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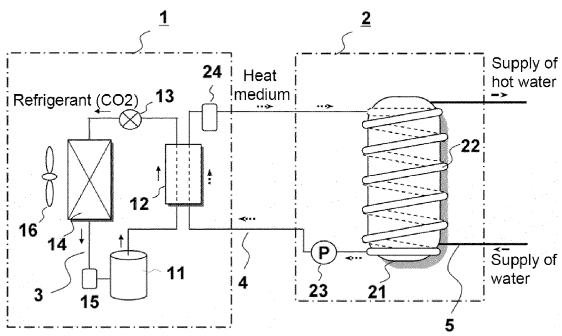
(54) Water heater

(57) A water heater including: a refrigerant circuit 3 configured by annularly connecting, to one another through refrigerant pipes, a compressor 11, a first radiator 12, an expansion device 13, and an evaporator 14; a hot water tank 21; and a heat medium circuit 4 configured by annularly connecting, to one another through heat medium pipes, the first radiator 12, a second radiator 22, and a circulation device 23, wherein the refrigerant circulating through the refrigerant circuit 3 is carbon dioxide, and in the second radiator 22, the heat medium pipe is wound around an outer surface of the hot water tank 21, and the heat medium releases heat to water in the hot water tank 21. Therefore, it is possible to efficiently produce high temperature water while suppressing precipitation of scale.

[Fig. 1]



1	Heat source unit
2	Tank unit
3	Refrigerant circuit
4	Heat medium circuit
5	Hot water supply circuit
11	Compressor
12	Refrigerant/heat medium heat exchanger (first radiator)
13	Expansion valve (expansion device
14	Refrigerant/air heat exchanger (evaporator)
21	Hot water tank
22	Hot water-storing heat exchanger (second radiator)
23	Circulation pump (circulation device)
24	Expansion tank

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Description

[TECHNICAL FIELD]

[0001] The present invention relates to a water heater for producing high temperature water by a heat pump heat source.

[BACKGROUND TECHNIQUE]

[0002] According to a conventional water heater of this kind, water is heated by a heat pump heat source which uses carbon dioxide refrigerant, and the water heater produces warm water having higher temperature than a heat pump heat source which uses CFC-based refrigerant. The produced high temperature water is stored in a hot water tank, and the high temperature water is supplied (see patent document 1 for example).

[0003] Fig. 8 shows a water heater described in patent document 1. As shown in Fig. 8, this water heater includes a heat pump unit 52 having a gas cooler (hot water-supply heat exchanger) 51, and a hot water storing unit 54 having a hot water tank 53. Hot water boiled by the gas cooler 51 is stored in the hot water tank 53.

[0004] The heat pump unit 52 includes a refrigerant circuit formed by annularly connecting a compressor 55, the gas cooler 51, an expansion valve (decompressor) 56 and an evaporator 57 to one another through a refrigerant pipes. Carbon dioxide (CO2) refrigerant circulates through the refrigerant circuit as refrigerant. The hot water storing unit 54 includes a circulation pump 58 through which hot water circulates, the hot water tank 53, a water supply pipe 60 through which water is supplied from a water pipe to the hot water tank 53, and a hot water supply pipe 59 through which high temperature water stored in the hot water tank 53 is supplied. The circulation pump 58, the hot water tank 53 and the gas cooler 51 are annularly connected to one another through a water supply pipe, thereby configuring a water circuit.

[0005] Water stored in a lower portion of the hot water tank 53 is conveyed to the gas cooler 51 by the circulation pump 58, the conveyed water and high temperature and high pressure gas refrigerant compressed by the compressor 55 exchange heat in the gas cooler 51, and high temperature water (e.g., 85°C) is produced. The produced high temperature water is conveyed to the hot water tank 53 through the water circuit and is stored therein, the high temperature water is made to flow out from the hot water supply pipe 59 as need arises and the high temperature water is supplied. If carbon dioxide is used as refrigerant, it is possible to produce higher temperature water as compared with CFC-based refrigerant.

[0006] According to another conventional water heater, a heat-transfer pipe is wound around an outer wall surface of a hot water tank, and a vapor compression type refrigeration cycle is used as a heat source. High temperature and high pressure refrigerant discharged from a compressor is made to flow into a heat-transfer pipe which is wound around a hot water tank, and water in the hot water tank is heated (see patent document 2 for example).

[0007] Fig. 9 shows a water heater described in patent document 2. As shown in Fig. 9, the water heater 100 includes a refrigerant circuit 90 through which refrigerant circulates, and a hot water tank 110 in which warm water is stored.

[0008] The refrigerant circuit 90 is configured by annularly connecting a compressor 101, a hot water storing-side heat exchanger 116, an expansion device 104 and an air-side heat exchanger 106 to one another through refrigerant pipes.

[0009] A heat-transfer pipe is disposed in a hot water tank 110 as a hot water storing-side heat exchanger 116 such that the heat-transfer pipe is in contact with an outer wall surface of the hot water tank 110. Water is supplied to the hot water tank 110 through a water supply pipe 119.

[0010] At the time of a hot water storing operation for producing high temperature water, refrigerant flows through the refrigerant circuit 90 in directions of solid arrows in Fig. 9. Gas phase high temperature and high pressure refrigerant discharged from the compressor 101 flows into the hot water storing-side heat exchanger 116, releases heat to water in the hot water tank 110 through a partition thereof, and condenses. As a result, the refrigerant phase-changes from a gas/liquid two phase state to a supercooled liquid state. That is, the hot water storing-side heat exchanger 116 functions as a condenser of refrigerant, and high temperature water is produced in the hot water tank 110.

[0011] The refrigerant in the supercooled liquid state which is liquefied and condensed in the hot water storing-side heat exchanger 116 is decompressed by the expansion device 104, and is brought into a low pressure gas/liquid two phase state, and the refrigerant flows into the air-side heat exchanger 106 (evaporator). The refrigerant absorbs heat from outside air sucked by an outdoor fan 105 in the air-side heat exchanger 106 (evaporator) and evaporates, and the refrigerant phase-changes from the gas/liquid two phase state to a superheated state. Then, the refrigerant flows into the compressor 101 and is again compressed, and is brought into a high temperature and high pressure gas phase state.

[0012] If such refrigerant circulates, hot water in the hot water tank 110 is heated, and high temperature water can be stored.

[PRIOR ART DOCUMENT]

[PATENT DOCUMENTS]

[0013]

[Patent Document 1] Japanese Patent Application Laid-open No.2011-69572
[Patent Document 2] Japanese Patent Application Laid-open No.S62-59337

[SUMMARY OF THE INVENTION]

[PROBLEM TO BE SOLVED BY THE INVENTION]

[0014] In the configuration of patent document 1, water supplied to the hot water tank 53 through the water supply pipe 60 exchanges heat with carbon dioxide refrigerant in the gas cooler 51 and the water is heated. Therefore, when water containing much hardness component is heated, there is a problem that hardness component is precipitated as scale in the gas cooler 51 or water supply pipe through which high temperature water flows, and this scale component is deposited, and the water supply pipe is clogged.

[0015] To suppress the deposition of the scale component, it is considered that high temperature water is produced using carbon dioxide refrigerant in the configuration of patent document 2. However, when carbon dioxide refrigerant is used, it is necessary to increase a diameter of a pipe to enhance pressure resistance so that it is possible to withstand about two to three times pressure of CFC-based refrigerant. Therefore, there is a problem that machining man-hour and machining costs for bringing the pipe into intimate contact with an outer periphery of the hot water tank 110 are increased.

[0016] The present invention has been accomplished to solve the conventional problems, and it is an object of the invention to provide a water heater capable of efficiently producing high temperature water while suppressing precipitation of scale.

[MEANS FOR SOLVING THE PROBLEM]

[0017] To solve the above problems, the present invention provides a water heater including: a refrigerant circuit configured by annularly connecting, to one another through refrigerant pipes, a compressor for compressing refrigerant, a first radiator for exchanging heat between the refrigerant and heat medium, an expansion device for expanding the refrigerant, and an evaporator for evaporating the refrigerant, and the refrigerant circulating through the refrigerant circuit; a hot water tank in which water is stored; and a heat medium circuit configured by annularly connecting, to one another through heat medium pipes, the first radiator, a second radiator for exchanging heat between the heat medium and the water, and a circulation device, and the heat medium circulating through the heat medium circuit, wherein the refrigerant circulating through the refrigerant circuit is carbon dioxide, and in the second radiator, the heat medium pipe is wound around an outer surface of the hot water tank, and the heat medium releases heat to water in the hot water tank.

[0018] The precipitation of scale is prone to be generated especially when water having much hardness component is heated to high temperature and this high temperature water flows through a pipe having a small diameter like an outlet of a heat medium of a gas cooler. Hence, according to the configuration of the invention, since the heat medium circuit and a hot water supply circuit are separated from each other, it is possible to effectively suppress the precipitate of scale.

[0019] Further, since carbon dioxide refrigerant is used, high pressure-side pressure in the refrigerant circuit is brought into a supercritical region. Hence, heat medium on an inlet side of the second radiator disposed in the hot water tank can be brought into high temperature, and a temperature difference between the heat medium flowing through the heat medium pipe of the second radiator and water in the hot water tank is increased. Therefore, it is possible to secure a heating amount while reducing a circulation amount of heat medium when water in the hot water tank is heated.

[EFFECT OF THE INVENTION]

[0020] According to the present invention, it is possible to provide a water heater capable of efficiently producing high temperature water while suppressing precipitation of scale.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0021]

Fig. 1 is a schematic block diagram of a water heater in a first embodiment of the present invention;
Fig. 2 is a block diagram of a hot water tank of the water heater;
Fig. 3 is a Mollier diagram for explaining variation in a refrigeration cycle of a refrigerant circuit of the water heater;
Fig. 4 is a conceptual diagram showing water temperature variation in the hot water tank of the water heater;
Fig. 5 is a diagram showing a relation between an operation efficiency ratio and a pipe length L/in-pipe cross-sectional area S at the time of hot water storing operation of the water heater;
Fig. 6 is a diagram showing a relation between a pressure loss dP and the pipe length L/in-pipe cross-sectional area S at the time of hot water storing operation of the water heater;
Fig. 7 is a schematic diagram showing a configuration for explaining a relation of a contact length W between a pipe diameter d of the heat medium pipe and the hot water tank in a hot water-storing heat exchanger of the water heater;
Fig. 8 is a schematic block diagram of a conventional water heater; and
Fig. 9 is a schematic block diagram of another conventional water heater.

[MODE FOR CARRYING OUT THE INVENTION]

[0022] A first aspect of the present invention provides a water heater including: a refrigerant circuit configured by annularly connecting, to one another through refrigerant pipes, a compressor for compressing refrigerant, a first radiator for exchanging heat between the refrigerant and heat medium, an expansion device for expanding the refrigerant, and an evaporator for evaporating the refrigerant, and the refrigerant circulating through the refrigerant circuit; a hot water tank in which water is stored; and a heat medium circuit configured by annularly connecting, to one another through heat medium pipes, the first radiator, a second radiator for exchanging heat between the heat medium and the water, and a circulation device, and the heat medium circulating through the heat medium circuit, wherein the refrigerant circulating through the refrigerant circuit is carbon dioxide, and in the second radiator, the heat medium pipe is wound around an outer surface of the hot water tank, and the heat medium releases heat to water in the hot water tank.

[0023] The precipitation of scale is prone to be generated especially when water having much hardness component is heated to high temperature and this high temperature water flows through a pipe having a small diameter like an outlet of a heat medium of a gas cooler. Hence, according to the configuration of the invention, since the heat medium circuit and a hot water supply circuit are separated from each other, it is possible to effectively suppress the precipitate of scale. That is, the heat medium circuit which is under such a temperature condition that high temperature fluid circulates and scale is prone to be precipitated is closed. Hence, fluid having much hardness component does not flow any time, and it is possible to effectively suppress the precipitate of scale.

[0024] Further, since carbon dioxide refrigerant is used, high pressure-side pressure in the refrigerant circuit is brought into a supercritical region. Hence, heat medium is heated to high temperature by the first radiator and the heat medium on the inlet side of the second radiator which is wound around the outer periphery of the hot water tank such that the second radiator is in contact with the outer periphery can be brought into high temperature, and a temperature difference between the heat medium flowing through the heat medium pipe of the second radiator and water in the hot water tank is increased. Therefore, it is possible to secure a heating amount while reducing a circulation amount of heat medium when water in the hot water tank is heated.

[0025] By reducing the circulation amount of the heat medium, the heat medium releases heat to water in the hot water tank in the second radiator, and temperature of the heat medium is sufficiently lowered. Thereafter, the heat medium flows out from the second radiator and flows into the first radiator. That is, since the temperature of the heat medium flowing into the first radiator is lowered, excessive pressure rise on the high pressure side in the refrigerant circuit is suppressed. Since a circulation water amount of heat medium which flows through the heat medium pipe is reduced, it is possible to increase the length of the heat medium pipe of the second radiator, and to reduce a diameter of the heat medium pipe while suppressing the increase in the pressure loss in the heat medium pipe.

[0026] Therefore, deterioration in the operation efficiency of the compressor is suppressed. If the pipe length of the heat medium pipe is increased, a heat transfer area is increased. If turbulent flow generated by reducing a diameter of the heat medium pipe is facilitated, a heat passage rate is increased. As a result, by this synergetic effect, it is possible to enhance the efficiency at the time of the hot water storing operation of the water heater.

[0027] According to a second aspect of the invention, in the water heater of the first aspect, when an entire length of the heat medium pipe configuring the second radiator is defined as L (m) and an in-pipe cross-sectional area of the heat medium pipe is defined as S (mm^2), L/S (m/mm^2) is 2.8 or more and 5.3 or less.

[0028] According to this, in the water heater which uses carbon dioxide refrigerant, which heats water in the hot water tank through the heat medium, and which produces high temperature water, it is possible to produce high temperature water while maximizing the operation efficiency.

[0029] According to a third aspect of the invention, in the water heater of the first or second aspect, the heat medium flows from an upper portion to a lower portion of the second radiator.

[0030] According to this, water in the hot water tank is heated in order from above at the time of hot water storing operation, temperature of upper side water in the hot water tank is maintained high, and temperature of lower side water is maintained low. That is, temperature stratification is formed in the hot water tank while suppressing natural convection of hot water in the hot water tank.

[0031] Hence, a temperature difference between the heat medium and water in the hot water tank can appropriately be maintained. It is possible to efficiently heat water while suppressing temperature rise of heat medium which flows into the first radiator. Therefore, it is possible to enhance energy saving as a water heater.

[0032] An embodiment of the present invention will be described below with reference to the drawings. The invention is not limited to the embodiment.

[0033] Fig. 1 is a schematic diagram of a water heater in an embodiment of the present invention. The water heater of the embodiment includes a heat source unit 1 for heating heat medium, and a tank unit 2 having a hot water tank 21 in which warm water produced by the heated heat medium is stored.

[0034] The water heater of the embodiment includes a refrigerant circuit 3 as a heat pump unit, i.e., a heat source, through which refrigerant circulates, a heat medium circuit 4 through which heat medium circulates, and a hot water supply circuit 5 which supplies water into the hot water tank and supplies heated warm water. In this embodiment, carbon dioxide (CO2) is used as refrigerant which circulates through the refrigerant circuit 3, and water is used as heat medium which circulates through the heat medium circuit 4.

[0035] The refrigerant circuit 3 is configured by annularly connecting a compressor 11, a refrigerant/heat medium heat exchanger 12, an expansion valve (expansion device) 13 which expands refrigerant, and a refrigerant/air heat exchanger 14 to one another through refrigerant pipes. The refrigerant/heat medium heat exchanger 12 functions as a first radiator, and exchanges heat between refrigerant and heat medium. The refrigerant/heat medium heat exchanger 12 includes a refrigerant flow path through which refrigerant flows, and a heat medium flow path through which heat medium flows. Refrigerant and heat medium exchange heat through partitions forming the respective flow paths, thereby producing high temperature heat medium. The refrigerant/air heat exchanger 14 is a fin tube heat exchanger, functions as an evaporator, and exchanges heat between refrigerant and air. A blower 16 disposed adjacent to the refrigerant/air heat exchanger 14 sends air to the heat exchanger 14, and the sent air and refrigerant exchange heat.

[0036] The heat medium circuit 4 is configured by annularly connecting, to one another through heat medium pipes, the refrigerant/heat medium heat exchanger 12, an expansion tank 24 corresponding to expansion of warm water, a hot water-storing heat exchanger 22 which functions as a second radiator, and a circulation pump (circulation device) 23.

[0037] The hot water-storing heat exchanger 22 is spirally wound around an outer periphery of the hot water tank 21 such that the heat medium pipe comes into contact with an outer surface of the hot water tank 21. That is, high temperature heat medium produced in the refrigerant/heat medium heat exchanger 12 flows into the hot water-storing heat exchanger 22, exchanges heat with water in the hot water tank 21, and heats water in the hot water tank 21. After the heat medium exchanges heat with water in the hot water tank 21, the heat medium flows out from the hot water-storing heat exchanger 22. At this time, to reduce thermal resistance between the heat medium pipe configuring the hot water-storing heat exchanger 22 and the outer surface of the hot water tank 21, adhesive 25 for facilitating adhesion and thermal conductivity is applied to the outer surface of the hot water tank 21. In this embodiment, when a length of the heat medium pipe configuring the hot water-storing heat exchanger 22 is defined as L (m) and an in-pipe cross-sectional area of the heat medium pipe is defined as S (mm^2), L/S (m/mm^2) is 2.8 or more and 5.3 or less.

[0038] The hot water supply circuit 5 includes the hot water tank 21, a water supply pipe 5b connected to a lower portion of the hot water tank 21 and supplies water to the hot water tank 21, and a hot water supply pipe 5a connected to an upper portion of the hot water tank 21 and supplies warm water to a user. At the time of a hot water storing operation for heating water in the hot water tank 21 to produce high temperature water, high temperature heat medium heated in the refrigerant/heat medium heat exchanger 12 flows into the hot water-storing heat exchanger 22, this high temperature heat medium and water stored in the hot water tank 21 exchange heat through the heat medium pipe of the hot water-storing heat exchanger 22 and the hot water tank 21. High temperature water stored in the hot water tank 21 is supplied to a user through the hot water supply pipe 5a. According to this, if an amount of hot water in the hot water tank 21 is reduced, water is supplied from the water supply pipe 5b to the hot water tank 21

[0039] As shown in Fig. 2, the hot water tank 21 is composed of a cylindrical central portion 21a, an upper member 21b and a lower member 21c. One end of each of the upper member 21b and the lower member 21c opens and the other end is formed into a dome shape. The central portion 21a, the upper member 21b and the lower member 21c are welded and bonded to one another through bonded portions 21d.

[0040] The heat medium pipe forming the hot water-storing heat exchanger 22 is disposed around the outer periphery of the hot water tank 21. This heat medium pipe comes into contact with the outer surface of the hot water tank 21 at an inlet portion 4a, the heat medium pipe is spirally wound up to a lower portion of the hot water tank 21, and separates from the outer periphery of the hot water tank 21 at an outlet portion 4b of the lower member 21c. As shown in Fig. 2, the upper member 21b is provided with the inlet portion 4a, and the lower member 21c is provided with the outlet portion 4b.

[0041] That is, as shown in Fig. 2, a portion of the heat medium pipe from the inlet portion 4a to the outlet portion 4b is in contact with the outer surface of the hot water tank 21, and the hot water-storing heat exchanger 22 is formed. Since the heat medium pipe is spirally wound from the upper member 21b to the lower member 21c, it is possible to form the hot water-storing heat exchanger 22 over the entire hot water tank 21. Therefore, it is possible to heat entire water in the hot water tank 21 to high temperature.

[0042] Water is supplied from the water supply pipe 5b connected to a lower connected portion 5d of the lower member 21c to the hot water tank 21, high temperature water heated in the hot water-storing heat exchanger 22 flows out from the hot water supply pipe 5a connected to an upper connected portion 5c of the upper member 21b, and the high temperature water is supplied to a user.

[0043] By connecting the hot water supply pipe or the water supply pipe to the upper member 21b and the lower member 21c in this manner, mounted portions of the pipes are gathered, and it is possible to enhance machining properties and pressure resistance of the hot water tank 21.

[0044] As shown in Fig. 2, water is supplied from the water supply pipe 5b to the hot water tank 21 at a location higher than the outlet portion 4b. That is, the lower connected portion 5d is disposed at a location higher than the outlet portion 4b in the vertical direction of the hot water tank 21. According to this, at least a portion of the heat medium pipe which forms the hot water-storing heat exchanger 22 is disposed at a location lower than the lower connected portion 5d. Therefore, it is possible to efficiently heat low temperature water which is prone to stay in the lower portion of the hot water tank 21 by natural convection, and to produce high temperature water in the entire interior of the hot water tank 21.

[0045] As shown in Fig. 2, hot water is supplied from the hot water supply pipe 5a to a user at a location higher than the inlet portion 4a. That is, the upper connected portion 5c is disposed at a location higher than the inlet portion 4a in the vertical direction of the hot water tank 21. According to this, high temperature water which is heated by the hot water-storing heat exchanger 22 and which is stored in the upper portion in the hot water tank 21 by the natural convection can efficiently be used for hot water supply.

[0046] A connection relation between the hot water supply pipe 5a and the hot water tank 21, a connection relation between the water supply pipe 5b and the hot water tank 21, a positional relation between the inlet portion 4a and the upper connected portion 5c, and a positional relation between the outlet portion 4b and the lower connected portion 5d can selectively be applied.

[0047] Action of the water heater having the above-described configuration will be described below using Figs. 1, 3 and 4. Fig. 3 is a P-h diagram (Mollier diagram) showing a relation between refrigerant pressure P of the refrigerant circuit and refrigerant enthalpy h, and Fig. 4 is a schematic diagram showing water temperature variation in the hot water tank 21.

[0048] If the hot water storing operation for heating water in the hot water tank 21 and storing the warm water is started, CO2 refrigerant circulates through the refrigerant circuit 3 in directions of solid arrows in Fig. 1. Then, CO2 refrigerant in a saturated or superheated state is sucked by the compressor 11 (point a in Fig. 3), the CO2 refrigerant is compressed up to supercritical pressure by the compressor 11, and the CO2 refrigerant is brought into a high temperature and high pressure gas state (point b in Fig. 3). The CO2 refrigerant in the high temperature and high pressure gas state is sent to the refrigerant/heat medium heat exchanger 12, the CO2 refrigerant exchanges heat with heat medium, and high temperature heat medium is produced.

[0049] The CO2 refrigerant is cooled in the refrigerant/heat medium heat exchanger 12, the CO2 refrigerant flows out from the refrigerant/heat medium heat exchanger 12 and then flows into the expansion valve 13 (point c in Fig. 3). Thereafter, the CO2 refrigerant is decompressed and expanded by the expansion valve 13, and is brought into a liquid state (points c to d in Fig. 3), and the CO2 refrigerant flows into the refrigerant/air heat exchanger 14. Thereafter, the CO2 refrigerant absorbs heat from air which is sent by the blower 16 in the refrigerant/air heat exchanger 14 and evaporates and is brought into a saturated gas state or superheated gas state and again flows into the compressor 11 (point a in Fig. 3).

[0050] In the heat medium circuit 4, high temperature heat medium produced in the refrigerant/heat medium heat exchanger 12 flows in directions of dotted line arrows in Fig. 1. The heat medium flows from an upper portion of the hot water tank 21 into the hot water-storing heat exchanger 22 through the expansion tank 24 existing on the inlet side of the hot water tank 21. Heat energy possessed by the high temperature heat medium is transmitted to water in the hot water tank 21 through the heat medium pipe of the hot water-storing heat exchanger 22 and the hot water tank 21, and high temperature water is produced.

[0051] According to this configuration, fluid flowing through the heat medium circuit 4 and fluid flowing through the hot water supply circuit 5 are completely separated from each other. Precipitation of scale is prone to be generated especially when water having much hardness component is heated to high temperature and this high temperature water flows through a pipe having a small diameter. Hence, according to this configuration, it is possible to effectively suppress the precipitation of scale.

[0052] Since CO2 refrigerant is used, high pressure-side pressure in the refrigerant circuit 3 can be increased to a supercritical region. Hence, it is possible to produce high temperature heat medium in the refrigerant/heat medium heat exchanger 12, and the high temperature heat medium can be made to flow into the hot water-storing heat exchanger 22. Therefore, it is possible to increase a temperature difference between water and heat medium in the hot water-storing heat exchanger 22.

[0053] According to this, even if a circulation amount of heat medium is small, it is possible to secure a predetermined heating amount. After heat medium releases heat to water in the hot water tank 21 and temperature of the heat medium is sufficiently lowered, the heat medium flows out from the hot water-storing heat exchanger 22, and it is possible to maintain, at low temperature, heat medium which flows into the refrigerant/heat medium heat exchanger 12. Therefore, it is possible to suppress excessive rise of high pressure-side pressure in the refrigerant circuit 3.

[0054] Especially if high temperature heat medium is made to flow from the upper portion of the hot water-storing heat exchanger 22 and is made to flow out from the lower portion of the hot water-storing heat exchanger 22, water in the hot water tank 21 is heated in order from above, and warm water distribution in the hot water tank 21 moves from the upper portion to the lower portion with progression of the hot water storing operation as shown in Fig. 4. Therefore, until temperature of water stored in the bottom of the hot water tank 21 rises, temperature of heat medium flowing out from the hot water-storing heat exchanger 22 does not rise. Hence, it is possible to heat the heat medium in the refrigerant/heat medium heat exchanger 12 to high temperature while maintaining, at lower temperature, the heat medium flowing into the refrigerant/heat medium heat exchanger 12. Therefore, it is possible to efficiently operate the heat pump while suppressing rise of high pressure-side pressure of the refrigerant circuit 3.

[0055] Further, since a circulation amount of heat medium which flows through the hot water-storing heat exchanger 22 is reduced, it is possible to increase the pipe length of the heat medium pipe which restraining a pressure loss from increasing, and a diameter of the heat medium pipe can be reduced.

[0056] As described above, the operation efficiency of the heat pump is enhanced. By increasing the pipe length of the heat medium pipe, a contact area is increased. By facilitating turbulent flow generated by reducing the diameter of the heat medium pipe, a heat passage rate is increased. As a result, it is possible to enhance the efficiency at the time of the hot water storing operation of the water heater by the synergetic effect.

[0057] Next, a configuration of the hot water-storing heat exchanger 22 will be described using Figs. 5 to 7.

[0058] Here, heat medium is made to flow into the hot water-storing heat exchanger 22 from an upper portion thereof and flow out from a lower portion thereof. An average heating ability Q = 2.0 to 2.5 kW is secured and the water heater is operated under such conditions that a length L of the heat medium pipe of the hot water-storing heat exchanger 22 is 25 to 45 (m), an inner diameter di of the heat-transfer pipe is 3 to 28 (mm) and an internal volume Vt of the hot water tank is 150 to 300 (liters). Fig. 5 shows a relation between L/S and a ratio (called "operation efficiency ratio", hereinafter) of average operation efficiency when the conditions are changed. That is, Fig. 5 shows a case where heating temperature of water in the hot water tank 21 is 55°C using the conventional CFC-based refrigerant and a case where the heating temperature of water in the hot water tank 21 is 85°C using carbon dioxide refrigerant.

[0059] Fig. 6 shows a relation between L/S and a pressure loss dP in the heat medium pipe of the hot water-storing heat exchanger 22 under the same conditions as those shown in Fig. 5.

[0060] Fig. 7 is a schematic diagram for determining a contact length between the hot water tank 21 and the heat medium pipe forming the hot water-storing heat exchanger 22.

[0061] A vertical axis in Fig. 5 shows an operation efficiency ratio. The operation efficiency ratio shows a relative ratio in which a peak value ηo of operation efficiency η when heating temperature of water in the hot water tank 21 is set to 55°C is defined as 100%. A horizontal axis in Fig. 5 shows L/S. If a length L of one heat medium pipe configuring the hot water-storing heat exchanger 22 is increased or the inner diameter di of the heat medium pipe is reduced, L/S is increased, and if the length L is reduced or the inner diameter di is increased, L/S is reduced.

[0062] In this embodiment, when the length of one heat medium pipe configuring the hot water-storing heat exchanger 22 is defined as L (m) and an in-pipe cross-sectional area of the heat medium pipe is defined as S (mm^2), the hot water-storing heat exchanger 22 is configured such that L/S (m/mm^2) becomes 2.8 or more and 5.3 or less. According to this configuration, it is possible to maximize the operation efficiency η while taking a performance error of constituent parts of the compressor and other refrigerant circuit into consideration.

[0063] This is based on such a tendency that when the heat medium pipe is disposed in the hot water tank 21 and water in the hot water tank 21 is heated, a peak value ηo of the operation efficiency (COP) is varied depending upon a ratio between the length L of the heat medium pipe and the in-pipe cross-sectional area S of the heat medium pipe, and the variation in the peak value ηo is largely varied depending upon temperature of produced warm water.

[0064] The peak value ηo of the operation efficiency η is varied depending upon L/S due to the following phenomenon:

[0065] That is, as L/S is gradually increased from zero, i.e., as the length L of the heat medium pipe of the hot water-storing heat exchanger 22 is increased, a surface area of the hot water-storing heat exchanger 22 is increased. Therefore, there is a tendency that the operation efficiency η is gradually increased. If the L/S is increased, this means that the length L of the heat medium pipe is increased or the in-pipe pipe di of the heat medium pipe is reduced.

[0066] Hence, as shown in Fig. 6, if L/S is increased, the pressure loss dP in the heat medium pipe is increased by more than square of L/S, consumed power of the circulation pump 23 is also increased by the increase of the pressure loss dP, and the operation efficiency η is gradually deteriorated. If the in-pipe pipe di of the heat medium pipe is reduced, thermal conductivity in the inner surface of the heat medium pipe is increased, but the heat transfer area of the heat medium pipe is reduced on the other hand.

[0067] As shown in Fig. 7, when thicknesses tf of adhesion/thermal conductivity accelerating agents applied to the outer surfaces of the hot water tanks 21 are the same, as the pipe diameter of the heat-transfer pipe is reduced (d1>d2), there is a tendency that a contact length (heat transfer area) of the outer surface of the heat-transfer pipe which is in contact with the adhesion/thermal conductivity accelerating agent is reduced (W1>W2) and thus, L/S is increased, i.e., as the in-pipe pipe di of the heat medium pipe of the hot water-storing heat exchanger 22 is reduced, the operation efficiency η is deteriorated.

[0068] Therefore, as shown in Fig. 5, the operation efficiency η has such characteristics that the operation efficiency η is increased together with increase of L/S, and after the operation efficiency η reaches the peak value ηo, the operation efficiency is gradually deteriorated. If heating temperature of water in the hot water tank 21 is set to 85°C, it is necessary to further increase a compression ratio in the compressor 11 as compared with a case where the heating temperature is 55°C. Therefore, if the compressor power is increased, the operation efficiency η is lowered as compared with the case where the heating temperature is 55°C.

[0069] If heat medium is produced using CO2 refrigerant and water in the hot water tank 21 is heated to high temperature, i.e., 85°C, it is possible to increase the temperature difference between the water in the hot water tank 21 and the heat medium as compared with a case where the heating temperature is 55°C. According to this, since the flow rate of circulating heat medium can be reduced under such a condition that average heating abilities are equal to each other, a pressure loss in the heat medium pipe which configures the hot water-storing heat exchanger 22 has such characteristics that the pressure loss is reduced as compared with the case where the heating temperature is 55°C as shown in Fig. 6.

[0070] Therefore, if the length L of the heat medium pipe is increased and the heat transfer area is increased, or if the in-pipe cross-sectional area S of the heat medium pipe is reduced and flowing speed of the heat medium is increased, thermal conductivity is increased. Hence, when heat medium flowing into the hot water-storing heat exchanger 22 is heated to high temperature, i.e., 85°C and warm water is produced in the hot water tank 21, the operation efficiency η can be maximized by increasing L/S as compared with the case where the heating temperature is 55°C as shown in Fig. 5.

[0071] That is, as shown in Fig. 5, when heat medium is heated using CFC-based refrigerant and warm water of 55°C is produced by heating water by the heated heat medium, the operation efficiency η reaches the peak value ηo under such a condition that L/S (m/mm^2) is between 1.2 or more and 1.8 or less.

[0072] When heat medium is heated using CO2 refrigerant and water is heated by the heated heat medium to produce high temperature water of 85°C, the heat medium pipe is configured such that the L/S(m/mm^2) falls within a range of 2.8 or more and 5.3 or less. According to this, it is possible to maximize the average operation efficiency while taking the performance error (3%) of constituent parts of the compressor and other refrigerant circuit into consideration.

[0073] Although water is used as heat medium which circulates through the heat medium circuit 4 in the embodiment, the invention is not limited to this, and antifreeze liquid may be used for example.

[0074] Although the heat medium circuit 4 is provided with the expansion tank 24 in the embodiment, if a circulation amount of heat medium is small and an expansion amount of heat medium is small, the heat medium circuit 4 may be not provided with the expansion tank 24.

[INDUSTRIAL APPLICABILITY]

[0075] Since the water heater of the present invention can efficiently produce high temperature water while suppressing precipitation of scale, the invention can be applied to domestic or professional use water heaters.

[EXPLANATION OF SYMBOLS]

[0076]

1	heat source unit
2	tank unit
3	refrigerant circuit
4	heat medium circuit
5	hot water supply circuit
11	compressor
12	refrigerant/heat medium heat exchanger (first radiator)
13	expansion valve (expansion device)
14	refrigerant/air heat exchanger (evaporator)
21	hot water tank
22	hot water-storing heat exchanger (second radiator)
23	circulation pump (circulation device)

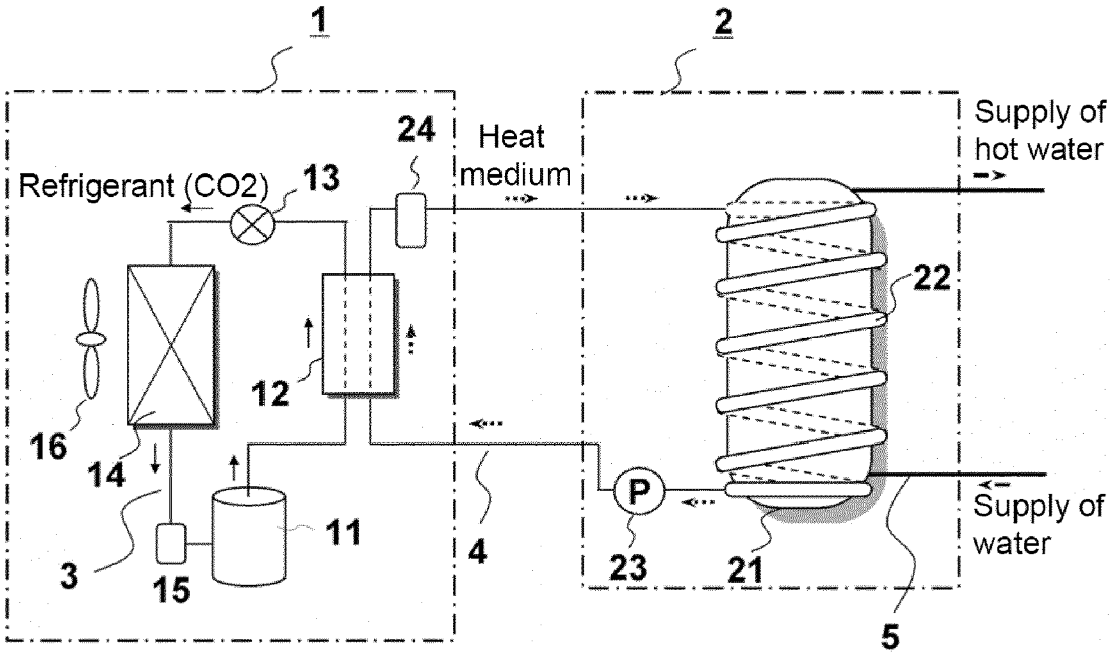
Claims

1. A water heater comprising: a refrigerant circuit configured by annularly connecting, to one another through refrigerant pipes, a compressor for compressing refrigerant, a first radiator for exchanging heat between the refrigerant and heat medium, an expansion device for expanding the refrigerant, and an evaporator for evaporating the refrigerant, and the refrigerant circulating through the refrigerant circuit;
a hot water tank in which water is stored; and
a heat medium circuit configured by annularly connecting, to one another through heat medium pipes, the first radiator, a second radiator for exchanging heat between the heat medium and the water, and a circulation device, and the heat medium circulating through the heat medium circuit, wherein
the refrigerant circulating through the refrigerant circuit is carbon dioxide, and
in the second radiator, the heat medium pipe is wound around an outer surface of the hot water tank, and the heat medium releases heat to water in the hot water tank.

2. The water heater according to claim 1, wherein when an entire length of the heat medium pipe configuring the second radiator is defined as L (m) and an in-pipe cross-sectional area of the heat medium pipe is defined as S (mm^2), L/S (m/mm^2) is 2.8 or more and 5.3 or less.

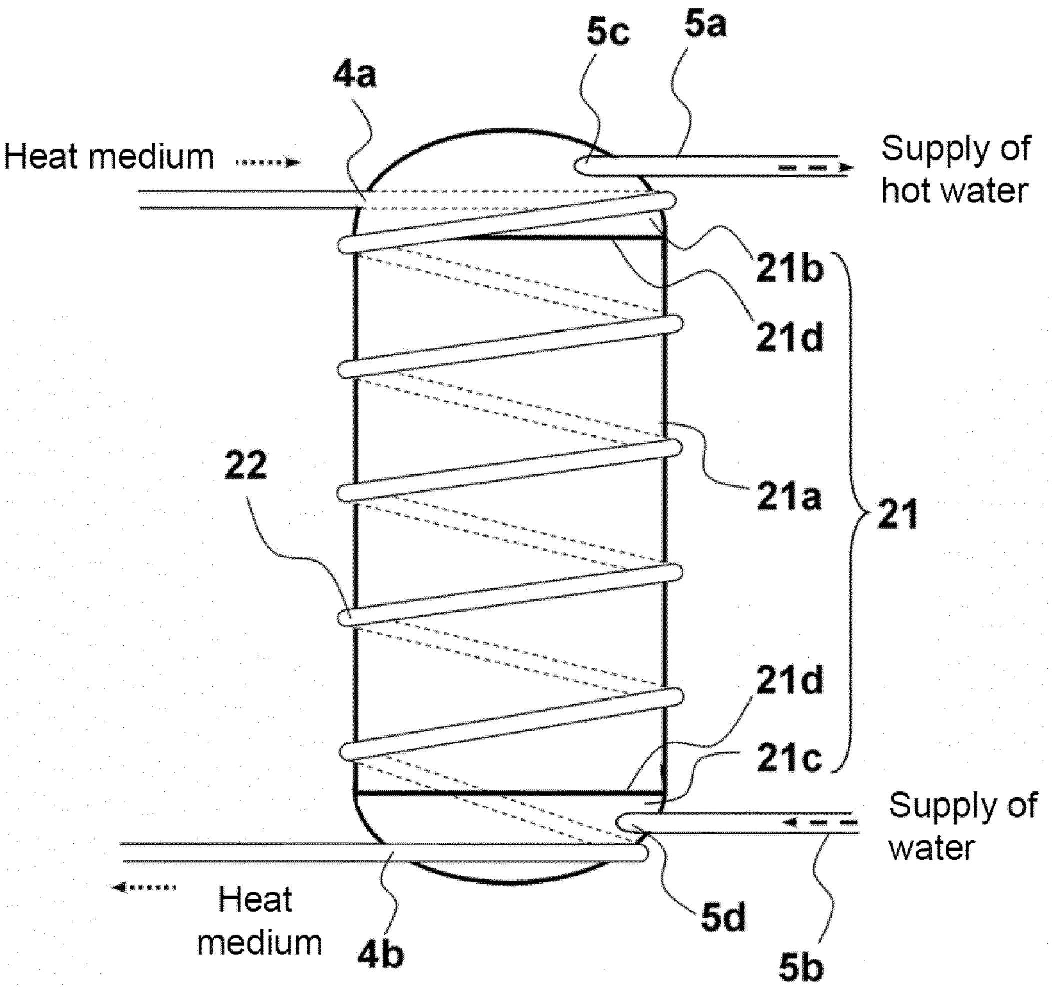
3. The water heater according to claim 1 or 2, wherein the heat medium flows from an upper portion to a lower portion of the second radiator.

[Fig. 1]

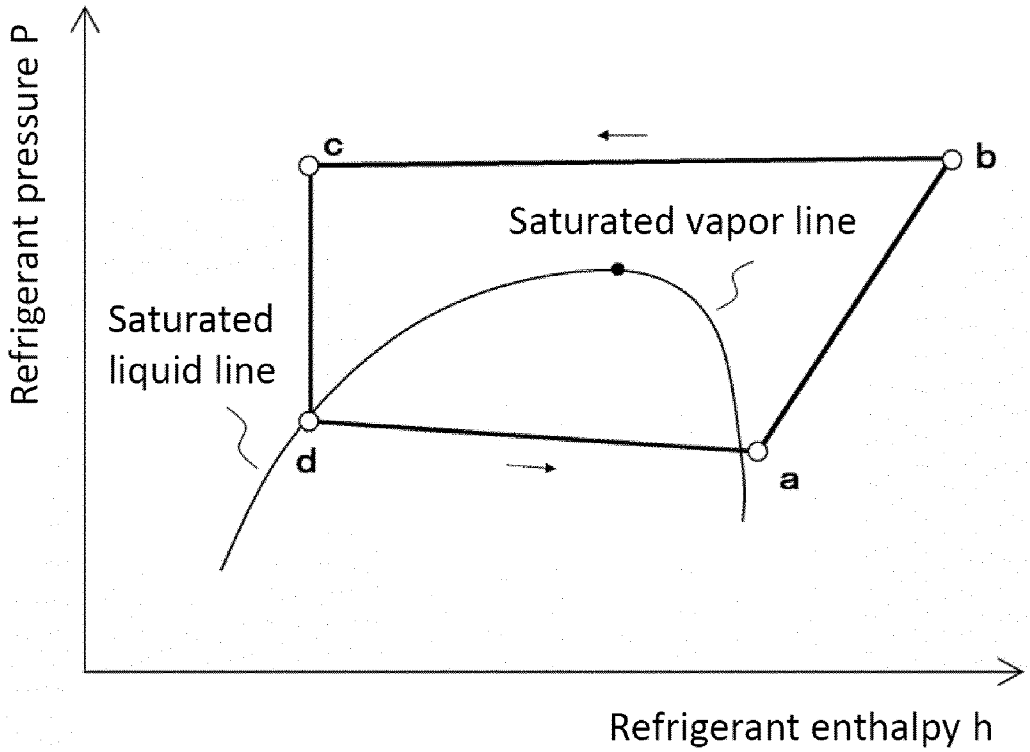


1	Heat source unit
2	Tank unit
3	Refrigerant circuit
4	Heat medium circuit
5	Hot water supply circuit
11	Compressor
12	Refrigerant/heat medium heat exchanger (first radiator)
13	Expansion valve (expansion device
14	Refrigerant/air heat exchanger (evaporator)
21	Hot water tank
22	Hot water-storing heat exchanger (second radiator)
23	Circulation pump (circulation device)
24	Expansion tank

[Fig. 2]

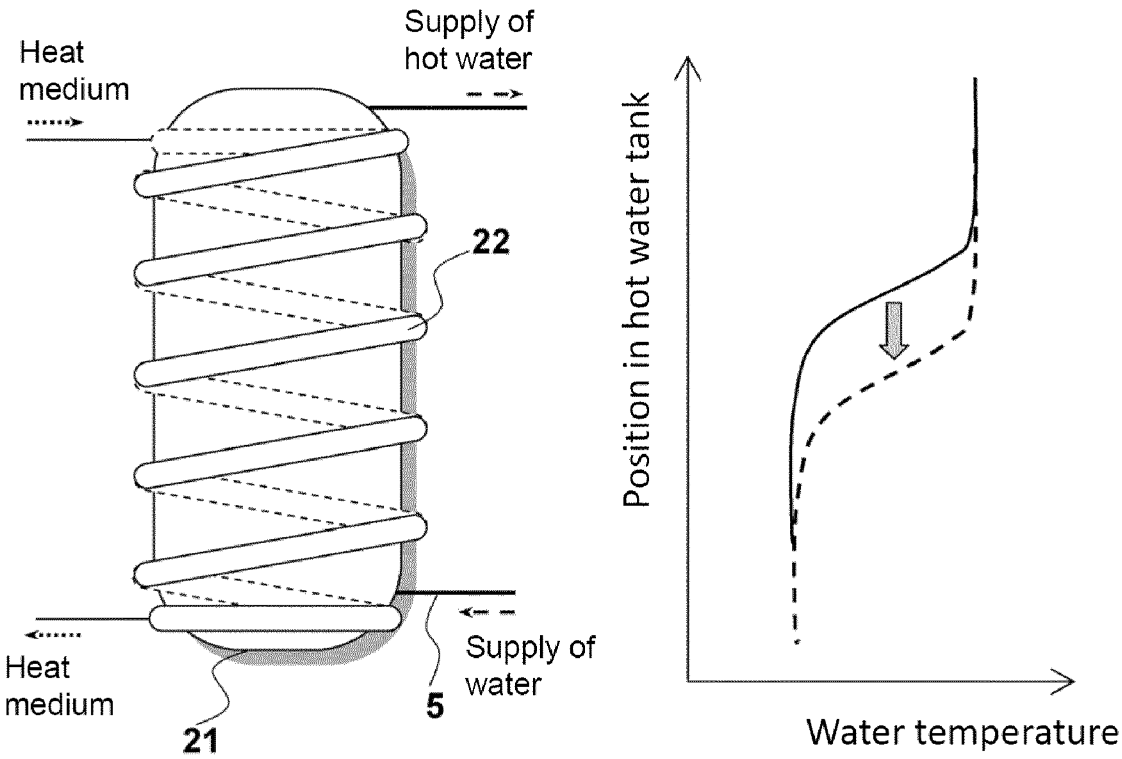

5c
5a
4a
Heat medium
Supply of
hot water
21b
21d
22
21a
21
21d
21c
Supply of
water
Heat
medium
4b
5d
5b

[Fig. 3]



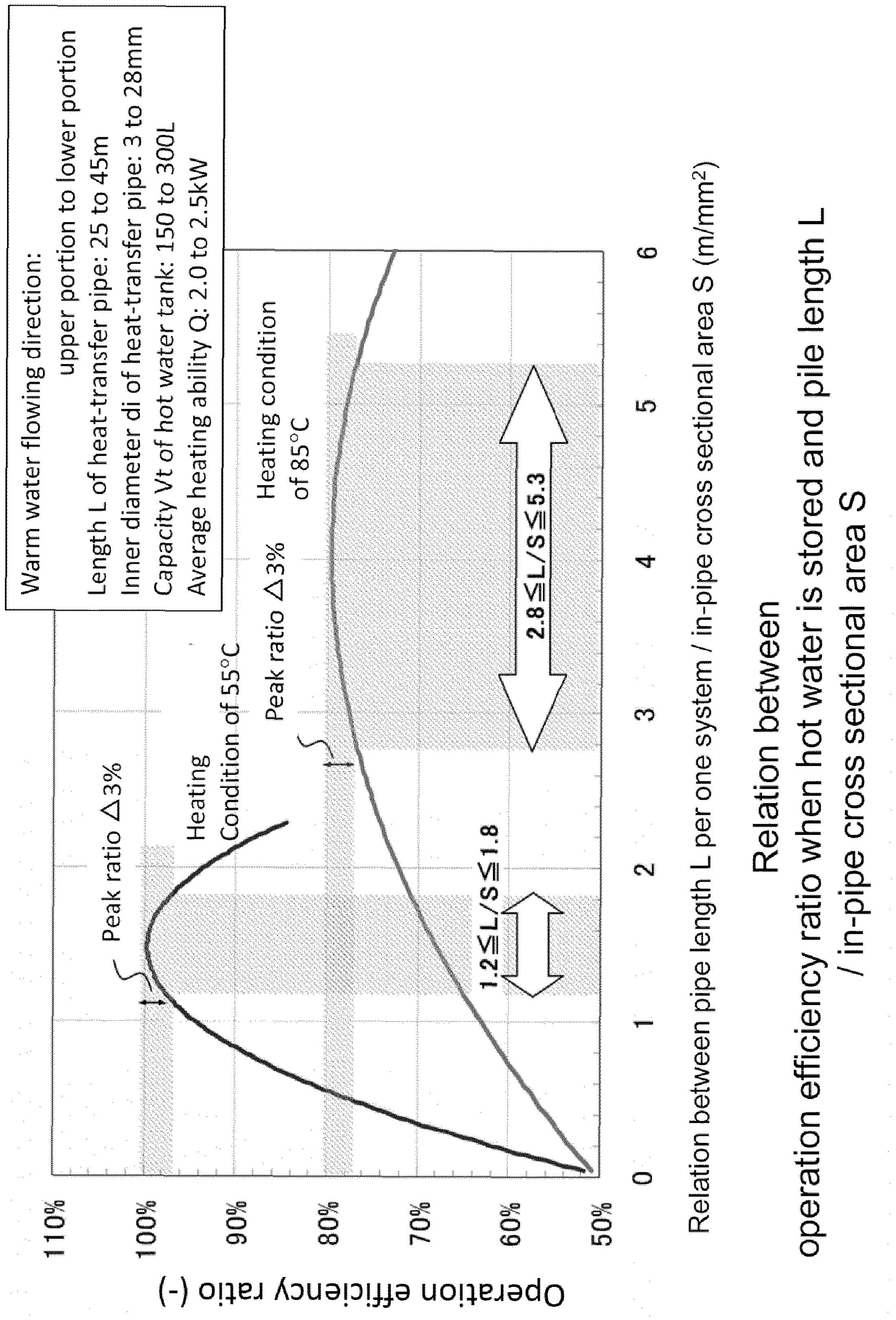
P-h diagram of refrigerant circuit (Mollier diagram)

[Fig. 4]



Conceptual diagram of variation in water temperature in hot water tank

[Fig. 5]


Warm water flowing direction:
upper portion to lower portion
Length L of heat-transfer pipe: 25 to 45m
Inner diameter di of heat-transfer pipe: 3 to 28mm
Capacity Vt of hot water tank: 150 to 300L
Average heating ability Q: 2.0 to 2.5kW
Peak ratio △3%
Heating
Condition of 55°C
Peak ratio △3%
Heating condition
of 85°C
1.2≦L/S≦1.8
2.8≦L/S≦5.3
110%
100%
90%
80%
70%
60%
50%
Operation efficiency ratio (-)
0
1
2
3
4
5
6
Relation between pipe length L per one system / in-pipe cross sectional area S (m/mm2)
Relation between
operation efficiency ratio when hot water is stored and pile length L
/ in-pipe cross sectional area S

[Fig. 6]

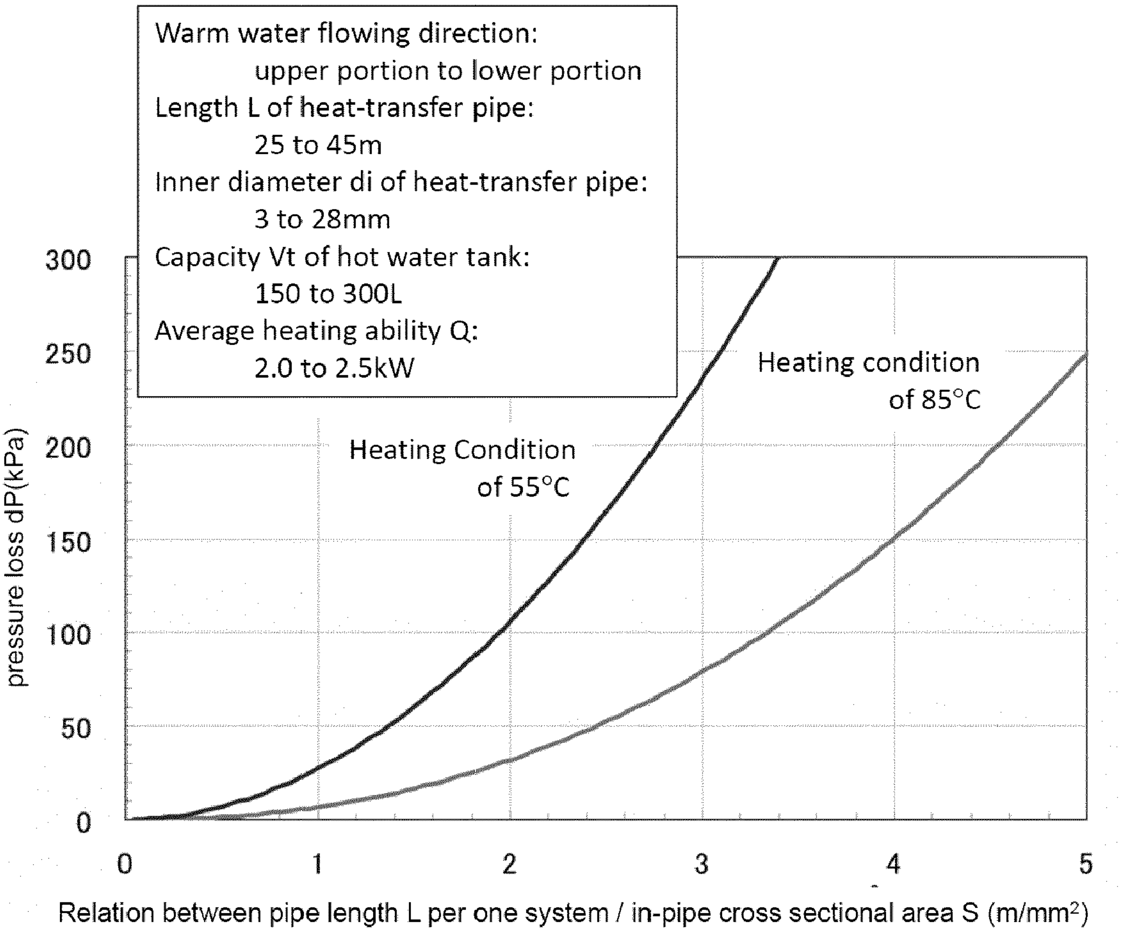


Diagram showing relation between
pressure loss dP when hot water is stored and pile length L
/ in-pipe cross sectional area S

[Fig. 7]

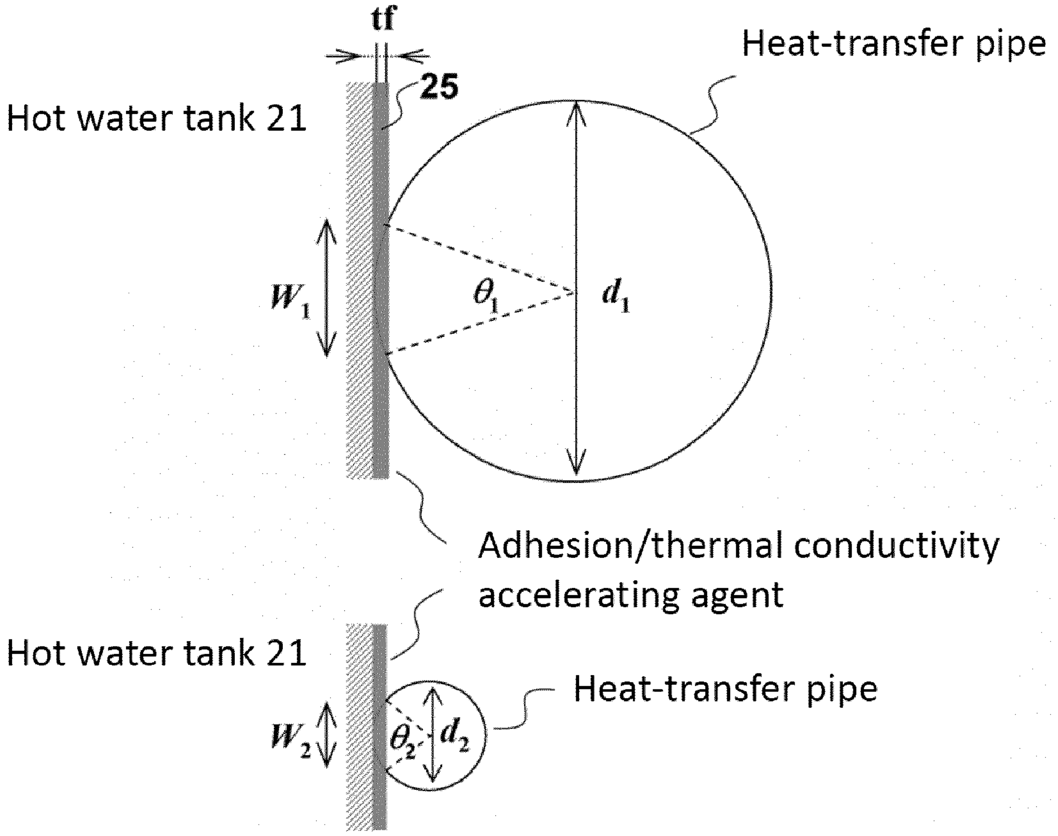
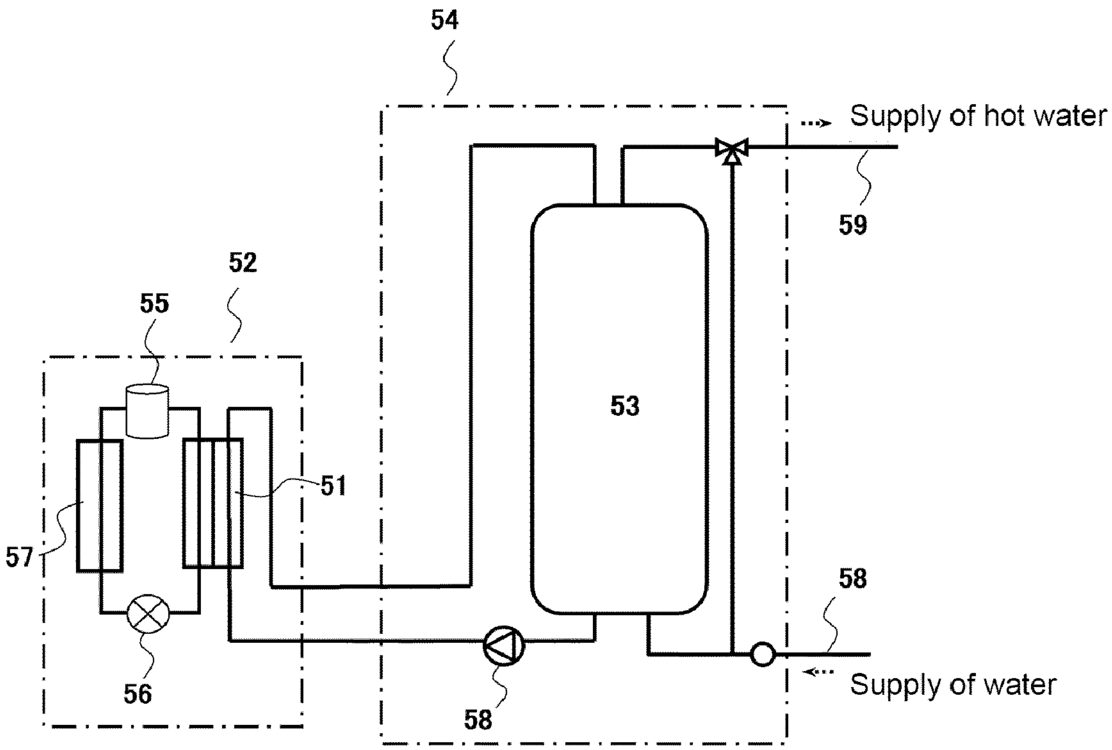
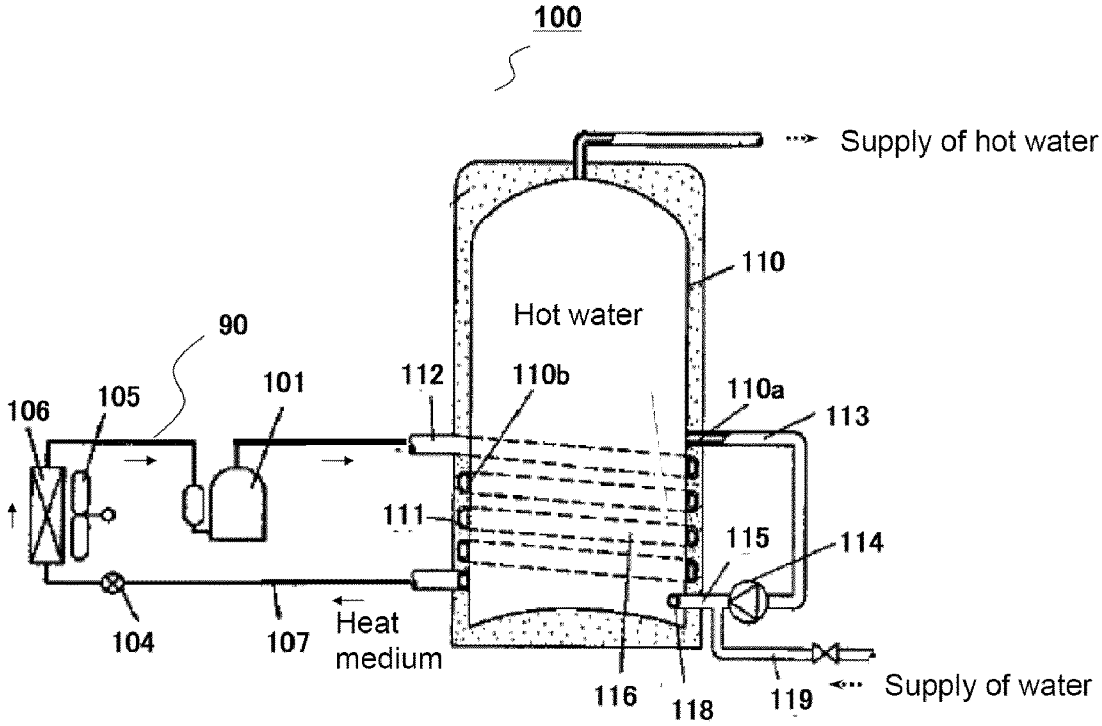


Diagram showing relation of contact length between diameter of heat-transfer pipe and hot water tank

[Fig. 8]



[Fig. 9]


100
Supply of hot water
110
Hot water
90
101
112
110b
110a
113
106
105
111
115
114
104
107
Heat
medium
116
118
119
Supply of water

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EUROPEAN SEARCH REPORT

Application Number
EP 14 15 5464

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The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	9 April 2014	Ritter, Christoph

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