought into a saturated gas state or a superheated gas state.

[0070] High pressure refrigerant which branches and flows into the bypass circuit 3 is decompressed by the bypass expansion valve 31, the refrigerant becomes low temperature and low pressure refrigerant, the refrigerant cools refrigerant in a saturated state or a supercooled liquid state which flows in the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23, and the low pressure refrigerant itself is heated and is brought into a saturated gas state or a superheated gas state.

[0071] The low pressure refrigerant which flows out from the bypass circuit 3 merges with low pressure refrigerant which exchanged heat with air in the evaporator 25, and is sucked into the compressor 21 through the gas/liquid separator 27.

[0072] As described above, air which flows into the evaporator 25 absorbs heat from high pressure refrigerant flowing through the outer pipe 23a, and temperature of the refrigerant rises. According to this, evaporating pressure in the evaporator 25 rises. A refrigerant pres-

sure loss in the evaporator 25 reduces. Therefore, if condensation pressure is made constant and refrigerant suction pressure is compared with the conventional technique, the refrigerant suction pressure sucked into the compressor 21 can rise to Ps2 from Ps1 as shown in Fig. 3.

[0073] The higher the suction pressure of the compressor 21 is, the higher the density of refrigerant becomes. When operation frequency of the compressor 21 is the same, a mass flow rate of main refrigerant which flows through the refrigeration cycle increases from Gr1 to Gr2 and thus, heating ability in the condenser 22 can be increased.

[0074] Next, control of a bypass flow rate carried out by the bypass expansion valve 31 will be described below in detail with reference to a flowchart shown in Fig. 4.

[0075] The control device 4 controls an opening degree of the bypass expansion valve 31, thereby controlling a bypass flow rate flowing through the bypass circuit 3. First, in step S11, suction pressure Ps of the compressor 21 and refrigerant temperature Tbyo on the outlet side of the bypass circuit 3 are detected.

[0076] Next, in step S12, refrigerant saturation temperature Tsat is calculated using the suction pressure Ps as a reference, and outlet-side refrigerant superheating degree SHby of the bypass circuit 3 is calculated based on a difference with respect to outlet-side refrigerant temperature Tbyo of the bypass circuit 3. That is, the suction pressure sensor 51 and the bypass circuit outlet temperature sensor 62 configure a first superheating degree detector.

[0077] In step S13, the outlet-side refrigerant superheating degree SHby of the bypass circuit 3 and an upper limit value SHo of a target superheating degree are compared with each other in terms of magnitude, and if SHby $\geq$ SHo, in step S14, an opening degree PLS1 of the bypass expansion valve 31 is opened by a first predetermined opening degree dP1 and then, the procedure proceeds on to step S17. It is more preferable that the upper limit value SHo of the target superheating degree is smaller in the aspect of performance, but if control stability is taken into consideration, it is preferable that the upper limit value SHo is set to about 1 to 3 K.

[0078] If SHby < SHo, in step S15, the outlet-side refrigerant superheating degree SHby of the bypass circuit 3 and a lower limit value 0 (zero) of the target superheating degree are compared with each other in terms of magnitude, and if SHby $\leq$ 0 (SHby $\approx$ 0), the opening degree PLS1 of the bypass expansion valve 31 is closed by the first predetermined opening degree dP1 in step S16 and then, the procedure proceeds on to step S 17.

[0079] If SHby > 0, this means that the outlet-side refrigerant superheating degree SHby of the bypass circuit 3 is between the lower limit value 0 (zero) of the target superheating degree and the upper limit value SHo, it is determined that control can be performed within a proper range, no operation is carried out, the procedure proceeds on to step S17, a predetermined control interval

is secured (standby) and then, the procedure returns to step S11, and operations of steps S11 to S17 are repeated.

[0080] Next, control of a refrigerant flow rate carried out by the main expansion valve 24 will be described below in detail with reference to a flowchart shown in Fig. 5.

[0081] The control device 4 controls an opening degree of the main expansion valve 24, thereby controlling a flow rate of main refrigerant which flows through the evaporator 25.

[0082] First, suction pressure P_s of the compressor 21 and refrigerant temperature T_{eo} on the outlet side of the evaporator 25 are detected in step S21.

[0083] Next, in step S22, refrigerant saturation temperature T_{sat} is calculated based on the suction pressure P_s , and the outlet-side refrigerant superheating degree SH_e of the evaporator 25 is calculated based on a difference with respect to the outlet-side refrigerant temperature T_{eo} of the evaporator 25. That is, the suction pressure sensor 51 and the evaporator outlet temperature sensor 61 configure the second superheating degree detector.

[0084] In step S23, the outlet-side refrigerant superheating degree SH_e of the evaporator 25 and an upper limit value SH_{oe} of the target superheating degree are compared with each other in terms of magnitude. If $SH_e \geq SH_{oe}$, in step S24, the opening degree PLS_2 of the main expansion valve 24 is opened by a second predetermined opening degree dP_2 and then, the procedure proceeds on to step S27. It is more preferable that the upper limit value SH_{oe} of the target superheating degree in this case is also smaller in the aspect of performance, but if control stability is taken into consideration, it is preferable that the upper limit value SH_{oe} is set to about 1 to 3 K.

[0085] If $SH_e < SH_{oe}$, in step S25, the outlet-side refrigerant superheating degree SH_e of the evaporator 25 and the lower limit value 0 (zero) of the target superheating degree are compared with each other in terms of magnitude, and if $SH_e \leq 0$ ($SH_{by} \approx 0$), in step S26, the opening degree PLS_2 of the main expansion valve 24 is closed by the second predetermined opening degree dP_2 and then, the procedure proceeds on to step S27.

[0086] If $SH_e > 0$, this means that the outlet-side refrigerant superheating degree SH_e of the evaporator 25 is between the lower limit value 0 (zero) and the upper limit value SH_{oe} of the target superheating degree, it is determined that control can be performed within a proper range, no operation is carried out, the procedure proceeds on to step S27, a predetermined control interval is secured (standby) and then, the procedure returns to step S21 and operations of steps S21 to S27 are repeated.

[0087] As described above, the refrigeration cycle apparatus of this embodiment includes the refrigerant circuit 2 provided with the refrigerant/refrigerant heat exchanger 23, and the bypass circuit 3 which branches off from a

downstream side of the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23 when heating operation of a heat medium is carried out, and which merges with the refrigerant circuit 2 between the evaporator 25 and the gas/liquid separator 27 through the bypass expansion valve 31 and the inner pipe 23b of the refrigerant/refrigerant heat exchanger 23. The refrigerant/refrigerant heat exchanger 23 is the double pipe-type heat exchanger, and the evaporator 25 is the refrigerant/air heat exchanger. The refrigerant/refrigerant heat exchanger 23 is disposed on the air flow path between the air suction port 40 which exchanges heat with the evaporator 25 and the evaporator 25.

[0088] According to this, in the heating operation of a heat medium especially in winter, air (low temperature outside air) induced by the evaporator 25 passes through the outer surface of the outer pipe 23a of the double pipe-type heat exchanger, and this air cools high temperature and high pressure refrigerant which flows in the outer pipe 23a through the outer pipe 23a, and the supercooling degree of the refrigerant is increased.

[0089] The air absorbs heat through the outer pipe 23a of the refrigerant/refrigerant heat exchanger 23, temperature thereof rises and the air is induced by the evaporator 25. Therefore, a temperature difference between the air and low temperature refrigerant which flows in the evaporator increases, and the heat exchanging amount in the evaporator 25 increases.

[0090] The refrigerant superheating degree SH_{by} on the outlet side of the bypass circuit 3 and the refrigerant superheating degree SH_e on the outlet side of evaporator 25 are calculated by the suction pressure sensor 51 which detects the suction-side refrigerant pressure P_s of the compressor 21, the evaporator outlet temperature sensor 61 which detects the outlet-side refrigerant temperature T_{eo} of the evaporator 25 and the bypass circuit outlet temperature sensor 62 which detects the refrigerant temperature on the outlet side of the bypass circuit 3. The control device 4 controls the bypass expansion valve 31 and the main expansion valve 24 so that these values become equal to predetermined values.

[0091] According to this, a degree of excess or deficiency of a bypass flow rate branching from the refrigerant circuit 2 to the bypass circuit 3 can be determined based on magnitude of the refrigerant superheating degree SH_{by} of the outlet of the bypass circuit 3, and a degree of excess or deficiency of a main refrigerant flow rate flowing through the refrigerant circuit 2 can be determined by the outlet superheating degree SH_e of the evaporator 25.

[0092] As a result, the bypass flow rate and the main refrigerant flow rate are controlled so that the refrigerant superheating degree SH_{by} on the outlet side of the bypass circuit 3 and the refrigerant superheating degree SH_e on the outlet side of the evaporator 25 fall within predetermined ranges, the ability of the refrigerant/refrigerant heat exchanger 23 can be exerted to a maximum extent in just proportion, and the ability of the evaporator

25 can be exerted to a maximum extent. Therefore, it is possible to reduce the compression ratio of the compressor 21, power of the compressor 21 is reduced, and energy can be saved.

[0093] It is not absolutely necessary that the bypass circuit 3 branches off from the refrigerant circuit 2 between the refrigerant/refrigerant heat exchanger 23 and the main expansion valve 24. The bypass circuit 3 may branch off from the refrigerant circuit 2 between the condenser 22 and the refrigerant/refrigerant heat exchanger 23.

[0094] It is absolutely necessary that the main expansion valve 24 and the bypass expansion valve 31 of the present invention are expansion valves, and they may be expansion devices which collect power from expanding refrigerant. In this case, the number of rotations of the expansion device may be controlled by changing a load by a power generator connected to the expansion device.

[0095] It is absolutely necessary that fluid which is heated by the condenser 22 is water, and it may be air. That is, the present invention can be applied also to an air conditioner.

(Second Embodiment)

[0096] Fig. 6 shows a refrigeration cycle apparatus 1 in a second embodiment of the present invention. In the second embodiment, the same symbols are allocated to the same function members as those in the first embodiment, and detailed description thereof will be omitted. In the second embodiment, an inner pipe 23b of a refrigerant/refrigerant heat exchanger 23 is provided between an outlet side of an evaporator 25 of a refrigerant circuit 2 and a compressor 21.

[0097] That is, according to the refrigerant circuit 2 of the second embodiment, a refrigerant/refrigerant heat exchanger 23 functions as a liquid/gas heat exchanger in which high pressure refrigerant and low pressure refrigerant of the refrigerant circuit 2 exchange heat with each other. The refrigerant circuit 2 is provided with a suction pressure sensor 51 which detects suction-side refrigerant pressure P_s of the compressor 21, and a suction temperature sensor 63 which detects suction-side refrigerant temperature T_s of the compressor 21. A control device 4 controls a main expansion valve 24 based on detection values of the suction pressure sensor 51 and the suction temperature sensor 63.

[0098] Action and an effect of the refrigeration cycle apparatus having the above-described configuration will be described below.

[0099] In a heating operation of a heat medium, high temperature and high pressure gas refrigerant discharged from the compressor 21 is condensed by a condenser 22. High temperature and high pressure liquid refrigerant which flowed out from the condenser 22 flows into an interior (annular portion) of an outer pipe 23a of the refrigerant/refrigerant heat exchanger, and is cooled

by low temperature and low pressure refrigerant which flowed out from the evaporator 25 and which flows through an inner pipe 23b. That is, the refrigerant/refrigerant heat exchanger 23 functions so that high pressure which flowed out from the condenser 22 and low pressure refrigerant produced by decompressing the high pressure refrigerant by an expansion valve (main expansion valve 24) exchange heat with each other.

[0100] Outside air and refrigerant flowing through the outer pipe 23a exchange heat with each other through a heat transfer facilitating portion (heat exchanging fin) 30 provided on the outer surface of the outer pipe 23a of the refrigerant/refrigerant heat exchanger, and refrigerant flowing through the outer pipe 23a is further cooled.

[0101] Air which passed on the side of the outer surface of the outer pipe 23a of the refrigerant/refrigerant heat exchanger is heated by refrigerant which flows through the outer pipe 23a, temperature of the air rises and the air is induced by the evaporator 25. Therefore, a temperature difference between the air and low temperature refrigerant which flows in the evaporator 25 is increased. When a heat exchanging amount in the evaporator 25 is the same, evaporating pressure P_e on the side of refrigerant in the evaporator 25 rises as compared with the conventional technique.

[0102] A dry degree of refrigerant which flows into the evaporator 25 can be lowered as compared with the conventional technique. Therefore, branch flowing performance at the evaporator 25 is improved, that is, uneven distribution of a flow rate in a plurality of refrigerant paths becomes small, and a refrigerant pressure loss in the evaporator 25 can be made small.

[0103] The refrigeration cycle apparatus 1 of this embodiment exerts a rising degree of evaporating pressure caused by temperature rise of air which is caused by heating the air flowing into the evaporator 25 by high pressure refrigerant flowing in the outer pipe 23a, and a reducing effect of a pressure loss of refrigerant caused by improvement of branch flowing of refrigerant in the evaporator 25. Therefore, if condensation pressure is made constant and is compared, it becomes possible to increase suction pressure of the compressor 21, and when operation frequency of the compressor 21 is the same, a mass flow rate of main refrigerant which flows through the refrigeration cycle is increased, and heating ability in the condenser 22 can be increased.

[0104] As a result, it is possible to reduce a compression ratio of the compressor with a simple configuration having no bypass circuit, power of the compressor is reduced and energy can be saved.

[INDUSTRIAL APPLICABILITY]

[0105] The present invention is especially useful for a warm water producing apparatus in which heat medium such as water as utility-side heat medium is heated by a refrigeration cycle apparatus, and the heat medium is utilized for supplying hot water or heating a house.

[EXPLANATION OF SYMBOLS]

[0106]

1	refrigeration cycle apparatus	
2	refrigerant circuit	
3	bypass circuit	
4	control device	
21	compressor	
22	condenser (radiator)	10
23	refrigerant/refrigerant heat exchanger	
23a	outer pipe	
23b	inner pipe	
24	main expansion valve (expansion device)	
25	evaporator	15
30	heat transfer facilitating portion	
31	bypass expansion valve (bypass expansion device)	
40	air suction port	
51	suction pressure sensor (first superheating degree detector, second superheating degree detector)	20
61	evaporator outlet temperature sensor (second superheating degree detector)	
62	bypass circuit outlet temperature sensor (first superheating degree detector)	25

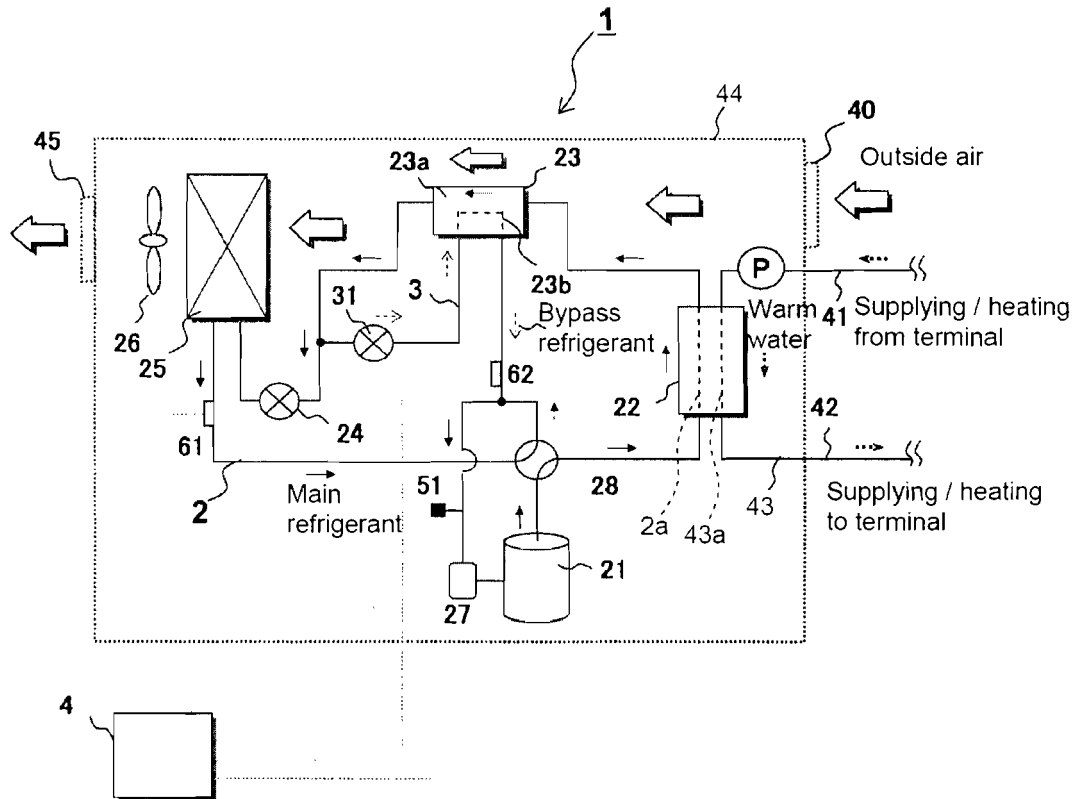
Claims

1. A refrigeration cycle apparatus comprising: a refrigerant circuit formed by annularly connecting a compressor which compresses refrigerant, a radiator which exchanges heat between a heat medium and the refrigerant compressed by the compressor, an expansion device which decompresses the refrigerant, and an evaporator which exchanges heat between the refrigerant and air, to one another in this order through refrigerant pipes; a refrigerant/refrigerant heat exchanger which is disposed in the refrigerant circuit between the radiator and the expansion device, and which cools high pressure refrigerant flowing out from the radiator by low pressure refrigerant flowing through the refrigerant circuit; and a control device, wherein the refrigerant/refrigerant heat exchanger includes an outer pipe through which the high pressure refrigerant flows, and an inner pipe which is disposed in the outer pipe and through which the low pressure refrigerant flows, and at least a portion of air flowing through the evaporator is induced into the refrigerant/refrigerant heat exchanger.
2. The refrigeration cycle apparatus according to claim 1, wherein an outer surface of the outer pipe includes a heat transfer facilitating portion for increasing a

contact area with respect to the air.

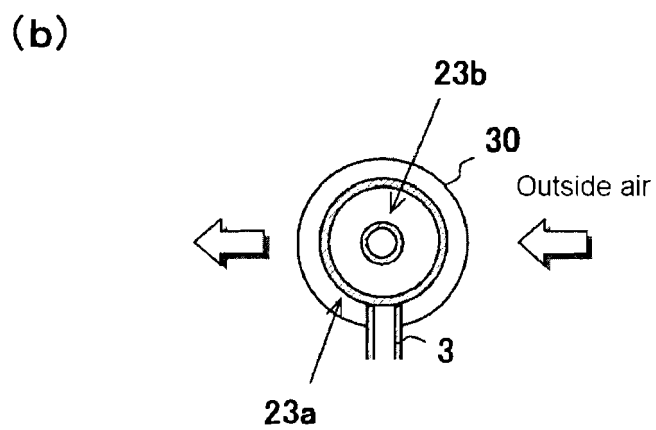
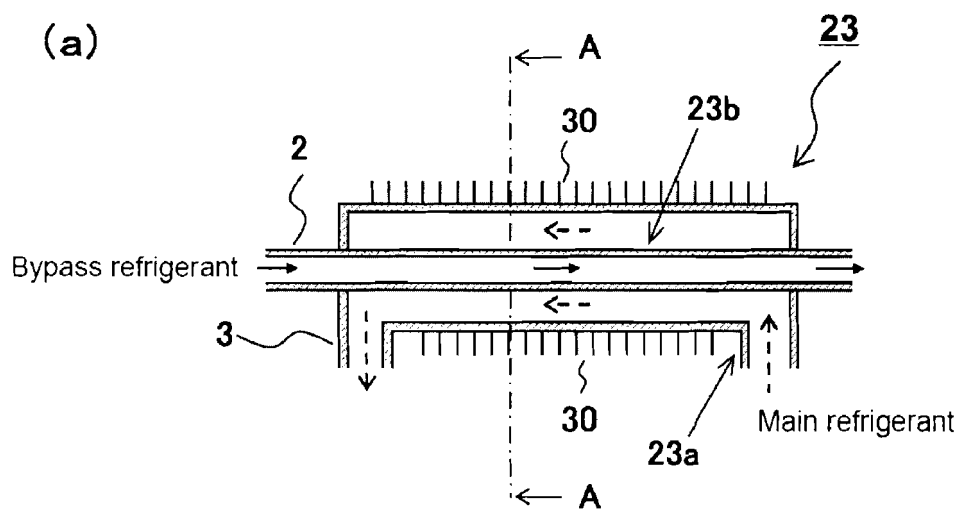
3. The refrigeration cycle apparatus according to claim 1 or 2, further comprising a bypass circuit which branches off from the refrigerant circuit between the radiator and the expansion device, wherein the bypass circuit includes a bypass expansion device and the refrigerant/refrigerant heat exchanger, the bypass circuit is connected to a compression chamber of the compressor or to the refrigerant circuit between the evaporator and the compressor, and in the refrigerant/refrigerant heat exchanger, the high pressure refrigerant flowing out from the radiator and flowing through the outer pipe is cooled by the low pressure refrigerant flowing out from the bypass expansion device and flowing through the inner pipe.
4. The refrigeration cycle apparatus according to claim 3, further comprising a first superheating degree detector which detects a refrigerant superheating degree on an outlet side of the bypass circuit, wherein the control device controls the bypass expansion device so that a detection value of the first superheating degree detector becomes equal to a predetermined value.
5. The refrigeration cycle apparatus according to claim 3 or 4, further comprising a second superheating degree detector which detects a refrigerant superheating degree on an outlet side of the evaporator, wherein the control device controls the expansion device so that a detection value of the second superheating degree detector becomes equal to a predetermined value.
6. The refrigeration cycle apparatus according to claim 1 or 2, wherein in the refrigerant/refrigerant heat exchanger, the high pressure refrigerant flowing out from the radiator and flowing through the outer pipe is cooled by the low pressure refrigerant flowing out from the evaporator and flowing through the inner pipe.
7. A warm water producing apparatus comprising the refrigeration cycle apparatus according to any one of claims 1 to 6, wherein the heat medium is water or antifreeze liquid, and the heat medium heated by the radiator is utilized for supplying hot water or heating a house.

[Fig. 1]

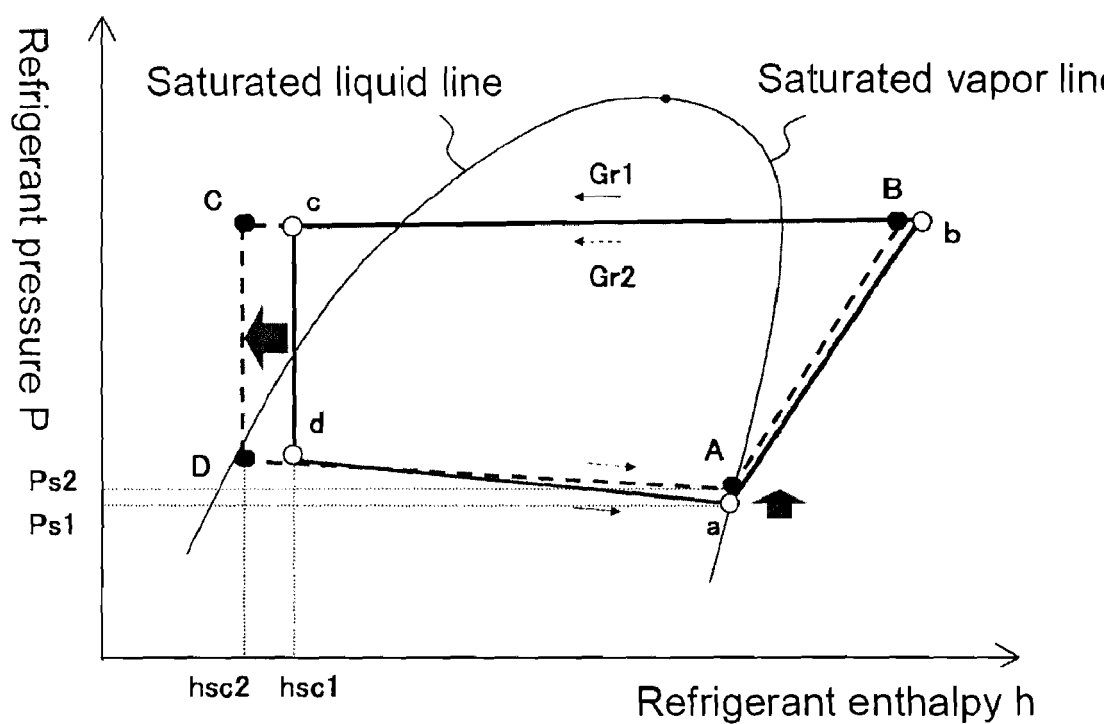


- 1 Refrigeration cycle apparatus
- 2 Refrigerant circuit
- 3 Bypass circuit
- 4 Control device
- 21 Compressor
- 22 Condenser (radiator)
- 23 Refrigerant/refrigerant heat exchanger
- 23a Outer pipe
- 23b Inner pipe
- 24 Main expansion valve (expansion device)
- 25 Evaporator
- 31 Bypass expansion valve (bypass expansion device)
- 40 Air suction port
- 45 Air discharge port
- 51 Suction pressure sensor (first superheating degree detector, second superheating degree detector)
- 61 Evaporator outlet temperature sensor (second superheating degree detector)
- 62 Bypass circuit outlet temperature sensor (first superheating degree detector)

[Fig. 2]

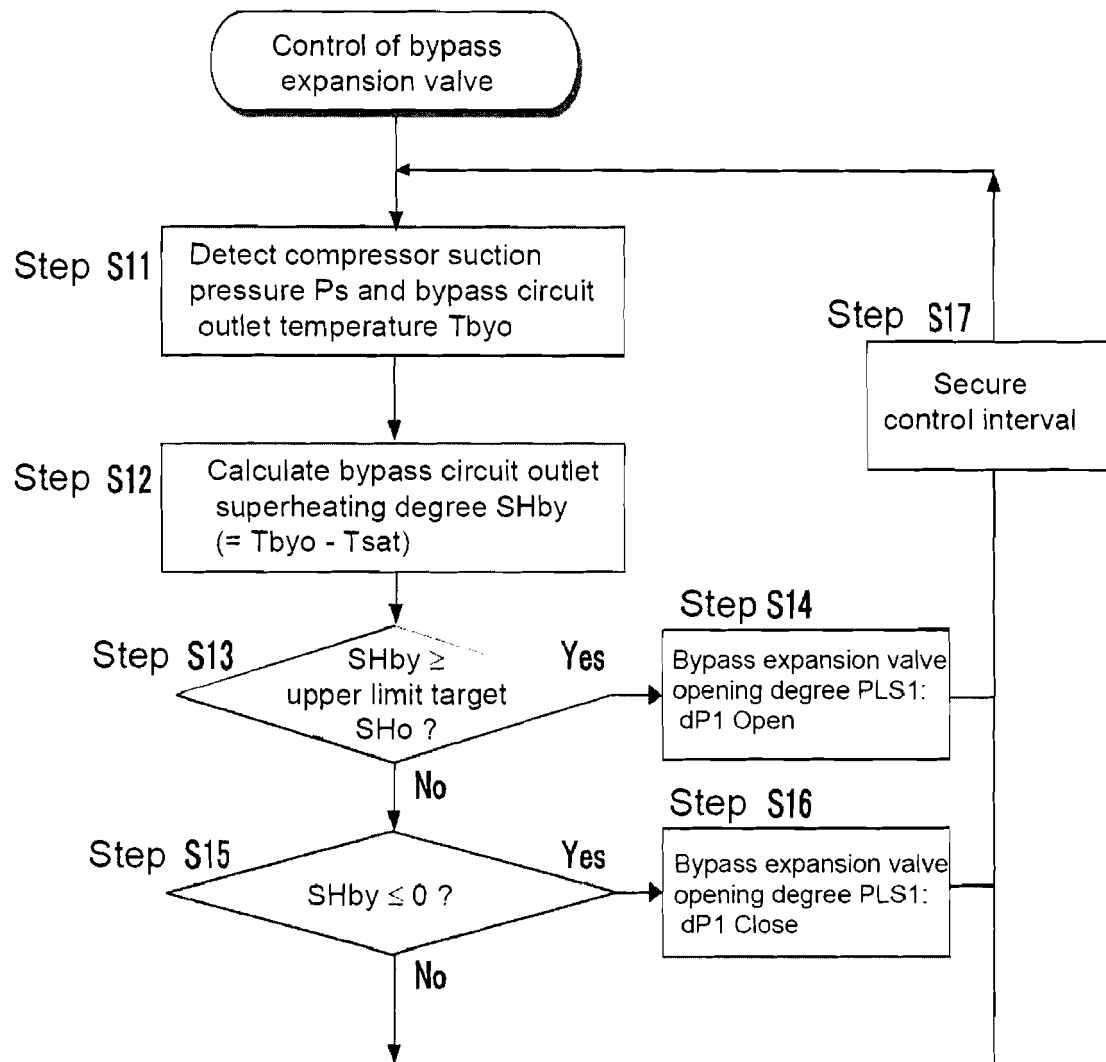


[Fig. 3]

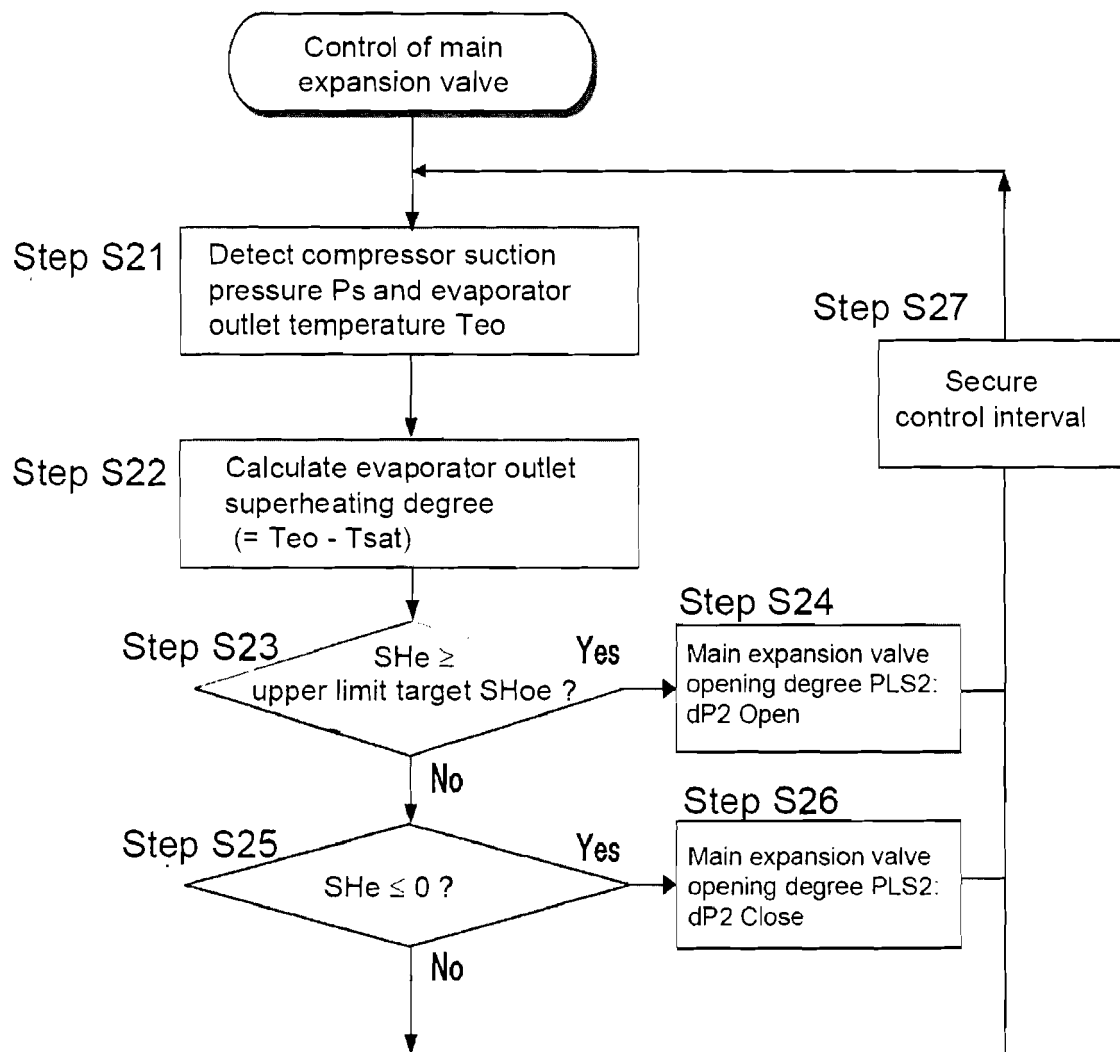


P-h diagram (Mollier diagram) of main refrigerant circuit

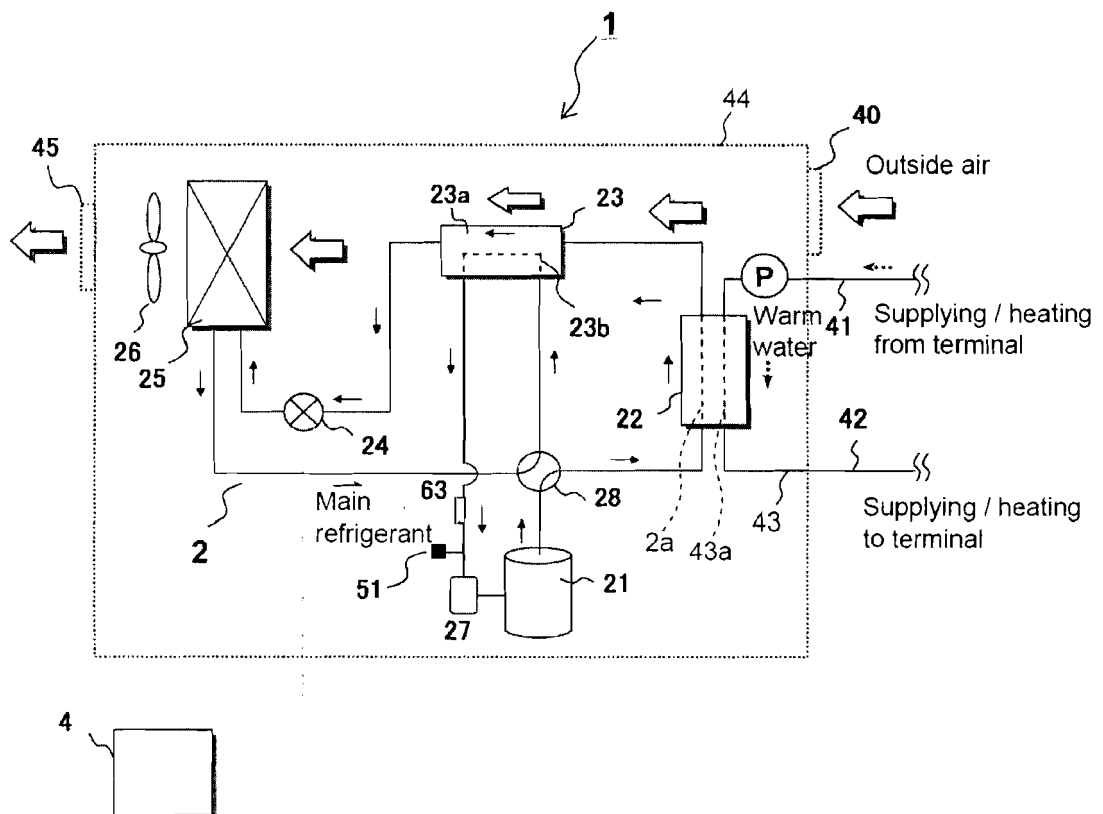
[Fig. 4]



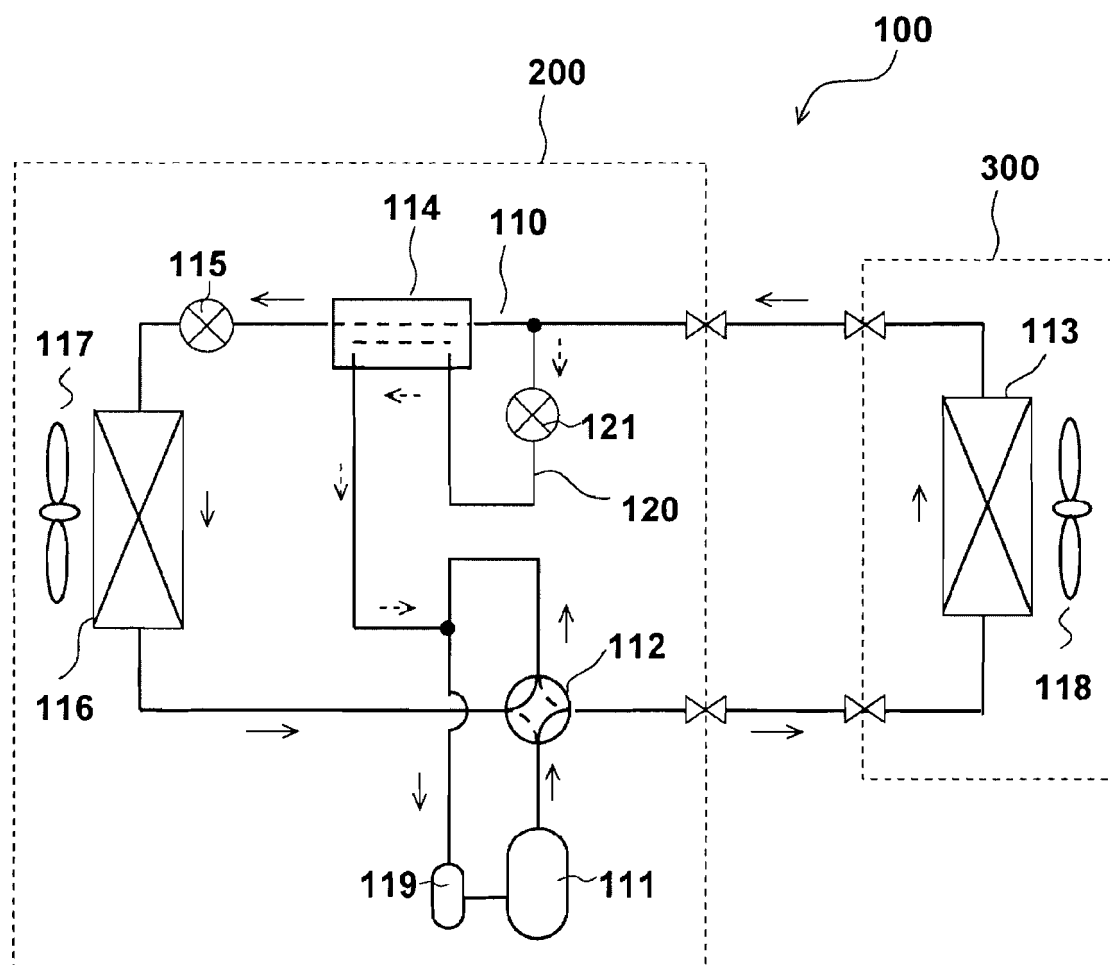
[Fig. 5]



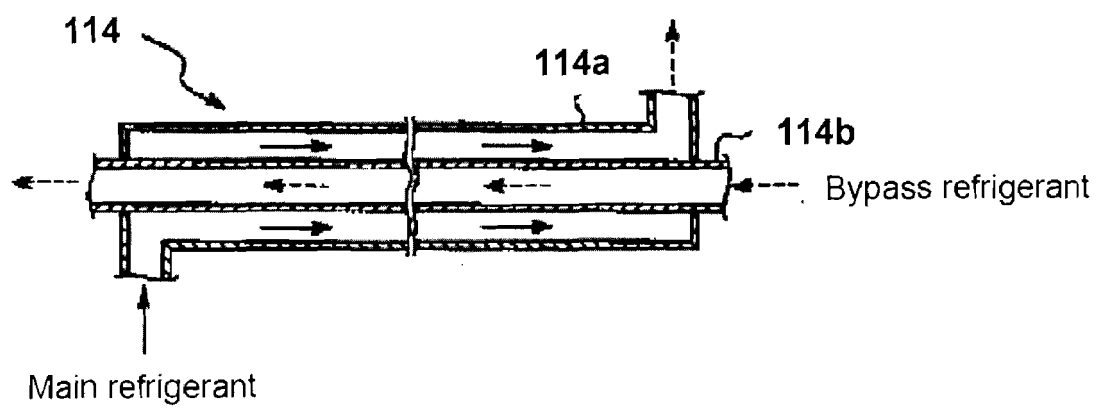
[Fig. 6]



[Fig. 7]



[Fig. 8]



REFERENCES CITED IN THE DESCRIPTION

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