(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 217 117 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.09.2017 Bulletin 2017/37

(21) Application number: **16186102.6**

(22) Date of filing: **29.08.2016**

(51) Int Cl.:
F25B 7/00 *(2006.01)* ***F25B 30/02*** *(2006.01)*
F25B 9/00 *(2006.01)* *F25B 13/00* *(2006.01)*

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

(30) Priority: **09.03.2016 JP 2016046253**

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

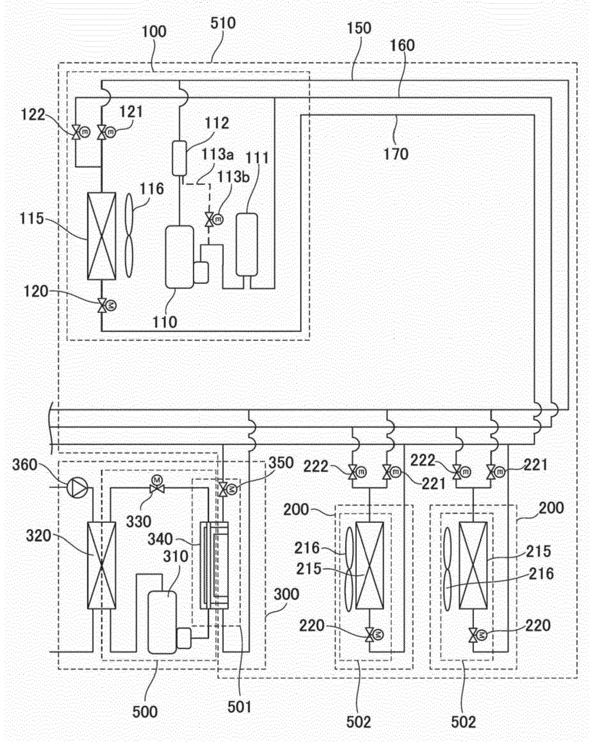
(72) Inventors:
- **IITAKA, Seishi**
  Osaka, 540-6207 (JP)
- **SHIGETA, Akihiro**
  Osaka, 540-6207 (JP)
- **MATSUI, Masaru**
  Osaka, 540-6207 (JP)

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

(54) **AIR-CONDITIONING/HOT-WATER SUPPLY SYSTEM**

(57) Provided is an air-conditioning/hot-water supply system that can prevent the thermal conductivities of a refrigerant for hot water supply and a refrigerant for air conditioning in a cascade heat exchanger from decreasing and improve refrigeration cycle performance of a hot-water supply system even in a boiling end when an inflow water temperature rises. In an air-conditioning/hot-water supply system, a double pipe-type heat exchanger including an outer pipe 420 and an inner pipe 410 is used as a cascade heat exchanger 340 and a refrigerant for hot water supply is circulated in the inner pipe 410. Consequently, in a so-called boiling end operation in which an inflow water temperature rises, even when an annular flow is predominant as a flow regime of a high-stage side refrigerant, a liquid-phase refrigerant, which is a heat absorption source, adheres to and concentrates on the inner surface of the inner pipe and, even when an overheated gas state is predominant as a state of a low-stage side refrigerant in the boiling end operation, an oil film serving as heat resistance adheres to and concentrates on the inner surface of the outer pipe 420. An overheated gas refrigerant, which is a heat medium, easily comes into contact with the outer surface of the inner pipe 410, which is a heat transfer surface.

FIG.1



EP 3 217 117 A1

Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an air-conditioning/hot-water supply system that can simultaneously supply hot and cold heats necessary for cooling, warming, and hot water supply, the air-conditioning/hot-water supply system being mounted with a refrigeration cycle for generating hot water for hot water supply and performing heat exchange between an air-conditioning refrigerant and hot-water-supply refrigerant via a cascade heat exchanger.

Description of the Related Art

[0002] As a hot-water supply apparatus that generates hot water, stores the hot water in a hot water storage tank, and uses the hot water for hot water supply, there has been a hot-water supply apparatus including a refrigerant circuit in which a refrigerant circulates and a water circuit in which water circulates, the refrigerant circuit being a single-stage heat pump cycle in which a compressor, a heat exchanger for hot water generation, an expansion valve, and a heat-source-side heat exchanger are connected, and a carbon dioxide refrigerant being used as the refrigerant. Further, there has been proposed as a binary-cycle hot-water supply machine thermally connected to a cycler for air conditioning in order to improve operation efficiency of a hot-water supply apparatus (Refer to Japanese Patent Laid-Open No. 2004-132647 (Japanese Patent No. 3925383)).

[0003] The configuration of the binary-cycle hot-water supply machine described in Japanese Patent Laid-Open No. 2004-132647 (Japanese Patent No. 3925383) is shown in FIG. 9.

[0004] In a hot-water supply apparatus including a refrigerant circuit 300 for hot water supply in which a compressor for hot water supply 310, a heat exchanger for hot water supply 320, a refrigerant-for-hot-water-supply-flow-rate regulating valve 330, and a cascade heat exchanger 340 are connected in order and a carbon dioxide refrigerant is filled, the heat exchanger for hot water supply 320 is configured to be capable of performing heat exchange of water of a hot water circuit for hot water supply and the carbon dioxide refrigerant and the cascade heat exchanger 340 is configured to be capable of performing heat exchange of a refrigerant of a refrigerant circuit for air conditioning and the carbon dioxide refrigerant.

[0005] Consequently, even when outdoor temperature is low and efficiency of refrigeration cycle decreases because a pressure ratio is excessively large in a single-stage heat pump cycle hot water supply machine, extraction of heat from the outdoor air can be performed in a cycle for air conditioning and a cycle for hot water supply can extract heat from a heated refrigerant for air conditioning and generate high-temperature hot water.

[0006] Therefore, pressure ratios of both of the cycle for air conditioning and the cycle for hot water supply are appropriately suppressed. It is possible to make a refrigeration cycle in an entire system efficient and improve hot water storage efficiency.

[0007] In a system for refrigeration, a binary-refrigeration cycle is proposed as in a system for hot water supply. As the configuration of the cascade heat exchanger 340, for example, as described in Japanese Patent Laid-Open No. 2007-218459, there has been proposed a configuration in which a double pipe-type heat exchanger is used and a carbon dioxide refrigerant is fed to an outer pipe.

[0008] A system for refrigeration described in Japanese Patent Laid-Open No.-2007-218459 is configured by a binary refrigeration cycle in which a carbon dioxide refrigerant is used as a low-stage side refrigerant, a refrigerant having pressure lower than the pressure of carbon dioxide is used as a high-stage side refrigerant, and a low-stage side refrigeration circuit and a high-stage refrigeration circuit are thermally connected by a cascade heat exchanger.

[0009] In this case, by using, as the cascade heat exchanger, a double pipe-type heat exchanger including, in the middle between an inner pipe and an outer pipe, a hollow section that communicates with an external world, when damage occurs in a pipe wall that partitions the inner pipe and the outer pipe, the inner pipe having low strength and the hollow section or the outer pipe and the hollow section communicate before the inner pipe and the outer pipe communicate. Consequently, it is possible to prevent a situation in which the low-stage side carbon dioxide refrigerant flows into the high-stage side refrigeration circuit and constituent apparatuses of the high-stage side refrigeration circuit are broken.

[0010] As shown in FIG. 10, by feeding the low-stage side carbon dioxide refrigerant having temperature higher than the temperature on the high-stage side to the outer pipe, it is possible to suppress frost formation and dew condensation on the surface of the double pipe-type heat exchanger.

[0011] However, in a so-called air-conditioning/hot-water supply system in which a low-stage side cycle is used for air conditioning and a high-stage side cycle is used for hot water supply as in Japanese Patent Laid-Open No. 2004-132647 (Japanese Patent No. 3925383), when the carbon dioxide refrigerant is used as a refrigerant for hot water supply and the double pipe-type heat exchanger is used as the cascade heat exchanger 340, if the carbon dioxide refrigerant is fed to the outer pipe of the double pipe-type heat exchanger as in Japanese Patent Laid-Open No. 2007-218459, in heat exchange of the refrigerant for air conditioning flowing in the inner pipe and the carbon dioxide refrigerant flowing in the outer pipe, a decrease in thermal conductivities of the refrigerant for hot water supply and the refrigerant for air conditioning due to a flow regime of the refrigerant for hot water supply and a flow regime of the refrigerant for air conditioning occurs.

[0012] First, the decrease in the thermal conductivity due to the flow regime of the refrigerant for hot water supply is explained.

[0013] When the carbon dioxide refrigerant is fed to the outer pipe of the double pipe-type heat exchanger as in Japanese Patent Laid-Open No. 2007-218459, a flow regime of a gas-liquid two-phase refrigerant evaporating in the double pipe-type heat exchanger is an annular flow in a place where dryness of the refrigerant is high. As shown in FIG. 6, a liquid-phase refrigerant having a large heat capacity concentratedly flows to the inner surface of the outer pipe apart from a heat transfer surface. Therefore, the thermal conductivity of the carbon dioxide refrigerant in heat exchange with the outer surface of the inner pipe decreases.

[0014] The refrigerant for hot water supply obtains heat from the refrigerant for air conditioning in the cascade heat exchanger 340 and generates hot water having high temperature of 60 to 90°C in the heat exchanger for hot water supply 320. In a hot-water supply system in which hot water heated to high temperature is stored in a hot-water storage tank, the temperature of water supplied from the hot-water storage tank to the heat exchanger for hot water supply 320, that is, an inflow water temperature changes according to a degree of accumulation of the hot water in the hot-water storage tank. For example, in a boiling end condition in which the hot water in the hot-water storage tank approaches full tank, the inflow water temperature rises to 40 to 60°C.

[0015] A Mollier diagram of a hot-water supply cycle is shown in FIG. 5. Reference numeral 301 denotes a hot-water supply cycle in the case of the inflow water temperature of 5°C and reference numeral 302 denotes a hot-water supply cycle in the case of the inflow water temperature of 60°C of the boiling end condition.

[0016] As shown in FIG. 5, the carbon dioxide refrigerant discharges heat to the water side in the heat exchanger for hot water supply 320. A temperature difference between the temperature of the carbon dioxide refrigerant in an outlet of the heat exchanger for hot water supply 320 and the inflow water temperature is 5 K.

[0017] Therefore, at the time of the inflow water temperature of 5°C, the temperature of the carbon dioxide refrigerant in the outlet of the heat exchanger for hot water supply 320 is 10°C. At the time of the inflow water temperature of 60°C of the boiling end condition, the temperature of the carbon dioxide refrigerant in the outlet of the heat exchanger for hot water supply 320 is 65°C. That is, a specific enthalpy of the carbon dioxide refrigerant in the outlet of the heat exchanger for hot water supply 320 is higher at the time of the inflow water temperature of 60°C than at the time of the inflow water temperature of 5°C.

[0018] As a result, dryness of the carbon dioxide refrigerant flowing into the cascade heat exchanger 340 after flowing out from the heat exchanger for hot water supply 320 and undergoing isenthalpic expansion in the expansion valve 330 is higher at the time of the inflow water temperature of 60°C than at the time of the inflow water temperature of 5°C. The carbon dioxide refrigerant changes to a gas-rich gas-liquid two-phase state with the dryness of 0.8 at the time of the inflow water temperature of 60°C.

[0019] The carbon dioxide refrigerant flowed into the cascade heat exchanger 340 at the dryness of 0.8 performs heat exchange with the refrigerant for air conditioning in the cascade heat exchanger 340 to evaporate, changes to an overheated gas state, and flows out.

[0020] At this point, the annular flow is predominant as the flow regime of the carbon dioxide in the cascade heat exchanger 340. A liquid-phase refrigerant having a large heat capacity concentratedly flows to the inner surface of the outer pipe apart from the heat transfer surface. Therefore, the thermal conductivity of the carbon dioxide refrigerant in the heat exchange with the outer surface of the inner pipe decreases.

[0021] A decrease in heat exchange efficiency due to the flow regime of the refrigerant for air conditioning is explained. As shown in FIG. 5, in the boiling end condition in which the inflow water temperature is high, since a specific enthalpy difference between the inlet and the outlet of the carbon dioxide refrigerant in the cascade heat exchanger 340 decreases, an exchanged heat quantity decreases. Therefore, condensation of the refrigerant for air conditioning flowing into the cascade heat exchanger 340 in the overheated gas state is not sufficiently performed.

[0022] A Mollier diagram an air conditioning cycle is shown in FIG. 7. Reference numeral 101 denotes an air conditioning cycle in the case of the inflow water temperature of 5°C and reference numeral 102 denotes an air conditioning cycle in the case of the inflow water temperature of 60°C of the boiling end condition.

[0023] As shown in FIG. 7, under the boiling end condition, since condensation of the refrigerant for air conditioning is not sufficiently performed, the refrigerant for air conditioning flowed into the cascade heat exchanger 340 in the overheated gas state flows out in a gas-liquid two-phase state with high dryness. Therefore, most of the refrigerant for air conditioning flowing in the cascade heat exchanger 340 changes to the overheated gas state.

[0024] When mixed fluid of refrigerator oil and a refrigerant flows in a pipe in the overheated gas state, as shown in FIG. 8, the refrigerator oil adheres to the inner surface of the pipe and forms an oil film. The oil film acts as thermal resistance and hinders heat transfer of the refrigerant.

[0025] Therefore, when the refrigerant for air conditioning is fed to the inner pipe of the double pipe-type heat exchanger as described in Japanese Patent Laid-Open No. 2007-218459, under the boiling end condition in which the inflow water temperature rises, the oil film serving as the thermal resistance adheres to and concentrates on the inner surface of the inner pipe. The thermal conductivity of the refrigerant for air conditioning in the heat exchange with the inner surface of the outer pipe decreases.

[0026] As explained above, there is a problem in that refrigeration cycle performance of the hot-water supply system under the boiling end condition decreases according to a decrease in the thermal conductivities of the refrigerant for hot water supply and the refrigerant for air conditioning in the cascade heat exchanger 340 respectively due to the flow regime of the refrigerant for hot water supply and the flow regime of the refrigerant for air conditioning.

[0027] The present invention solves the problems explained above and an object of the present invention is to provide an air-conditioning/hot-water supply system that can prevent the thermal conductivities of a refrigerant for hot water supply and a refrigerant for air conditioning in a cascade heat exchanger from decreasing and improve refrigeration cycle performance of a hot-water supply system even in a boiling end when an inflow water temperature rises.

SUMMARY OF THE INVENTION

[0028] In order to solve the problems, an air-conditioning/hot-water supply system of the present invention includes: a first refrigeration cycle in which a compressor for hot water supply that compresses a refrigerant for hot water supply, a heat exchanger for hot water supply in which the refrigerant for hot water supply and a heat medium for hot water supply perform heat exchange, a refrigerant-for-hot-water-supply-flow-rate regulating valve that controls a flow rate of the refrigerant for hot water supply, and a cascade heat exchanger in which the refrigerant for hot water supply and a refrigerant for air conditioning perform heat exchange are annularly connected; and a second refrigeration cycle in which a heat load circuit in which a first circuit and at least one second circuit are connected in parallel is connected to a compressor for air conditioning that compresses the refrigerant for air conditioning and to an outdoor heat exchanger, the first circuit being configured in which the cascade heat exchanger and a heat-generation-unit-refrigerant-flow-rate regulating valve that controls a flow rate of the refrigerant for air conditioning supplied to the cascade heat exchanger are connected in series and the second circuit being configured in which an indoor heat exchanger in which the refrigerant for air conditioning and indoor air perform heat exchange and an indoor-refrigerant-flow-rate regulating valve that controls a flow rate of the refrigerant for air conditioning supplied to an indoor heat exchanger are connected in series. A double pipe-type heat exchanger including an outer pipe and an inner pipe is used as the cascade heat exchanger to cause the refrigerant for hot water supply to flow to the inner pipe.

[0029] In the air-conditioning/hot-water supply system of the present invention, when an inflow water temperature rises in a boiling end, a specific enthalpy difference between an inlet and an outlet of a carbon dioxide refrigerant in the heat exchanger for hot water supply decreases. Therefore, the carbon dioxide refrigerant flowing into the cascade heat exchanger changes to a gas-rich gas-liquid two-phase state with dryness of 0.8.

[0030] In this case, an annular flow is predominant as a flow regime of the carbon dioxide refrigerant flowing in the double pipe-type heat exchanger. However, since the carbon dioxide refrigerant is circulated to the inner pipe, a liquid-phase refrigerant having a large heat capacity flows while adhering to and concentrating on the inner surface of the inner pipe, which is a heat transfer surface. Therefore, the thermal conductivity of the carbon dioxide refrigerant in heat exchange with the inner surface of the inner pipe increases.

[0031] When the inflow water temperature rises in the boiling end and the specific enthalpy difference between the inlet and the outlet of the carbon dioxide refrigerant in the cascade heat exchanger decreases, an exchanged heat quantity in the double pipe-type heat exchanger decreases, condensation of the refrigerant for air conditioning flowing into the cascade heat exchanger in an overheated gas state is not sufficiently performed. The refrigerant for air conditioning flows out from the cascade heat exchanger in a gas-liquid two-phase state with high dryness.

[0032] In this case, most of the refrigerant for air conditioning flowing in the double pipe-type heat exchanger changes to an overheated gas state. However, since a low-stage side refrigerant for air conditioning is circulated to the outer pipe of the double pipe-type heat exchanger, an oil film serving as heat resistance adheres to and concentrates on the inner surface of the outer pipe and an overheated gas refrigerant, which is a heat medium, flows in contact with the outer surface of the inner pipe, which is a heat transfer surface. Therefore, the thermal conductivity of the refrigerant for air conditioning in heat exchange with the outer surface of the inner pipe increases.

[0033] In the air-conditioning/hot-water supply system of the present invention, a high-stage side carbon dioxide refrigerant is caused to flow to the inner pipe of the double pipe-type heat exchanger. Therefore, it is possible to increase the thermal conductivities of the refrigerant for hot water supply and the refrigerant for air conditioning in the cascade heat exchanger in the boiling end when the inflow water temperature rises. It is possible to improve refrigeration cycle performance of a hot-water supply system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034]

FIG. 1 is a refrigeration cycle configuration diagram of an air-conditioning/hot-water supply system in a first embodiment of the present invention;

FIG. 2 is a plan view showing the internal structure of a heat generation unit in the embodiment;

FIG. 3 is a front view showing the internal structure of the heat generation unit in the embodiment;

FIG. 4 is a sectional view of a connecting section of a cascade heat exchanger and a refrigerant pipe of the present invention;

FIG. 5 is a Mollier diagram of a hot-water supply cycle;

FIG. 6 is a diagram showing a way of flowing of an annular flow in the cascade heat exchanger;

FIG. 7 is a Mollier diagram of an air conditioning cycle;

FIG. 8 is a diagram showing a way of flowing of overheated gas and refrigerator oil in the cascade heat exchanger;

FIG. 9 is a refrigeration cycle diagram of an air-conditioning/hot-water supply system in Japanese Patent Laid-Open No. 2004-132647 (Japanese Patent No. 3925383); and

FIG. 10 is a sectional view of a cascade heat exchanger and a diagram showing a low-stage side carbon dioxide refrigerant channel in Japanese Patent Laid-Open No. 2007-218459.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] A first invention is an air-conditioning/hot-water supply system which includes: a first refrigeration cycle in which a compressor for hot water supply that compresses a refrigerant for hot water supply, a heat exchanger for hot water supply in which the refrigerant for hot water supply and a heat medium for hot water supply perform heat exchange, a refrigerant-for-hot-water-supply-flow-rate regulating valve that controls a flow rate of the refrigerant for hot water supply, and a cascade heat exchanger in which the refrigerant for hot water supply and a refrigerant for air conditioning perform heat exchange are annularly connected; and a second refrigeration cycle in which a heat load circuit in which a first circuit and at least one second circuit are connected in parallel is connected to a compressor for air conditioning that compresses the refrigerant for air conditioning and to an outdoor heat exchanger, the first circuit being configured in which the cascade heat exchanger and a heat-generation-unit-refrigerant-flow-rate regulating valve that controls a flow rate of the refrigerant for air conditioning supplied to the cascade heat exchanger are connected in series and the second circuit being configured in which an indoor heat exchanger in which the refrigerant for air conditioning and indoor air perform heat exchange and an indoor-refrigerant-flow-rate regulating valve that controls a flow rate of the refrigerant for air conditioning supplied to an indoor heat exchanger are connected in series. A double pipe-type heat exchanger including an outer pipe and an inner pipe is used as the cascade heat exchanger to cause the refrigerant for hot water supply to flow to the inner pipe.

[0036] Consequently, by circulating the refrigerant for hot water supply to the inner pipe of the double pipe-type heat exchanger, when an inflow water temperature rises in a boiling end and an annular flow is predominant as a flow regime of the refrigerant for hot water supply flowing in the double pipe-type heat exchanger, a liquid-phase refrigerant having a large heat capacity flows while adhering to and concentrating on the inner surface of the inner pipe, which is a heat transfer surface. Therefore, the thermal conductivity of the refrigerant for hot water supply in heat exchange with the inner surface of the inner pipe increases.

[0037] The inflow water temperature rises in the boiling end, an exchanged heat quantity in the double pipe-type heat exchanger decreases, and the refrigerant for air conditioning flowing in the double pipe-type heat exchanger flows out from the cascade heat exchanger in a high dryness state. Therefore, most of the refrigerant for air conditioning in the cascade heat exchanger changes to an overheated state. In the case, an oil film serving as heat resistance adheres to and concentrates on the inner surface of the outer pipe and an overheated gas refrigerant, which is a heat medium, flows in contact with the outer surface of the inner pipe, which is a heat transfer surface. Therefore, the thermal conductivity of the refrigerant for air conditioning in heat exchange with the outer surface of the inner pipe increases.

[0038] Therefore, even when the inflow water temperature rises in the boiling end, it is possible to increase the thermal conductivities of the refrigerant for hot water supply and the refrigerant for air conditioning in the cascade heat exchanger. It is possible to improve refrigeration cycle performance of a hot-water supply system.

[0039] In a second invention, in the air-conditioning/hot-water supply system of the first invention, in a branching section where the inner pipe and the outer pipe of the cascade heat exchanger are respectively connected to a refrigerant pipe for hot water supply and a refrigerant pipe for air conditioning, the outer pipe and the refrigerant pipe for air conditioning are connected in a substantially perpendicular direction with respect to a flowing direction of the refrigerant for air conditioning flowing near the branching section in the cascade heat exchanger, and the inner pipe and the refrigerant pipe for hot water supply are connected in a substantially horizontal direction with respect to a flowing direction of the refrigerant for hot water supply flowing near the branching section in the cascade heat exchanger.

[0040] Consequently, even when an air conditioning load increases and a condensation temperature of the refrigerant for air conditioning flowing in the first circuit drops, an evaporation temperature of the refrigerant for hot water supply that performs heat exchange with the refrigerant for air conditioning in the cascade heat exchanger drops, and the viscosity of refrigerator oil encapsulated in the first refrigeration cycle increases, the refrigerator oil is prevented from being held up in the branching section where the inner pipe of the cascade heat exchanger and the refrigerant pipe for hot water supply are connected. An excessive pressure loss of the refrigerant for hot water supply in the cascade heat exchanger does not occur. Therefore, efficiency of the first refrigeration cycle does not decrease.

[0041] Therefore, in the present invention, in addition to the first invention, even when the air conditioning load increases and the condensation temperature of the refrigerant for air conditioning flowing in the first circuit drops, it is possible to reduce the pressure loss of the refrigerant for hot water supply in the branching section where the inner pipe of the cascade heat exchanger and the refrigerant pipe for hot water supply are connected, which is a cause of an efficiency decrease in the first refrigeration cycle. Therefore, it is possible to improve the efficiency of the first refrigeration cycle.

[0042] Embodiments of the present invention are explained below with reference to the drawings. Note that the present invention is not limited by the embodiments.

First Embodiment

[0043] FIG. 1 is a cycle configuration diagram of an air-conditioning/hot-water supply system according to an embodiment of the present invention.

[0044] The air-conditioning/hot-water supply system shown in FIG. 1 includes an outdoor unit 100, indoor units 200, and a heat generation unit 300. In this embodiment, two indoor units and one heat generation unit are connected to one outdoor unit. Note that a refrigeration cycle configuration is not limited to the configuration shown in FIG. 1. For example, two or more outdoor units, one or three or more indoor units, and two or more heat generation units can be connected in parallel.

[0045] The outdoor unit 100, the indoor units 200, and the heat generation unit 300 are coupled by pipes in which a refrigerant for air conditioning circulates. The outdoor unit 100 and the indoor units 200 are connected by a gas pipe 150 in which a high-temperature and high-pressure gasified refrigerant for air conditioning flows, a suction pipe 160 in which a low-pressure refrigerant for air conditioning flows, and a liquid pipe 170 in which a high-pressure liquefied refrigerant for air conditioning flows. When the two indoor units 200 are present as shown in FIG. 1, the indoor units 200 are connected in parallel to three pipes. On the other hand, the outdoor unit 100 and the heat generation unit 300 are connected to the pipes in parallel like the indoor units 200. However, the outdoor unit 100 and the heat generation unit 300 communicate with only the gas pipe 150 and the liquid pipe 170.

[0046] The outdoor unit 100 includes a compressor for air conditioning 110 that compresses the refrigerant for air conditioning. An accumulator 111 that supplies a gas refrigerant to the compressor for air conditioning 110 is connected to a suction side of the compressor for air conditioning 110. An oil separator 112 that separates refrigerator oil included in the refrigerant for air conditioning in a gas state to be discharged is connected to a discharge side of the compressor for air conditioning 110. The refrigerator oil separated by the oil separator 112 is returned to the compressor for air conditioning 110 by an oil return pipe 113a. Communication of the oil return pipe 113a is controlled according to opening and closing of an oil-return-pipe on-off valve 113b.

[0047] The outdoor unit 100 includes an outdoor heat exchanger 115. An outdoor blower fan 116 that supplies the air around the outdoor unit 100 to the outdoor heat exchanger 115 is provided in the vicinity of the outdoor heat exchanger 115. The outdoor heat exchanger 115 is configured such that the air sent by the outdoor blower fan 116 and the refrigerant for air conditioning perform heat exchange. In general, a heat exchanger of a fan/tube type or a micro tube type is used.

[0048] The outdoor unit 100 includes an outdoor-refrigerant-flow-rate regulating valve 120 that adjusts a flow rate of the refrigerant for air conditioning supplied to the outdoor heat exchanger 115, an outdoor-gas-pipe on-off valve 121 that controls a flow rate of the refrigerant for air conditioning in the gas pipe 150, and an outdoor-suction-pipe on-off valve 122 that controls a flow rate of the refrigerant for air conditioning in the suction pipe 160.

[0049] The indoor units 200 include indoor heat exchangers 215, indoor blower fans 216 that supply the air around the indoor units 200 to the indoor heat exchangers 215, and indoor-refrigerant-flow-rate regulating valves 220 that adjust a flow rate of the refrigerant for air conditioning supplied to the indoor heat exchangers 215. The indoor heat exchangers 215 are configured such that the air sent by the indoor blower fans 216 and the refrigerant for air conditioning perform heat exchange. In general, a heat exchanger of a fan/tube type or a micro tube type is used.

[0050] The indoor units 200 include indoor-gas-pipe on-off valves 221 that control presence or absence of circulation of the refrigerant for air conditioning to and from the gas pipe 150 and indoor-suction-pipe on-off valves 222 that control presence or absence of circulation of the refrigerant for air conditioning to and from the suction pipe 160.

[0051] The heat generation unit 300 includes a compressor for hot water supply 310 that compresses a refrigerant for hot water supply, a heat exchanger for hot water supply 320 in which the refrigerant for hot water supply and a heat medium containing water as a main component perform heat exchange, and a refrigerant-for-hot-water-supply-flow-rate regulating valve 330 that adjusts a flow rate of the refrigerant for hot water supply.

[0052] The heat generation unit 300 includes a cascade heat exchanger 340 in which the refrigerant for air conditioning supplied from the gas pipe 150 and the refrigerant for hot water supply perform heat exchange, a heat-generation-unit-refrigerant-flow-rate regulating valve 350 that adjusts a flow rate of the refrigerant for air conditioning supplied to the cascade heat exchanger

340, and a heat medium pump 360 that supplies a heat medium to the heat exchanger for hot water supply 320.

[0053] The compressor for hot water supply 310, the heat exchanger for hot water supply 320, the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, and the cascade heat exchanger 340 are annularly connected to configure a first refrigeration cycle 500.

[0054] A heat load circuit in which a first circuit 501 and at least one second circuit 502 are connected in parallel is connected to the compressor for air conditioning 110 and to the outdoor heat exchanger 115 to configure a second refrigeration cycle 510. The first circuit 501 is configured in which the cascade heat exchanger 340 and the heat-generation-unit-refrigerant-flow-rate regulating valve 350 are connected in series, the second circuit 502 is configured in which the indoor heat exchanger 215 and the indoor-refrigerant-flow-rate regulating valve 220 that supplies the refrigerant for air conditioning to the indoor heat exchanger 215 are connected in series

[0055] Note that a fluorocarbon refrigerant or a carbon dioxide refrigerant is used as the refrigerant for hot water supply. Water or an antifreeze solution is used as the heat medium. In the following explanation, the carbon dioxide refrigerant is used as the refrigerant for hot water supply and water is used as the heat medium.

[0056] As the refrigerant for air conditioning, R410A, R32, R407C, or the like, which is a refrigerant generally used in an air conditioner for home use and an air conditioner for building, is used.

[0057] As physical properties of carbon dioxide, values derived by Reference Fluid Thermodynamic and Transport Properties Ver. 9.0 (hereinafter abbreviated as Refprop Ver. 9.0) issued by the National Institute of Standards and Technology (hereinafter abbreviated as NIST) are used.

[0058] The internal structure of the heat generation unit 300 in this embodiment is explained.

[0059] FIG. 2 is a plan view showing the internal structure of the heat generation unit 300 in this embodiment. FIG. 3 is a front view showing the internal structure of the heat generation unit 300 in this embodiment.

[0060] In the heat generation unit 300, a refrigeration cycle formed by the compressor for hot water supply 310, the heat exchanger for hot water supply 320, the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, and the cascade heat exchanger 340, the heat-generation-unit-refrigerant-flow-rate regulating valve 350, and the heat medium pump 360 are housed in a casing 401.

[0061] In this embodiment, as the heat exchanger for hot water supply 320, for example, a double pipe-type heat exchanger is used. The double pipe-type heat exchanger is a heat exchanger formed by inserting one or more pipes (inner pipes) into a pipe (an outer pipe) having a substantially circular section. When a plurality of inner pipes are present, the inner pipes are spirally twisted and inserted into the outer pipe. When the carbon dioxide refrigerant is used as the refrigerant for hot water supply, the carbon dioxide refrigerant is fed to the inner pipes of the heat exchanger for hot water supply 320 and water is fed to between the outer pipe and the inner pipes.

[0062] Note that, when the double pipe-type heat exchanger is used as the heat exchanger for hot water supply 320, a copper pipe having high thermal conduction performance is often used as a material of the double pipe-type heat exchanger.

[0063] As the heat exchanger for hot water supply 320, a plate-type heat exchanger, a shell and tube-type heat exchanger, and the like may be used.

[0064] A heat exchange ability of the double pipe-type heat exchanger is proportional to the length of a double pipe. Therefore, the double pipe-type heat exchanger is molded by winding the double pipe in order to secure a maximum limit heat exchange ability within a limited setting capacity. When the double pipe-type heat exchanger is set, the double pipe is set as horizontal as possible in order to prevent a situation in which the air is held up in a portion where the heat medium passes in the double pipe and heat exchange performance is markedly decreases.

[0065] As the cascade heat exchanger 340, a double pipe-type heat exchanger is used. The double pipe-type heat exchanger is a heat exchanger formed by inserting one or more pipes (inner pipes) into a pipe (an outer pipe) having a substantially circular section. When a plurality of inner pipes are present, the inner pipes are spirally twisted and inserted into the outer pipe. When the carbon dioxide refrigerant is used as the refrigerant for hot water supply, the carbon dioxide refrigerant is fed to the inner pipes of the cascade heat exchanger 340 and the refrigerant for air conditioning is fed to between the outer pipe and the inner pipes.

[0066] FIG. 4 is a sectional view of a connecting section of the cascade heat exchanger 340 and the refrigerant pipe. As shown in FIG. 4, an inner pipe 410 of the cascade heat exchanger 340 is connected to a refrigerant pipe for hot water supply. An outer pipe 420 is connected to a refrigerant pipe for air conditioning.

[0067] In branching sections where the inner pipe 410 and the outer pipe 420 are respectively connected to the refrigerant pipe for hot water supply and the refrigerant pipe for air conditioning, the outer pipe 420 and the refrigerant pipe for air conditioning are connected in a substantially perpendicular direction with respect to a flowing direction of the refrigerant for air conditioning flowing near the branching section in the cascade heat exchanger 340. The inner pipe 410 and the refrigerant pipe for hot water supply are connected in a substantially horizontal direction with respect to a flowing direction of the refrigerant for hot water supply flowing near the branching section in the cascade heat exchanger 340.

[0068] As shown in FIGS. 2 and 3, anti-vibration members 311 such as rubber are sandwiched between the compressor for hot water supply 310 and a bottom plate member 370. Then, the compressor for hot water supply 310 is fixed to the bottom plate member 370 by fixing members 312.

[0069] The heat exchanger for hot water supply 320 is also fixed on the bottom plate member 370. The cascade heat exchanger 340 is set on the heat exchanger for hot water supply 320.

[0070] The lower end face of the heat medium pump 360 is set in a position lower than the lower end face of the cascade heat exchanger 340.

[0071] Both of the heat exchanger for hot water supply 320 and the cascade heat exchanger 340 shown in FIGS. 2 and 3 include heat insulation materials such as styrene foam or thick felt and constituent members that surround the heat insulation materials. In particular, in the heat exchanger for hot water supply 320, deformation of the heat insulation material due to the weight of the cascade heat exchanger 340 set on the heat exchanger for hot water supply 320 is assumed. The heat exchanger for hot water supply 320 is surrounded by an iron plate having high strength to protect the surface of the heat insulation material.

[0072] Note that the cascade heat exchanger 340 does not always need to be in contact with the constituent member that surrounds the heat exchanger for hot water supply 320. In this case, the cascade heat exchanger 340 and the heat insulation material around the cascade heat exchanger 340 are surrounded by a constituent member having strength sufficient for supporting the weight of the cascade heat exchanger 340 and the heat insulation material and then fixed by a constituent member connected to at least one of a side plate member 400 and the bottom plate member 370 of the heat generation unit 300.

[0073] Further, as shown in FIGS. 2 and 3, in the bottom plate member 370, a water discharge port 390 is provided in a region where the heat exchanger for hot water supply 320 and the heat medium pump 360 are projected on the bottom plate member 370 when vertically viewed from above. The upper surface of the bottom plate member 370 is appropriately inclined toward the water discharge port 390 such that water can be quickly discharged from the water discharge port 390 to the outside of the heat generation unit 300.

[0074] A flow of the heat medium in heat medium pipes 380a, 380b, and 380c is caused by driving of the heat medium pump 360. The heat medium flowed into the heat generation unit 300 flows into the heat medium pump 360 through the heat medium pipe 380a and delivered to the heat medium pipe 380b. Further, the heat medium enters the heat exchanger for hot water supply 320 and is heated by the refrigerant for hot water supply to high temperature of 70 to 90°C. Thereafter, the heat medium is delivered to the outside of the heat generation unit 300 through the heat medium pipe 380c.

[0075] A flow regime of fluid flowing in the cascade heat exchanger 340 is explained.

[0076] First, the temperature of the heat medium flowing into the heat exchanger for hot water supply 320 is affected by an outdoor air temperature and a heat medium temperature in a hot water storage tank and changes between 5°C and 60°C.

[0077] In the heat exchanger for hot water supply 320, when the heat medium absorbed from the refrigerant for hot water supply and heated flows out from the heat exchanger for hot water supply 320, the temperature of the heat medium changes between 65°C and 90°C. In the heat exchanger for hot water supply 320, the water and the carbon dioxide refrigerant are used as opposed flows such that a log-means temperature difference increases.

[0078] When an inflow water temperature is 5°C and an outflow hot water temperature is 90°C, on the outlet side of the carbon dioxide refrigerant of the heat exchanger for hot water supply 320, a temperature difference between the temperature of the carbon dioxide refrigerant and the inflow water temperature is generally set to 5 K. Therefore, the temperature of the carbon dioxide refrigerant in the outlet of the heat exchanger for hot water supply 320 is 10°C.

[0079] On the other hand, a refrigerant temperature on the inlet side of the carbon dioxide refrigerant of the heat exchanger for hot water supply 320 is 110°C equal to a discharge refrigerant temperature of the compressor for hot water supply 310. In the heat exchanger for hot water supply 320, a pinch temperature of the water and the carbon dioxide refrigerant is generally set to 5 K. The inflow water temperature is 5°C, the outflow hot water temperature is 90°C, the refrigerant temperature on the carbon dioxide inlet side is 110°C, and the refrigerant temperature on the outlet side is 10°C. Therefore, high pressure in the cycle for hot water supply 10, in which the pinch temperature of the water and the carbon dioxide refrigerant is 5 K, is 12.4 MPa.

[0080] Subsequently, the carbon dioxide refrigerant flowed out from the heat exchanger for hot water supply 320 in a state of the pressure of 12.4 MPa and the temperature of 10°C undergoes isenthalpic expansion in the refrigerant-for-hot-water-supply-flow-rate regulating valve 330 and flows into the cascade heat exchanger 340. In the cascade heat exchanger 340, the carbon dioxide refrigerant absorbs heat from the refrigerant for air conditioning, evaporates, and flows out from the cascade heat exchanger 340 in a state of overheated gas.

[0081] A condensation temperature of the refrigerant for air conditioning flowing into the cascade heat exchanger is 45 to 55°C. A temperature difference between the refrigerant for air conditioning and the carbon dioxide refrigerant is generally set to 10 K. In this case, the carbon dioxide is heated to 35 to 45°C to change to a supercritical state.

[0082] When the carbon dioxide refrigerant flowing into the compressor for hot water supply 310 is in the supercritical state, it is likely that the viscosity of the refrigerator oil in the compressor is markedly reduced, a lubricant effect of the refrigerator oil decreases, and a deficiency such as seizure of a sliding section occurs.

[0083] Therefore, an evaporation temperature of the carbon dioxide refrigerant is desirably set to 20°C lower than the critical temperature of 31.1°C by 11 K such that the efficiency of the refrigeration cycle is improved and the reliability of the compressor for hot water supply 310 is improved.

[0084] Therefore, the carbon dioxide refrigerant flowed out from the heat exchanger for hot water supply 320 in the state of the pressure of 12.4 MPa and the temperature of 10°C undergoes the isenthalpic expansion in the refrigerant-for-hot-water-supply-flow-rate regulating valve 330 and flows into the cascade heat exchanger 340 at pressure of 5.7 MPa equivalent to the evaporation temperature of 20°C. A state of the carbon dioxide refrigerant at this point is an overcooled state.

[0085] In an evaporation process, a refrigerant in the gas-liquid two-phase state at dryness of 0.8 or more generally flows as an annular flow. However, when the refrigerant flows into the cascade heat exchanger 340 in the overcooled state and flows out as overheated gas, a ratio of the annular flow is equal to or lower than 20%.

[0086] On the other hand, when the inflow water temperature is 60°C and the outflow hot water temperature is 90°C, as explained above, the temperature difference between the temperature of the carbon dioxide refrigerant and the inflow water temperature is generally set to 5 K on the outlet side of the carbon dioxide refrigerant of the heat exchanger for hot water supply 320. Therefore, the temperature of the carbon dioxide refrigerant in the outlet of the heat exchanger for hot water supply 320 is 65°C.

[0087] On the other hand, a refrigerant temperature on the inlet side of the carbon dioxide refrigerant of the heat exchanger for hot water supply 320 is 110°C equal to the discharge refrigerant temperature of the compressor for hot water supply 310. In the heat exchanger for hot water supply 320, a pinch temperature of the water and the carbon dioxide is generally set to 5 K. The inflow water temperature is 60°C, the outflow hot water temperature is 90°C, the refrigerant temperature on the carbon dioxide inlet side is 110°C, and the refrigerant temperature on the outlet side is 65°C. Therefore, high pressure in the cycle for hot water supply 10 in which the pinch temperature of the water and the carbon dioxide refrigerant is 5K is 14.2 MPa.

[0088] Subsequently, the carbon dioxide refrigerant flowed out from the heat exchanger for hot water supply 320 in a state of the pressure of 14.2 MPa and the temperature of 65°C undergoes the isenthalpic expansion in the refrigerant-for-hot-water-supply-flow-rate regulating valve 330 and flows into the cascade heat exchanger 340. In the cascade heat exchanger 340, the carbon dioxide refrigerant absorbs heat from the refrigerant for air conditioning, evaporates, and flows out from the cascade heat exchanger 340 in a state of overheated gas. As explained above, the evaporation temperature of the carbon dioxide refrigerant is desirably set to 20°C. Therefore, the carbon dioxide refrigerant flowed out from the heat exchanger for hot water supply 320 in the state of the pressure of 14.2 MPa and the temperature of 65°C undergoes the isenthalpic expansion in the refrigerant-for-hot-water-supply-flow-rate regulating valve 330 and flows into the cascade heat exchanger 340 at pressure of 5.7 MPa equivalent to the evaporation temperature of 20°C. A state of the carbon dioxide refrigerant at this point is dryness of 0.8.

[0089] In the cascade heat exchanger 340, the carbon dioxide refrigerant absorbs heat from the refrigerant for air conditioning and evaporates. The carbon dioxide refrigerant flows out from the cascade heat exchanger 340 as overheated gas. The overheated gas flowed out from the cascade heat exchanger 340 is absorbed by the compressor for hot water supply 310 and discharged as high-temperature and high-pressure overheated gas through an isenthalpic expansion process. As explained above, the high-temperature and high-pressure overheated gas discharged from the compressor for hot water supply 310 has the pressure of 14.3 MPa and the temperature of 110°C. Therefore, the refrigerant absorbed by the compressor for hot water supply 310 has pressure of 5.7 MPa and temperature of 40°C.

[0090] That is, the carbon dioxide refrigerant flows into the cascade heat exchanger 340 in a gas-liquid two-phase state of the pressure of 5.7 MPa, the temperature of 20°C, and the dryness of 0.8, absorbs heat from the refrigerant for air conditioning to evaporate, and flows out in an overheated gas state of the pressure of 5.7 MPa and the temperature of 40°C.

[0091] Therefore, an annular flow occupies most of a flow regime of the carbon dioxide refrigerant in the cascade heat exchanger 340 at the time of the inflow water temperature of 60°C and the outflow hot water temperature of 90°C.

[0092] As a flow of the gas-liquid two-phase refrigerant in the annular flow, a liquid-phase refrigerant having a large heat capacity flows while adhering to and concentrating on the pipe wall. In this embodiment, a channel of the carbon dioxide refrigerant flowing in the cascade heat exchanger 340 is disposed in the inner pipe 410. Therefore, the carbon dioxide refrigerant flowing into the cascade heat exchanger 340 in the gas-liquid two-phase state of the dryness of 0.8 forms an annular flow. The liquid-phase refrigerant having the large heat capacity adheres to and concentrates on the inner surface of the inner pipe 410, which is a heat transfer surface. Therefore, it is possible to efficiently absorb heat from the refrigerant for air conditioning flowing in the outer pipe 420 of the cascade heat exchanger 340.

[0093] At the time of the inflow water temperature of 60°C and the outflow hot water temperature of 90°C, a state of a sucked refrigerant of the compressor for hot water supply 310 is the pressure of 5.7 MPa and the temperature of 35°C as explained above. Therefore, density is 146 kg/m^3.

[0094] A state of the inlet refrigerant of the heat exchanger for hot water supply 320 is the pressure of 14.2 MPa and the temperature of 110°C. Therefore, a specific enthalpy is 488 kJ/kg. A state of the outlet refrigerant of the heat exchanger for hot water supply 320 is the pressure of 14.2 MPa and the temperature of 65°C. Therefore, a specific enthalpy is 373 kJ/kg.

[0095] Therefore, a heating ability per volume of the sucked refrigerant of the compressor for hot water supply 310 is calculated by multiplying a difference 115 kJ/kg of the specific enthalpies of the refrigerant in the inlet and the outlet of the heat exchanger for hot water supply 320 with the density 146 kg/m^3 of the sucked refrigerant of the compressor for hot water supply 310. The heating ability is 16790 kJ/m^3.

[0096] At the time of the inflow water temperature of 5°C and the outflow hot water temperature of 90°C, when a heating ability per volume of the sucked refrigerant of the compressor for hot water supply 310 is calculated in the same manner, the heating ability is 36170 kJ/m^3.

[0097] Therefore, in the boiling end when the inflow water temperature rises to 60°C, a heating ability in operating the compressor for hot water supply 310 at the same frequency is 46% compared with the heating ability at the time of the inflow water temperature of 5°C.

[0098] A state of the inlet refrigerant of the cascade heat exchanger 340 is the pressure of 5.7 MPa and the temperature of 65°C. The refrigerant flowed out from the heat exchanger for hot water supply 320 undergoes the isenthalpic expansion in the refrigerant-for-hot-water-supply-flow-rate regulating valve 330 and flows into the cascade heat exchanger 340. Therefore, a specific enthalpy is 373 kJ/kg. A state of the outlet refrigerant of the cascade heat exchanger 340 is the pressure of 5.7 MPa and the temperature of 35°C. Therefore, a specific enthalpy is 448 kJ/kg.

[0099] Therefore, a heat exchange amount of the refrigerant evaporating in the cascade heat exchanger 340 per volume of the sucked refrigerant of the compressor for hot water supply 310 is calculated by multiplying a difference 75 kJ/kg of the specific enthalpies of the refrigerant in the inlet and the outlet of the cascade heat exchanger 340 with the density 146 kg/m^3 of the sucked refrigerant of the compressor for hot water supply 310. The heat exchange amount is 10950 kJ/m^3.

[0100] At the time of the inflow water temperature of 5°C and the outflow hot water temperature of 90°C, when a heat exchange amount of the refrigerant evaporating in the cascade heat exchanger 340 per volume of the sucked refrigerant of the compressor for hot water supply 310 is calculated in the same manner, the heat exchange amount is 32500 kJ/m^3.

[0101] Therefore, in the boiling end when the inflow water temperature rises to 60°C, a heat exchange amount of the refrigerant evaporating in the cascade heat exchanger 340 in operating the compressor for hot water supply 310 at the same frequency is 34% compared with the heat exchange amount at the time of the inflow water temperature of 5°C.

[0102] The refrigerant for air conditioning flowing in the outer pipe of the cascade heat exchanger 340 flows into the cascade heat exchange 340 in an overheated gas state at the time of the inflow water temperature of 5°C and the outflow hot water temperature of 90°C, radiates heat to the carbon dioxide refrigerant to condense, and flows out in an overcooled state.

[0103] However, at the time of the inflow water temperature of 60°C and the outflow hot water temperature of 90°C, a heat quantity of the refrigerant evaporating in the cascade heat exchanger 340 of the carbon dioxide refrigerant decreases to 34% compared with the time of the inflow water temperature of 5°C and the outflow hot water temperature of 90°C. Therefore, the refrigerant for air conditioning flows out from the cascade heat exchanger 340 in the gas-liquid two-phase state with the dryness of 0.8. At the inflow water temperature of 60°C, the overheated gas state occupies most of (60 to 70%) of the refrigerant for air conditioning flowing in the cascade heat exchanger 340.

[0104] Incidentally, when mixed fluid of the refrigerator oil and the refrigerant flows in a pipe in the overheated gas state, the refrigerator oil adheres to the surface of the pipe and forms an oil film. The oil film acts as heat resistance and hinders heat transfer of the refrigerant.

[0105] In this embodiment, the channel for the refrigerant for heat exchange flowing in the cascade heat exchanger 340 is disposed in the outer pipe 420. Therefore, in mixed fluid of the refrigerant for air conditioning flowing in as the overheated gas and the refrigerator oil, an oil film serving as heat resistance adheres to and concentrates on the inner surface of the outer pipe 420. The overheated gas refrigerant, which is the heat medium, comes into contact with the outer surface of the inner pipe 410, which is the heat transfer surface. Therefore, it is possible to efficiently radiate heat to the carbon dioxide refrigerant flowing in the inner pipe 410 of the cascade heat exchanger 340.

[0106] A flow of the refrigerator oil in the branching section that connects the inner pipe 410 of the cascade heat exchanger 340 and the refrigerant pipe for hot water supply is explained.

[0107] An evaporation temperature of the refrigerant for hot water supply that performs heat exchange with the refrigerant for air conditioning in the cascade heat exchanger 340 is affected by a condensation temperature of the refrigerant for air conditioning. For example, when an air conditioning load increases and the condensation temperature of the refrigerant for air conditioning flowing in the first circuit 501 drops, the evaporation temperature of the refrigerant for hot water supply that performs heat exchange with the refrigerant for air conditioning in the cascade heat exchanger 340 drops.

[0108] When the evaporation temperature of the refrigerant for hot water supply drops, the viscosity of the refrigerator oil encapsulated in the first refrigeration cycle flowing in the cascade heat exchanger 340 increases. When the viscosity of the refrigerator oil increases, the refrigerator oil is held up in a bent portion of a pipe and hinders the flow of the refrigerant for hot water supply. As a result, a pressure loss occurs.

[0109] In this embodiment, the outer pipe 420 of the cascade heat exchanger 340 and the refrigerant pipe for air conditioning are connected in a substantially perpendicular direction with respect to a flowing direction of the refrigerant for air conditioning flowing near the branching section in the cascade heat exchanger 340. The inner pipe 410 of the cascade heat exchanger 340 and the refrigerant pipe for hot water supply are connected in a substantially horizontal direction with respect to a flowing direction of the refrigerant for hot water supply flowing near the branching section in the cascade heat exchanger 340. Therefore, it is possible to prevent the refrigerator oil from being held up in the branching section where the inner pipe 410 of the cascade heat exchanger 340 and the refrigerant pipe for hot water supply are connected and reduce a pressure loss of the refrigerant for hot water supply in the cascade heat exchanger 340.

[0110] The operations of the outdoor unit 100, the indoor units 200, and the heat generation unit 300 are explained with reference to the refrigeration cycle diagram of FIG. 1.

[0111] During cooling independent operation, in the outdoor unit 100, the outdoor-gas-pipe on-off valve 121 is set to open and the outdoor-suction-pipe on-off valve 122 is set to closed. In the indoor units 200, the indoor-gas-pipe on-off valves 221 are set to closed and the indoor-suction-pipe on-off valves 222 are set to open. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is set to fully-closed.

[0112] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 enters the outdoor heat exchanger 115 through the outdoor-gas-pipe on-off valve 121 and is cooled by the air around the outdoor unit 100 to change to a liquid state. The refrigerant for air conditioning in the liquid state flows into the liquid pipe 170 through the outdoor-refrigerant-flow-rate regulating valve 120 in the full-open state and reaches the indoor units 200.

[0113] The refrigerant for air conditioning reached the indoor units 200 is decompressed by the indoor-refrigerant-flow-rate regulating valves 220 to change to a low-temperature low-pressure gas-liquid two-phase state. Thereafter, the refrigerant for air conditioning flows into the indoor heat exchangers 215, takes heat from the indoor air, and performs cooling. The refrigerant for air conditioning evaporates in this process, enters the suction pipe 160 through the indoor-suction-pipe on-off valves 222, and returns to the outdoor unit 100. The refrigerant for air conditioning returned to the outdoor unit 100 returns to the compressor for air conditioning 110 through the accumulator 111.

[0114] During warming independent operation, in the outdoor unit 100, the outdoor-gas-pipe on-off valve 121 is set to closed and the outdoor-suction-pipe on-off valve 122 is set to open. In the indoor units 200, the indoor-gas-pipe on-off valves 221 are set to open and the indoor-suction-pipe on-off valves 222 are set to closed. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is set to fully-closed.

[0115] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 flows into the gas pipe 150 and reaches the indoor units 200. The refrigerant for air conditioning reached the indoor units 200 flows into the indoor heat exchangers 215 through the indoor-gas-pipe on-off valves 221, radiates heat to the indoor air, and performs warming. The refrigerant for air conditioning condenses and liquefies in this process, flows into the liquid pipe 170 through the indoor-refrigerant-flow-rate regulating valve 220 in the full-open state, and returns to the outdoor unit 100.

[0116] The refrigerant for air conditioning returned to the outdoor unit 100 is decompressed by the outdoor-refrigerant-flow-rate regulating valve 120 to change to a low-temperature and low-pressure gas-liquid two-phase state. Thereafter, the refrigerant for air conditioning enters the outdoor heat exchanger 115 and is heated by the air around the outdoor unit 100 to evaporate. The evaporated and gasified refrigerant for air conditioning returns to the compressor for air conditioning 110 through the outdoor-suction-pipe on-off valve 122 and the accumulator 111.

[0117] During hot water supply independent operation, in the outdoor unit 100, the outdoor-gas-pipe on-off valve 121 is set to closed and the outdoor-suction-pipe on-off valve 122 is set to open. In the indoor units 200, both of the indoor-gas-pipe on-off valves 221 and the indoor-suction-pipe on-off valves 222 are set to closed. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is opened.

[0118] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 flows into the gas pipe 150 and reaches the heat generation unit 300. On the other hand, in the heat generation unit 300, the compressor for hot water supply 310 operates. The refrigerant for hot water supply circulates through the compressor for hot water supply 310, the heat exchanger for hot water supply 320, the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, and the cascade heat exchanger 340 in this order.

[0119] The refrigerant for air conditioning reached the heat generation unit 300 heats the refrigerant for hot water supply in the cascade heat exchanger 340 and is cooled to liquefy. Thereafter, the refrigerant for air conditioning flows into the liquid pipe 170 through the heat-generation-unit-refrigerant-flow-rate regulating valve 350 and returns to the outdoor unit 100.

[0120] The refrigerant for air conditioning returned to the outdoor unit 100 is decompressed by the outdoor-refrigerant-flow-rate regulating valve 120 to change to a low-temperature and low-pressure gas-liquid two-phase state. Thereafter, the refrigerant for air conditioning enters the outdoor heat exchanger 115 and is heated by the air around the outdoor unit 100 to evaporate. The evaporated and gasified refrigerant for air conditioning returns to the compressor for air conditioning 110 through the outdoor-suction-pipe on-off valve 122 and the accumulator 111.

[0121] On the other hand, the refrigerant for hot water supply heated by the refrigerant for air conditioning in the cascade heat exchanger 340 gasifies and enters the compressor for hot water supply 310. The refrigerant for hot water supply compressed to high temperature and high pressure by the compressor for hot water supply 310 enters the heat exchanger for hot water supply 320 and heats the heat medium to 70 to 90°C. The refrigerant for hot water supply is cooled to liquefy in this process. After being decompressed by the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, the refrigerant for hot water supply returns to the cascade heat exchanger 340 again.

[0122] During simultaneous operation of cooling and warming, when a cooling load and a warming load are substantially equal, in the outdoor unit 100, both of the outdoor-gas-pipe on-off valve 121 and the outdoor-suction-pipe on-off valve 122 are set to closed.

[0123] In the indoor unit 200, which performs cooling, the indoor-gas-pipe on-off valve 221 is set to closed and the indoor-suction-pipe on-off valve 222 is set to open. In the indoor unit 200, which performs warming, the indoor-gas-pipe on-off valve 221 is set to open and the indoor-suction-pipe on-off valve 222 is set to closed. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is set to fully-closed.

[0124] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 flows into the gas pipe 150 and reaches the indoor unit 200, which performs warming. The refrigerant for air condition reached the indoor unit 200, which performs warming, flows into the indoor heat exchanger 215 through the indoor-gas-pipe on-off valve 221, radiates heat to the indoor air, and performs warming. The refrigerant for air conditioning condenses and liquefies in this process and flows into the liquid pipe 170 through the indoor-refrigerant-flow-rate regulating valve 220 in the full-open state.

[0125] The refrigerant for air conditioning in the liquid state flowed into the liquid pipe 170 reaches the indoor unit 200, which performs cooling. The refrigerant for air conditioning reached the indoor unit 200, which performs cooling, is decompressed by the indoor-refrigerant-flow-rate regulating valve 220 to change to a low-temperature and low-pressure gas-liquid two-phase state. Thereafter, the refrigerant for air conditioning flows into the indoor heat exchanger 215, takes heat from the indoor air, and performs cooling. The refrigerant for air conditioning evaporates in this process, enters the suction pipe 160 through the indoor-suction-pipe on-off valve 222, and returns to the outdoor unit 100. The refrigerant for air conditioning returned to the outdoor unit 100 returns to the compressor for air conditioning 110 through the accumulator 111.

[0126] Note that, when the cooling load is larger than the warming load, the liquid refrigerant supplied from the indoor unit 200, which performs warming, to the indoor unit 200, which performs cooling, is insufficient. Therefore, a part of the liquid refrigerant is generated by the outdoor heat exchanger 115 of the outdoor unit 100.

[0127] That is, the outdoor-gas-pipe on-off valve 121 is set to open while the outdoor-suction-pipe on-off valve 122 is kept closed. A part of the refrigerant discharged by the compressor for air conditioning 110 is supplied to the outdoor heat exchanger 115 and liquefied and, through the outdoor-refrigerant-flow-rate regulating valve 120 and the liquid pipe 170, supplied to the indoor unit 200, which performs cooling.

[0128] Conversely, when the warming load is larger than the cooling load, the liquid refrigerant supplied from the indoor unit 200, which performs warming, cannot be entirely evaporated in the indoor unit 200, which performs cooling. Therefore, a part of the liquid refrigerant is evaporated in the outdoor heat exchanger 115 of the outdoor unit 100.

[0129] That is, the outdoor-suction-pipe on-off valve 122 is set to open while the outdoor-gas-pipe on-off valve 121 is kept closed. The liquid refrigerant flowed out from the indoor unit 200, which performs warming, is returned to the outdoor unit 100 through the liquid pipe 170. The liquid refrigerant returned to the outdoor unit 100 is decompressed by the outdoor-refrigerant-flow-rate regulating valve 120 and thereafter evaporates in the outdoor heat exchanger 115. The gasified refrigerant for air conditioning returns to the accumulator 111 and the compressor for air conditioning 110 through the outdoor-suction-pipe on-off valve 122.

[0130] During the simultaneous operation of cooling and warming, when the cooling load and a hot water supply load are substantially equal, in the outdoor unit 100, both of the outdoor-gas-pipe on-off valve 121 and the outdoor-suction-pipe on-off valve 122 are set to closed.

[0131] In the indoor unit 200, which performs cooling, the indoor-gas-pipe on-off valve 221 is set to closed and the indoor-suction-pipe on-off valve 222 is set to open. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is opened.

[0132] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 flows into the gas pipe 150 and reaches the heat generation unit 300. On the other hand, in the heat generation unit 300, the compressor for hot water supply 310 operates. The refrigerant for hot water supply circulates through the compressor for hot water supply 310, the heat exchanger for hot water supply 320, the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, and the cascade heat exchanger 340 in this order.

[0133] The refrigerant for air conditioning reached the heat generation unit 300 heats the refrigerant for hot water supply in the cascade heat exchanger 340 and is cooled to liquefy. Thereafter, the refrigerant for air conditioning flows into the liquid pipe 170 through the heat-generation-unit-refrigerant-flow-rate regulating valve 350.

[0134] The refrigerant for air conditioning flowed into the liquid pipe 170 reaches the indoor unit 200, which performs cooling. The refrigerant for air conditioning reached the indoor unit 200, which performs cooling, is decompressed by the indoor-refrigerant-flow-rate regulating valve 220 to change to a low-temperature and low-pressure gas-liquid two-phase state. Thereafter, the refrigerant for air conditioning flows into the indoor heat exchanger 215, takes heat from the indoor air, and performs cooling.

[0135] The refrigerant for air conditioning evaporates in this process, enters the suction pipe 160 through the indoor-suction-pipe on-off valve 222, and returns to the outdoor unit 100. The refrigerant for air conditioning returned to the outdoor unit 100 returns to the compressor for air conditioning 110 through the accumulator 111.

[0136] On the other hand, the refrigerant for hot water supply heated by the refrigerant for air conditioning in the cascade heat exchanger 340 gasifies and enters the compressor for hot water supply 310. The refrigerant for hot water supply compressed to high temperature and high pressure by the compressor for hot water supply 310 enters the heat exchanger for hot water supply 320 and heats the heat medium to 70 to 90°C.

[0137] The refrigerant for hot water supply is cooled to liquefy in this process and is decompressed by the refrigerant-for-hot-water-supply-flow-rate regulating valve 330. Thereafter, the refrigerant for hot water supply returns to the cascade heat exchanger 340 again.

[0138] Note that, when the cooling load is larger than the hot water supply load, the liquid refrigerant supplied from the heat generation unit 300 to the indoor unit 200, which performs cooling, is insufficient. Therefore, a part of the liquid refrigerant is generated by the outdoor heat exchanger 115 of the outdoor unit 100.

[0139] That is, the outdoor-gas-pipe on-off valve 121 is set to open while the outdoor-suction-pipe on-off valve 122 is kept closed. A part of the refrigerant discharged by the compressor for air conditioning 110 is supplied to the outdoor heat exchanger 115 and liquefied and, through the outdoor-refrigerant-flow-rate regulating valve 120 and the liquid pipe 170, supplied to the indoor unit 200, which performs cooling.

[0140] On the other hand, when the hot water supply load is larger than the cooling load, the liquid refrigerant supplied from the heat generation unit 300 cannot be entirely evaporated in the indoor unit 200, which performs cooling. Therefore, a part of the liquid refrigerant is evaporated by the outdoor heat exchanger 115 of the outdoor unit 100.

[0141] That is, the outdoor-suction-pipe on-off valve 122 is set to open while the outdoor-gas-pipe on-off valve 121 is kept closed. A part of the liquid refrigerant flowed out from the indoor unit 200, which performs warming, is returned to the outdoor unit 100 through the liquid pipe 170.

[0142] The liquid refrigerant returned to the outdoor unit 100 is decompressed by the outdoor-refrigerant-flow-rate regulating valve 120 and thereafter evaporates in the outdoor heat exchanger 115. The gasified refrigerant for air conditioning returns to the accumulator 111 and the compressor for air conditioning 110 through the outdoor-suction-pipe on-off valve 122.

[0143] During simultaneous operation of warming and hot water supply, in the outdoor unit 100, the outdoor-gas-pipe on-off valve 121 is set to closed and the outdoor-suction-pipe on-off valve 122 is set to open. In the indoor units 200, the indoor-gas-pipe on-off valves 221 are set to open and the indoor-suction-pipe on-off valves 222 are set to closed. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is opened.

[0144] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 flows into the gas pipe 150 and reaches the indoor units 200 and the heat generation unit 300. The refrigerant for air conditioning reached the indoor units 200 flows into the indoor heat exchangers 215 through the indoor-gas-pipe on-off valves 221, radiates heat to the indoor air, and performs warming. The refrigerant for air conditioning condenses and liquefies in the process and flows into the liquid pipe 170 through the indoor-refrigerant-flow-rate regulating valves 220 in the full-open state.

[0145] The refrigerant for air conditioning reached the heat generation unit 300 heats the refrigerant for hot water supply in the cascade heat exchanger 340 and is cooled to liquefy. Thereafter, the refrigerant for air conditioning flows into the liquid pipe 170 through the heat-generation-unit-refrigerant-flow-rate regulating valve 350.

[0146] The liquid refrigerant merges with the liquid refrigerant flowed out from the indoor unit 200, which performs warming, and returns to the outdoor unit 100. The liquid refrigerant returned to the outdoor unit 100 is decompressed by the outdoor-refrigerant-flow-rate regulating valve 120 and thereafter evaporated in the outdoor heat exchanger 115. The gasified refrigerant for air conditioning returns to the accumulator 111 and the compressor for air conditioning 110 through the outdoor-suction-pipe on-off valve 122.

[0147] On the other hand, the refrigerant for hot water supply heated by the refrigerant for air conditioning in the cascade heat exchanger 340 gasifies and enters the compressor for hot water supply 310. The refrigerant for hot water supply compressed to high temperature and high pressure by the compressor for hot water supply 310 enters the heat exchanger for hot water supply 320 and heats the heat medium to 70 to 90°.

[0148] The refrigerant for hot water supply is cooled to liquefy in this process. After being decompressed by the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, the refrigerant for hot water supply returns to cascade heat exchanger 340 again.

[0149] During simultaneous operation of cooling, warming, and hot water supply, when the cooling load and a sum of the warming load and the hot water supply load are substantially equal, in the outdoor unit 100, both of the outdoor-gas-pipe on-off valve 121 and the outdoor-suction-pipe on-off valve 122 are set to closed.

[0150] In the indoor unit 200, which performs cooling, the indoor-gas-pipe on-off valve 221 is set to closed and the indoor-suction-pipe on-off valve 222 is set to open. In the indoor unit 200, which performs warming, the indoor-gas-pipe on-off valve 221 is set to open and the indoor-suction-pipe on-off valve 222 is set to closed. In the heat generation unit 300, the heat-generation-unit-refrigerant-flow-rate regulating valve 350 is opened.

[0151] The high-temperature and high-pressure refrigerant for air conditioning compressed by the compressor for air conditioning 110 flows into the gas pipe 150 and reaches the indoor unit 200, which performs warming, and the heat generation unit 300. On the other hand, in the heat generation unit 300, the compressor for hot water supply 310 operates. The refrigerant for hot water supply circulates through the compressor for hot water supply 310, the heat exchanger for hot water supply 320, the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, and the cascade heat exchanger 340 in this order.

[0152] The refrigerant for air conditioning reached the indoor unit 200, which performs warming, flows into the indoor heat exchanger 215 through the indoor-gas-pipe on-off valve 221, radiates heat to the indoor air, and performs warming. The refrigerant for air conditioning condenses and liquefies in this process and flows into the liquid pipe 170 through the indoor-refrigerant-flow-rate regulating valve 220 in the full-open state.

[0153] The refrigerant for air conditioning reached the heat generation unit 300 heats the refrigerant for hot water supply in the cascade heat exchanger 340 and is cooled to liquefy. Thereafter, the refrigerant for air conditioning flows into the liquid pipe 170 through the heat-generation-unit-refrigerant-flow-rate regulating valve 350.

[0154] The liquefied refrigerants for air conditioning flowed into the liquid pipe 170 from the indoor unit 200, which performs warming, and the heat generation unit 300 merge and reach the indoor unit 200, which performs cooling.

[0155] The refrigerant for air conditioning reached the indoor unit 200, which performs cooling, is decompressed by the indoor-refrigerant-flow-rate regulating valve 220 to change to a low-temperature and low-pressure gas-liquid two-phase state. Thereafter, the refrigerant for air conditioning flows into the indoor heat exchanger 215, takes heat from the indoor air, and performs cooling. The refrigerant for air conditioning evaporates in this process, enters the suction pipe 160 through the indoor-suction-pipe on-off valve 222, and returns to the outdoor unit 100.

[0156] The refrigerant for air conditioning returned to the outdoor unit 100 returns to the compressor for air conditioning 110 through the accumulator 111.

[0157] On the other hand, the refrigerant for hot water supply heated by the refrigerant for air conditioning in the cascade heat exchanger 340 gasifies and enters the compressor for hot water supply 310. The refrigerant for hot water supply compressed to high temperature and high pressure by the compressor for hot water supply 310 enters the heat exchanger for hot water supply 320 and heats the heat medium to 70 to 90°C.

[0158] The refrigerant for hot water supply is cooled to liquefy in this process. After being decompressed by the refrigerant-for-hot-water-supply-flow-rate regulating valve 330, the refrigerant for hot water supply returns to the cascade heat exchanger 340 again.

[0159] Note that, when the cooling load is larger than the sum of the warming load and the hot water supply load, the liquid refrigerant supplied to the indoor unit 200, which performs cooling, from the indoor unit 200, which performs warming, and the heat generation unit 300 is insufficient. Therefore, a part of the liquid refrigerant is generated by the outdoor heat exchanger 115.

[0160] That is, the outdoor-gas-pipe on-off valve 121 is set to open while the outdoor-suction-pipe on-off valve 122 is kept closed. A part of the refrigerant discharged by the compressor for air conditioning 110 is supplied to the outdoor heat exchanger 115 and liquefied and, through the outdoor-refrigerant-flow-rate regulating valve 120 and the liquid pipe 170, supplied to the indoor unit 200, which performs cooling.

[0161] On the other hand, when the sum of the warming load and the hot water supply load is larger than the cooling load, the liquid refrigerant supplied from the indoor unit 200, which performs warming, and the heat generation unit 300 cannot be entirely evaporated in the indoor unit 200, which performs cooling. Therefore, a part of the liquid refrigerant is evaporated by the outdoor heat exchanger 115 of the outdoor unit 100.

[0162] That is, the outdoor-suction-pipe on-off valve 122 is set to open while the outdoor-gas-pipe on-off valve 121 is kept closed. A part of the liquid refrigerant flowed out from the indoor unit 200, which performs warming, and the heat generation unit 300 is returned to the outdoor unit 100 through the liquid pipe 170.

[0163] The liquid refrigerant returned to the outdoor unit 100 is decompressed by the outdoor-refrigerant-flow-rate regulating valve 120 and thereafter evaporates in the outdoor heat exchanger 115. The gasified refrigerant for air conditioning returns to the accumulator 111 and the compressor for air conditioning 110 through the outdoor-suction-pipe on-off valve 122.

[0164] The operation of the heat medium in the heat generation unit 300 is explained with reference to FIGS. 2 and 3.

[0165] The compressor for hot water supply 310 and the heat medium pump 360 operate during the hot water supply independent operation, during the simultaneous operation of cooling and hot water supply, during the simultaneous operation of warming and hot water supply, and during the simultaneous operation of the cooling, warming, and hot water supply.

[0166] During the operation of the heat medium pump 360, the heat medium flows into the heat generation unit 300 from the outside of the heat generation unit 300 such as waterworks and enters the heat medium pump 360 through the heat medium pipe 380a.

[0167] The heat medium flowed into the heat medium pump 360 flows into the heat medium pipe 380b from a discharge port and enters the heat exchanger for hot water supply 320. The heat medium performs, in the heat exchanger for hot water supply 320, which is the double pipe-type heat exchanger, heat exchange with the high-temperature refrigerant for hot water supply discharged by the compressor for hot water supply 310. After being heated to 70 to 90°C, the heat medium is delivered to the outside of the heat generation unit 300 through the heat medium pipe 380c.

[0168] Note that, in the air-conditioning/hot-water supply system, when hot water is stored in the hot water storage tank, water having relatively low temperature in a lower part of the hot water storage tank is supplied to the heat generation unit 300. However, as the hot water accumulates in the hot water tank, the temperature of the water supplied to the heat generation unit 300 gradually rises, that is, so-called boiling end operation is performed.

[0169] As it is evident from the above description, in this embodiment, the double pipe-type heat exchanger including the outer pipe 420 and the inner pipe 410 is used as the cascade heat exchanger 340 and the refrigerant for hot water supply is circulated in the inner pipe 410. Consequently, in the so-called boiling end operation in which the inflow water temperature rises, even when the annular flow is predominant as the flow regime of the high-stage side refrigerant, the liquid-phase refrigerant, which is a heat absorption source, adheres to and concentrates on the inner surface of the inner pipe and, even when the overheated gas state is predominant as the state of the low-stage side refrigerant in the boiling end operation, the oil film serving as the heat resistance adheres to and concentrates on the inner surface of the outer pipe 420. The overheated gas refrigerant, which is the heat medium, easily comes into contact with the outer surface of the inner pipe 410, which is the heat transfer surface.

[0170] Therefore, even when the inflow water temperature of the water supplied to the heat generation unit 300 in the boiling end operation rises, heat exchange is efficiently performed between the high-stage side refrigerant and the low-stage side refrigerant in the cascade heat exchanger 340. It is possible to improve the operation efficiency of the hot water supply system.

[0171] Even when the air conditioning load increases and the condensation temperature of the refrigerant for air conditioning flowing in the first circuit 501 drops, it is possible to prevent the refrigerator oil in the branching section where the inner pipe 410 of the cascade heat exchanger 340 and the refrigerant pipe for hot water supply are connected, which is a cause of the efficiency decrease of the first refrigeration cycle 500, from being held up and suppress a pressure loss of the refrigerant for hot water supply. Therefore, it is possible to improve the efficiency of the first refrigeration cycle 500.

[0172] In this embodiment, in the branching section where the inner pipe 410 and the outer pipe 420 of the cascade heat exchanger 340 are respectively connected to the refrigerant pipe for hot water supply and the refrigerant pipe for air conditioning, the outer pipe 420 and the refrigerant pipe for air conditioning are connected in the substantially perpendicular direction with respect to the flowing direction of the refrigerant for air conditioning flowing near the branching section in the cascade heat exchanger 340, and the inner pipe 410 and the refrigerant pipe for hot water supply are connected in the substantially horizontal direction with respect to the flowing direction of the refrigerant for hot water supply flowing near the branching section in the cascade heat exchanger 340. Consequently, even when the air conditioning load increases and the condensation temperature of the refrigerant for air conditioning flowing in the first circuit 501 drops, it is possible to reduce a pressure loss of the refrigerant for hot water supply in the branching section where the inner pipe 410 of the cascade heat exchanger 340 and the refrigerant pipe for hot water supply are connected, which is a cause of the efficiency decrease of the first refrigeration cycle 500. Therefore, it is possible to improve the efficiency of the first refrigeration cycle 500.

[0173] The present invention can be suitably used for providing an air-conditioning/hot-water supply system that can simultaneously supply hot and cold heats necessary for cooling, warming, and hot water supply, the air-conditioning/hot-water supply system provides the hot-water supply system having high operation efficiency without thermal conductivities of a high-stage side refrigerant and a low-stage side refrigerant decreasing in the cascade heat exchanger 340 even when an inflow water temperature rises in a boiling end.

REFERENCE SIGNS LIST

[0174]

100	indoor unit
110	compressor for air conditioning
115	outdoor heat exchanger
150	gas pipe
160	suction pipe
170	liquid pipe
200	indoor unit
215	indoor heat exchanger
220	indoor-refrigerant-flow-rate regulating valve

300 heat generation unit
310 compressor for hot water supply
320 heat exchanger for hot water supply
330 refrigerant-for-hot-water-supply-flow-rate regulating valve
340 cascade heat exchanger
350 heat-generation-unit-refrigerant-flow-rate regulating valve
360 heat medium pump
380 heat medium pipe
390 water discharge port
400 side plate member
410 inner pipe
420 outer pipe
500 first refrigeration cycle
501 first circuit
502 second circuit
510 second refrigeration cycle

Claims

1. An air-conditioning/hot-water supply system comprising:

    a first refrigeration cycle (500) in which a compressor for hot water supply (310) that compresses a refrigerant for hot water supply, a heat exchanger for hot water supply (320) in which the refrigerant for hot water supply and a heat medium for hot water supply perform heat exchange, a refrigerant-for-hot-water-supply-flow-rate regulating valve (330) that controls a flow rate of the refrigerant for hot water supply, and a cascade heat exchanger (340) in which the refrigerant for hot water supply and a refrigerant for air conditioning perform heat exchange are annularly connected; and
    a second refrigeration cycle in which a heat load circuit in which a first circuit (501) and at least one second circuit (502) are connected in parallel is connected to a compressor for air conditioning (110) that compresses the refrigerant for air conditioning and to an outdoor heat exchanger (115), the first circuit being configured in which the cascade heat exchanger and a heat-generation-unit-refrigerant-flow-rate regulating valve (350) that controls a flow rate of the refrigerant for air conditioning supplied to the cascade heat exchanger are connected in series and the second circuit being configured in which an indoor heat exchanger (215) in which the refrigerant for air conditioning and indoor air perform heat exchange and an indoor-refrigerant-flow-rate regulating valve (220) that controls a flow rate of the refrigerant for air conditioning supplied to the indoor heat exchanger are connected in series, **characterized in that**
    a double pipe-type heat exchanger including an outer pipe (420) and an inner pipe (410) is used as the cascade heat exchanger to cause the refrigerant for hot water supply to flow to the inner pipe.

2. The air-conditioning/hot-water supply system according to claim 1, wherein, in a branching section where the inner pipe and the outer pipe of the cascade heat exchanger are respectively connected to a refrigerant pipe for hot water supply and a refrigerant pipe for air conditioning, the outer pipe and the refrigerant pipe for air conditioning are connected in a substantially perpendicular direction with respect to a flowing direction of the refrigerant for air conditioning flowing near the branching section in the cascade heat exchanger, and the inner pipe and the refrigerant pipe for hot water supply are connected in a substantially horizontal direction with respect to a flowing direction of the refrigerant for hot water supply flowing near the branching section in the cascade heat exchanger.

FIG.1

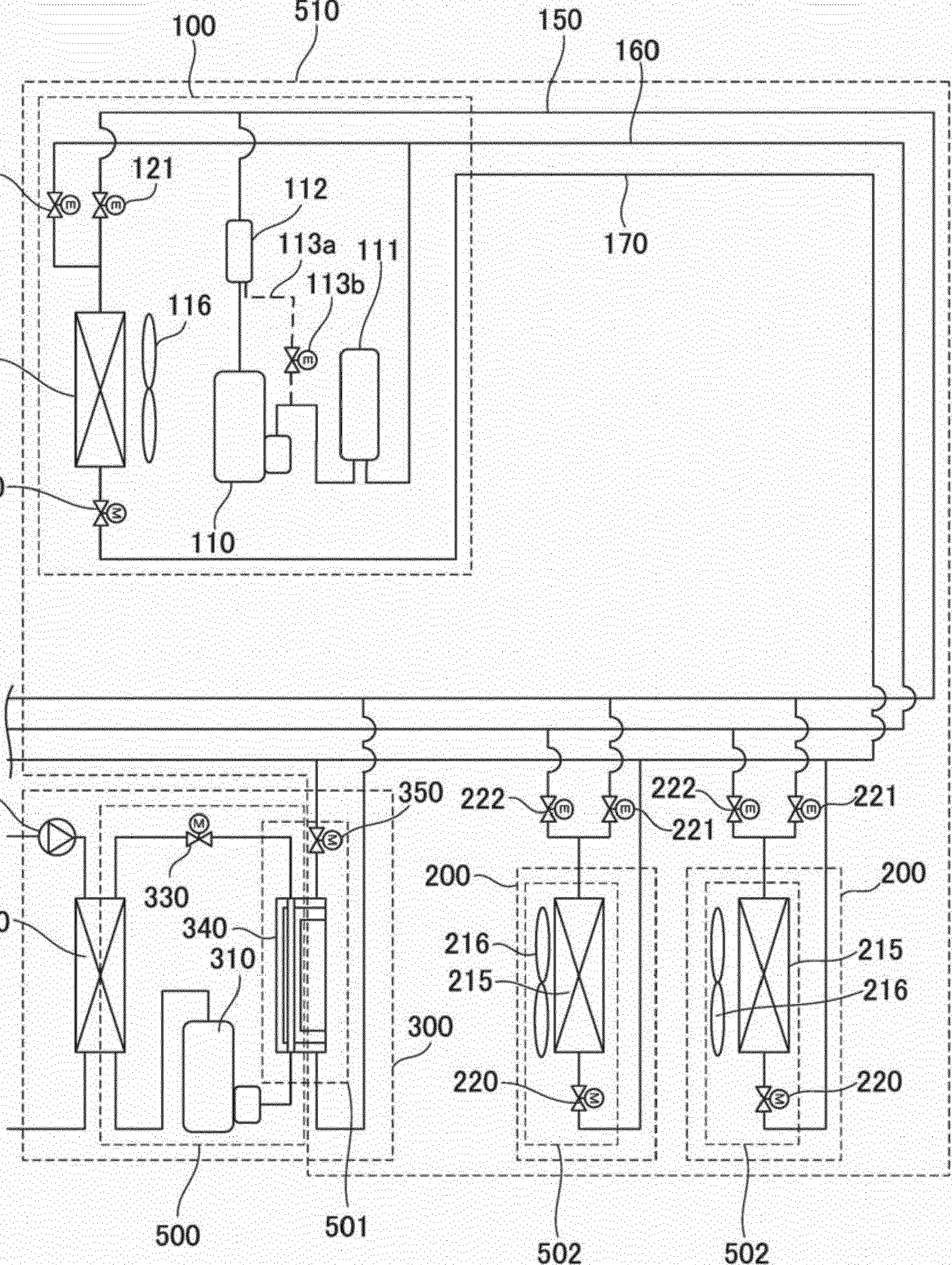

100
510
150
160
170
122
121
112
113a
111
113b
116
115
120
110
360
350
222
221
222
221
330
200
200
320
340
310
216
215
215
216
300
220
220
500
501
502
502

FIG.2

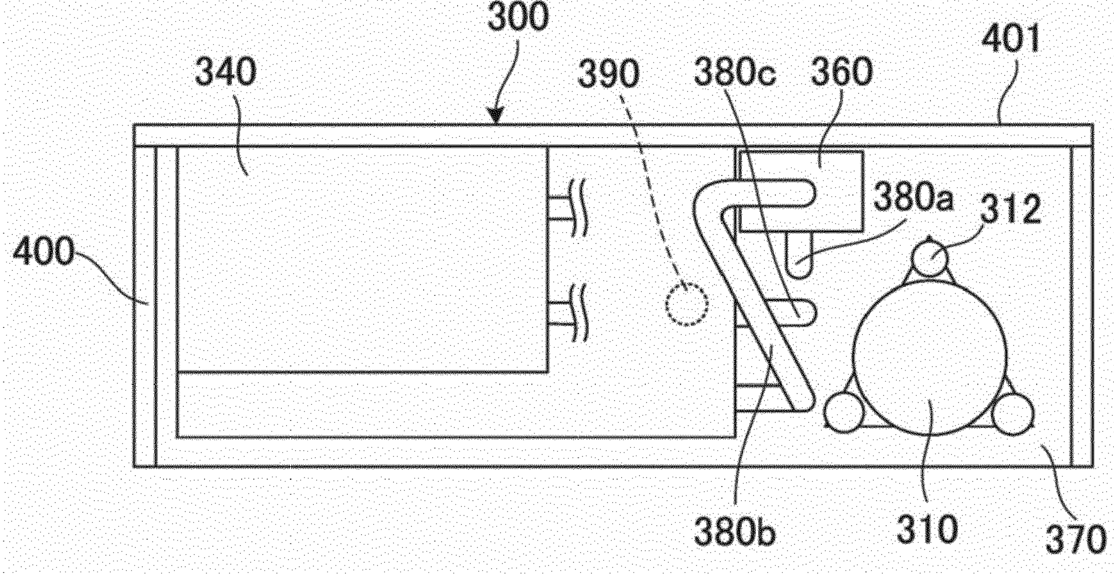


FIG.3

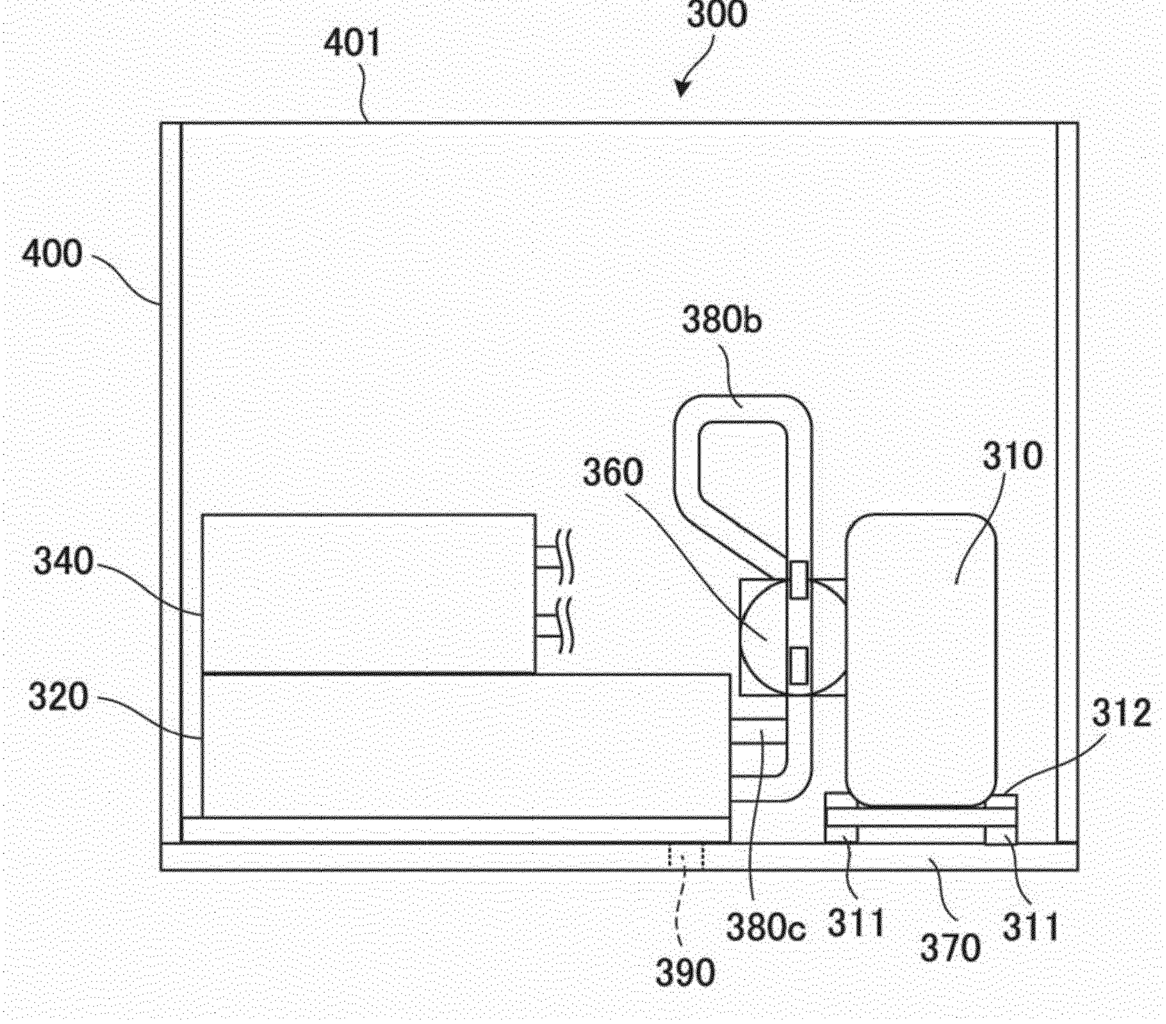


FIG.4

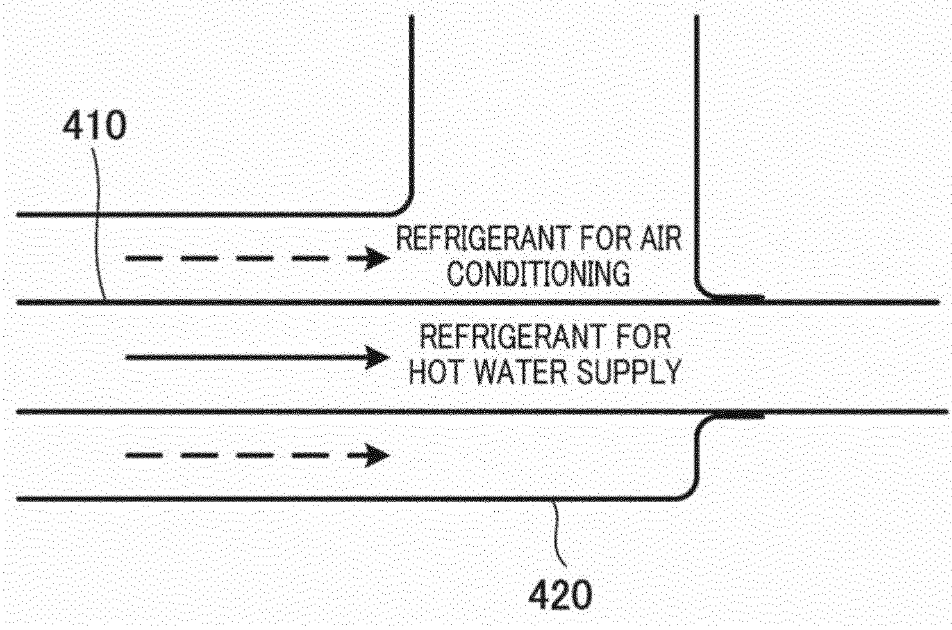

410
REFRIGERANT FOR AIR CONDITIONING
REFRIGERANT FOR HOT WATER SUPPLY
420

FIG.5

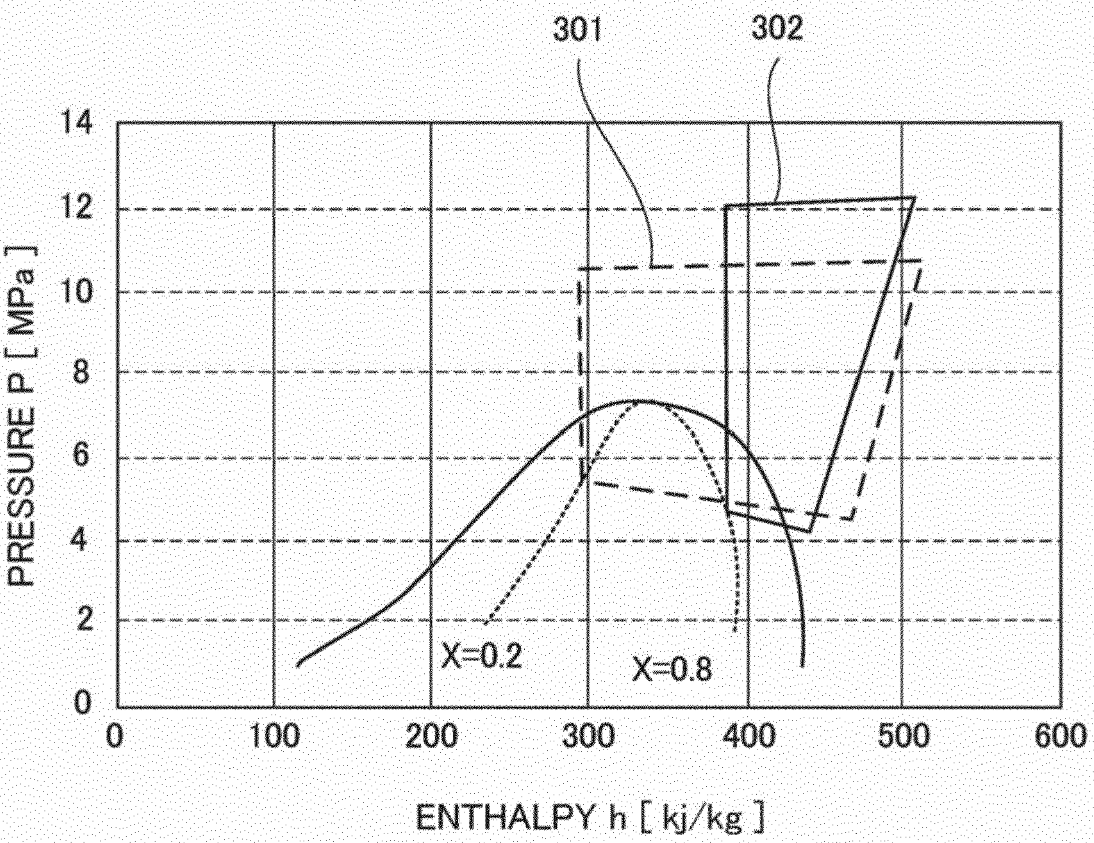

301
302
14
12
10
8
6
4
2
0
PRESSURE P [MPa]
X=0.2
X=0.8
0
100
200
300
400
500
600
ENTHALPY h [kj/kg]

FIG.6

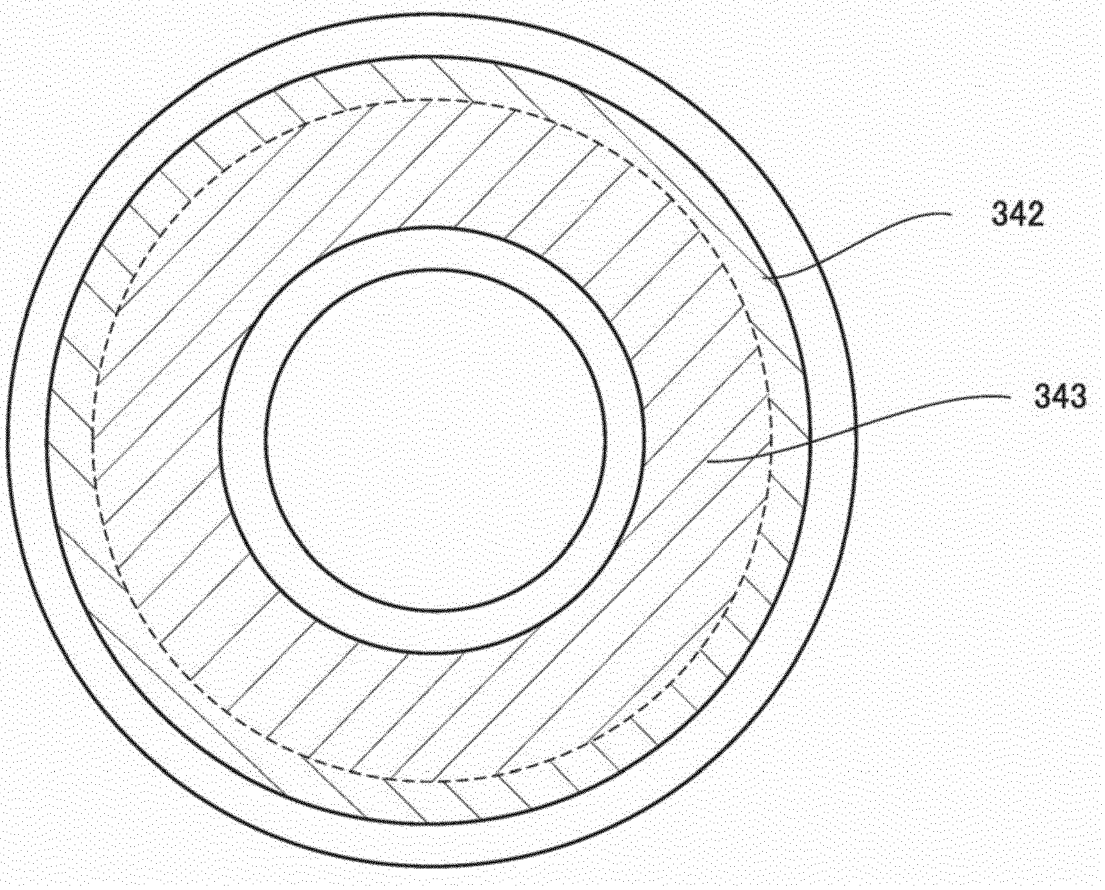


FIG.7

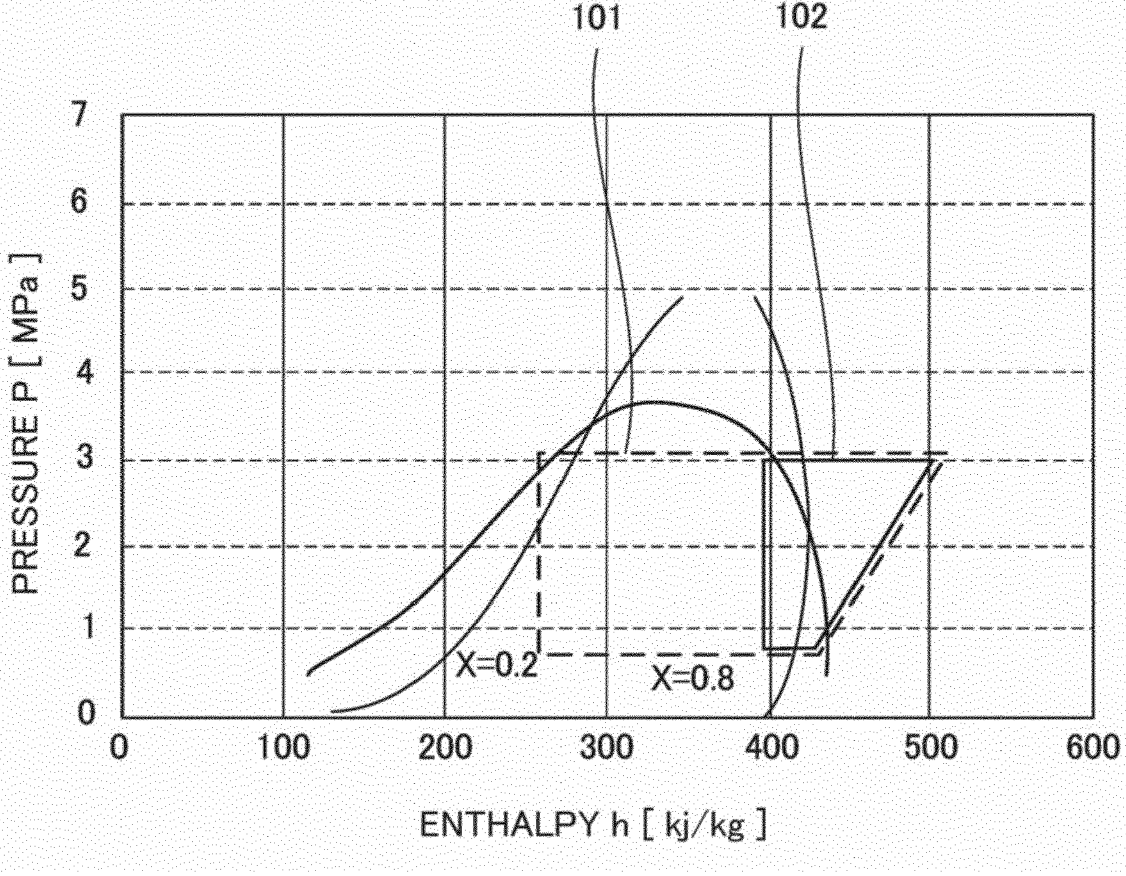

101
102
7
6
5
4
3
2
1
0
PRESSURE P [MPa]
X=0.2
X=0.8
0
100
200
300
400
500
600
ENTHALPY h [kj/kg]

FIG.8

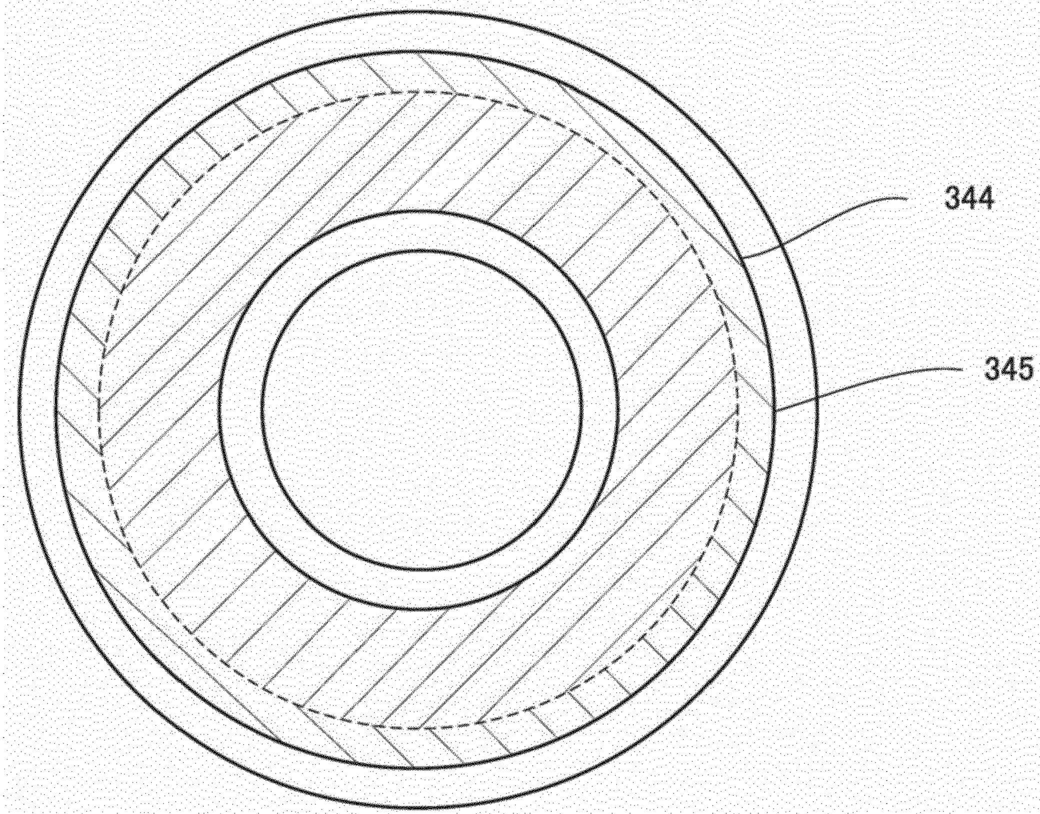


FIG.9

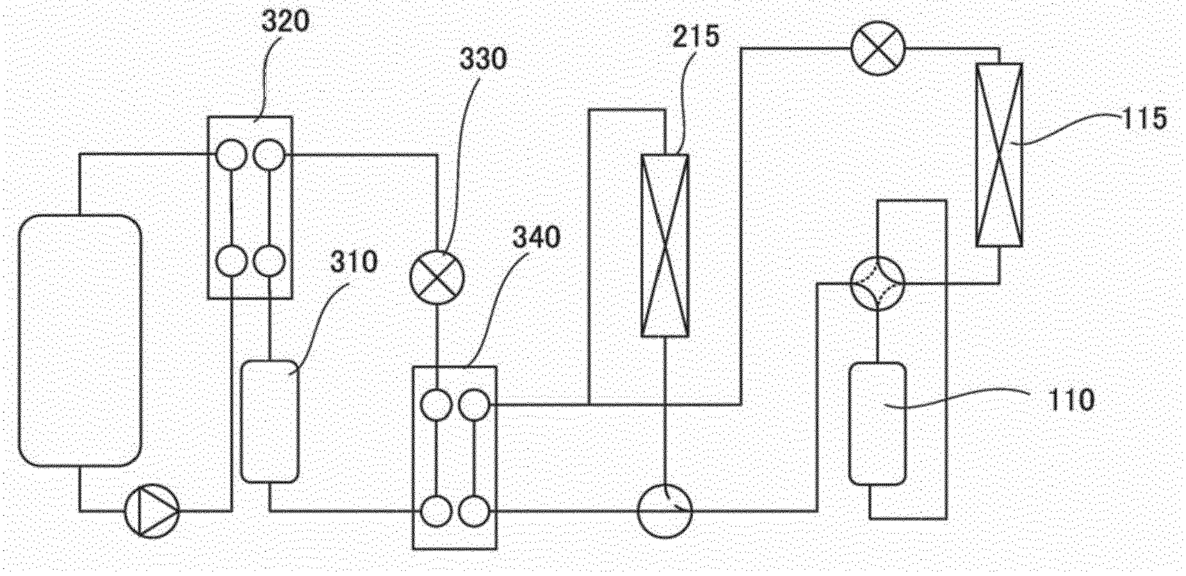
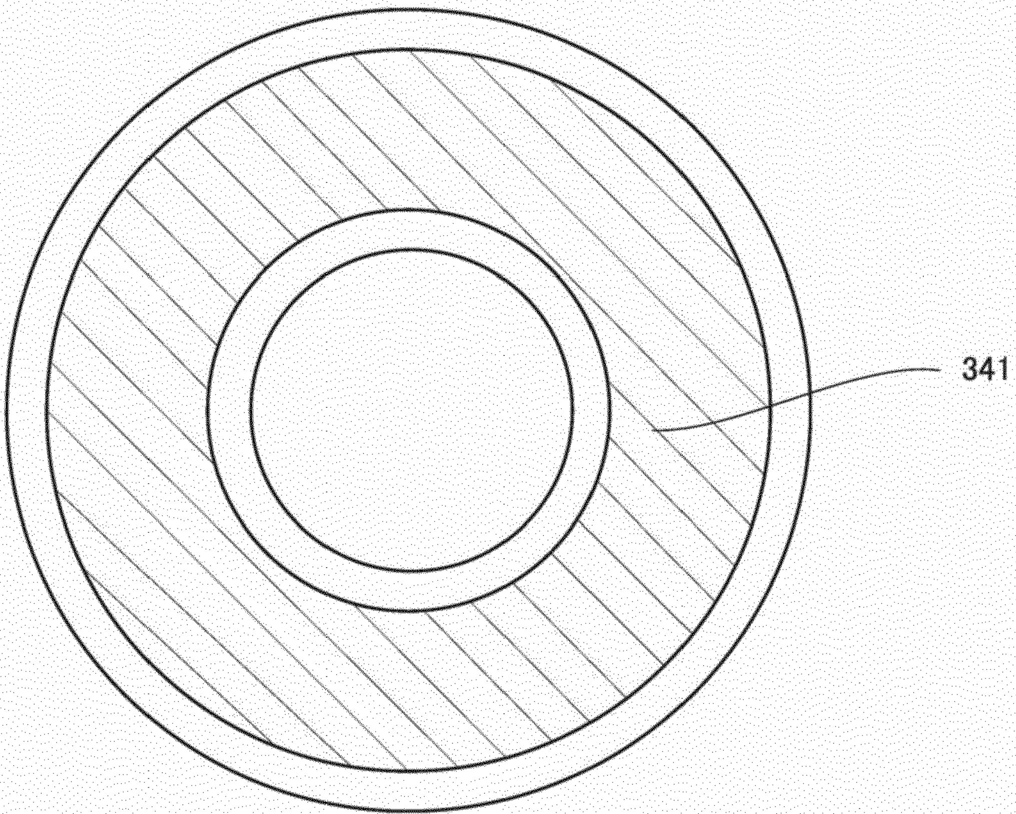


FIG.10



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 16 18 6102

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2010/109620 A1 (MITSUBISHI ELECTRIC CORP [JP]; YABUUCHI HIRONORI [JP]; KAMEYAMA JUNICH) 30 September 2010 (2010-09-30) * abstract; claim 2; figure 1 *	1 2	INV. F25B7/00 F25B30/02 ADD. F25B9/00 F25B13/00
X A	US 2013/205824 A1 (MORIMOTO HIROYUKI [JP] ET AL) 15 August 2013 (2013-08-15) * paragraph [0031] - paragraph [0193]; figures 1-9 * * paragraph [0071] *	1 2	
Y	US 4 438 633 A (HISER LELAND L [US]) 27 March 1984 (1984-03-27) * column 5, line 4 - column 9, line 12; figures 1-4 *	2	
A	US 2011/155356 A1 (WOO HYOUNG SUK [KR] ET AL) 30 June 2011 (2011-06-30) * paragraph [0068]; figures 4,5 *	2	

TECHNICAL FIELDS SEARCHED (IPC)

F25B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 July 2017	Szilagyi, Barnabas

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

1

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 18 6102

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

03-07-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010109620 A1	30-09-2010	JP 5202726 B2	05-06-2013
		JP WO2010109620 A1	20-09-2012
		WO 2010109620 A1	30-09-2010
US 2013205824 A1	15-08-2013	EP 2650620 A1	16-10-2013
		JP 5595521 B2	24-09-2014
		JP WO2012077156 A1	19-05-2014
		US 2013205824 A1	15-08-2013
		WO 2012077156 A1	14-06-2012
US 4438633 A	27-03-1984	NONE	
US 2011155356 A1	30-06-2011	CN 102135346 A	27-07-2011
		EP 2354721 A2	10-08-2011
		KR 20110079052 A	07-07-2011
		US 2011155356 A1	30-06-2011

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 2004132647 A **[0002] [0003] [0011] [0034]**
- JP 3925383 B **[0002] [0003] [0011] [0034]**
- JP 2007218459 A **[0007] [0008] [0011] [0013] [0025] [0034]**