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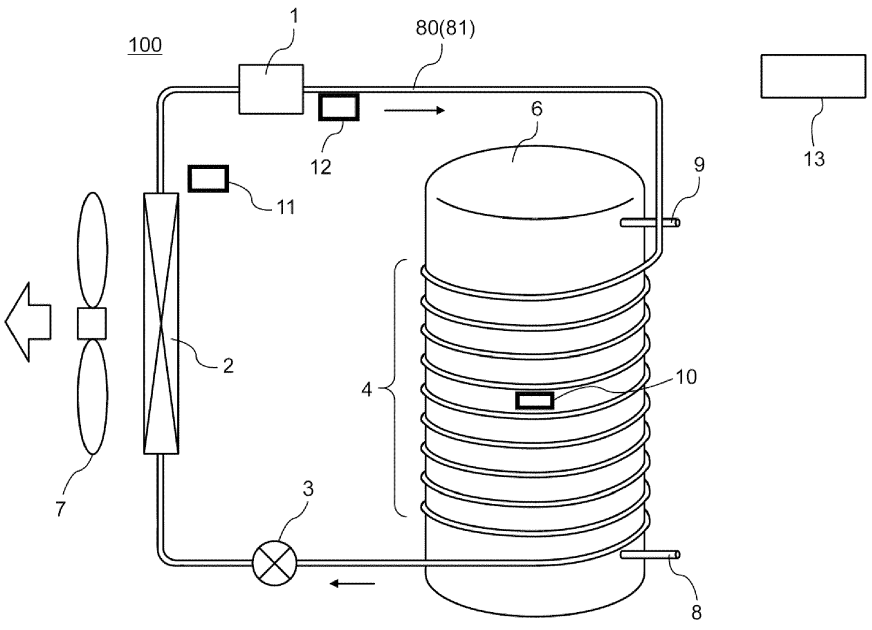
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(54) HEAT PUMP WATER HEATER

(57) A heat pump water heater according to the present disclosure includes a refrigerant circuit in which a compressor, a radiator, a decompressor, and an evaporator are connected in a loop by a refrigerant pipe, a fan for blowing air toward the evaporator, a water storage tank for storing hot water, a tank temperature sensor provided in the water storage tank, and a controller for controlling an operation of at least the fan. The radiator is configured such that the refrigerant pipe is wound around a periphery of the water storage tank. As compared to when a temperature of the hot water in the water storage tank is low, a rotation speed of the fan is lower when the temperature of the hot water in the water storage tank is high.

FIG. 1



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Description

BACKGROUND

1. Technical Field

[0001] The present disclosure relates to a heat pump water heater.

2. Description of the Related Art

[0002] Conventionally, as a heat pump water heater of this type, Unexamined Japanese Patent Publication No. 2001-263802 (PTL 1) proposes a heat pump water heater including: a heat pump device having a refrigerant circuit in which a compressor, a radiator, a decompressor, and an evaporator are connected in a loop by a refrigerant pipe; a water storage tank for storing hot water; and a heating circuit configured such that a lower portion and an upper portion of the water storage tank are connected in a loop by a water pipe, while a radiator and a pump are provided in a middle. In the conventional heat pump water heater, hot water in the lower portion of the water storage tank is delivered by the pump to the radiator, the hot water is heated and delivered back to the upper portion of the water storage tank, and the hot water is stored in the water storage tank.

[0003] In the conventional heat pump water heater, when a temperature of water entering into the radiator exceeds a predetermined temperature, a rotation speed of the pump increases. A heat exchange amount in the radiator therefore increases, and thus an increase in pressure in the heat pump device is suppressed.

[0004] As another heat pump water heater of this type, Chinese Examined Utility Model Application Publication No. 201463270 (PTL 2) proposes a heat pump water heater including a refrigerant circuit in which a compressor, a radiator, a decompressor, and an evaporator are connected in a loop by a refrigerant pipe, and a water storage tank for storing hot water, where the radiator is configured such that the refrigerant pipe is spirally wound.

[0005] With a configuration of PTL 1, under an operating condition where a temperature of water entering into the radiator rises, and thus pressure in a high pressure side of the refrigerant circuit easily increases, an increase in pressure in the high pressure side of the refrigerant circuit can be suppressed by using the pump to increase an amount of a heating target (water) flowing into the radiator to increase a heat exchange amount.

[0006] On the other hand, with a configuration of PTL 2 in which the radiator is configured such that the refrigerant pipe is wound around a periphery of the tank, an increase in heat exchange amount cannot be achieved by causing a heating target in the tank to flow. When a temperature of the heating target in the water storage tank increases, as shown in FIG. 5, pressure in the high pressure side of the refrigerant circuit therefore increases, which could increase pressure excessively.

SUMMARY

[0007] In view of the above problems in the conventional art, an object of the present disclosure is to provide a heat pump water heater that prevents pressure in a high pressure side of a refrigerant circuit from increasing excessively.

[0008] A heat pump water heater according to the present disclosure includes a refrigerant circuit in which a compressor, a radiator, a decompressor, and an evaporator are connected in a loop by a refrigerant pipe, a fan for blowing air toward the evaporator, a water storage tank for storing hot water, a tank temperature sensor provided in the water storage tank, and a controller for controlling an operation of at least the fan. The radiator is configured such that the refrigerant pipe is wound around a periphery of the water storage tank. As compared to when a temperature of the hot water in the water storage tank is low, a rotation speed of the fan is lower when the temperature of the hot water in the water storage tank is high.

[0009] Under a condition where a temperature of water in the water storage tank is high, and thus pressure in a high pressure side of the refrigerant circuit easily increases, a rotation speed of the fan is therefore lowered, and thus an evaporating capability is lowered. As a result, pressure in the high pressure side of the refrigerant circuit can be prevented from increasing excessively.

[0010] According to the present disclosure, a heat pump water heater that prevents pressure in a high pressure side of a refrigerant circuit from increasing excessively can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a schematic block diagram of a heat pump water heater according to a first exemplary embodiment of the present disclosure;

FIG. 2 is a graph illustrating transitions of a temperature of water in the water storage tank, a fan rotation speed, and refrigerant pressure under a heating operation of the heat pump water heater;

FIG. 3A is a graph illustrating transitions of a temperature of water in the water storage tank, a fan rotation speed, and refrigerant pressure under the heating operation of the heat pump water heater when an ambient temperature is high;

FIG. 3B is a graph illustrating transitions of a temperature of water in the water storage tank, a fan rotation speed, and refrigerant pressure under the heating operation of the heat pump water heater when an ambient temperature is low;

FIG. 4A is a graph illustrating a relationship of a temperature of water in the tank, pressure in a high pres-

sure side, and a fan rotation speed under the heating operation of the heat pump water heater;

FIG. 4B is a Mollier chart under the heating operation of the heat pump water heater; and

FIG. 5 is a graph illustrating a relationship of a temperature of water in a water storage tank, pressure in a high pressure side, and a fan rotation speed under a heating operation of a conventional heat pump water heater.

DETAILED DESCRIPTION

[0012] A heat pump water heater according to a first aspect of the present disclosure includes a refrigerant circuit in which a compressor, a radiator, a decompressor, and an evaporator are connected in a loop by a refrigerant pipe, a fan for blowing air toward the evaporator, a water storage tank for storing hot water, a tank temperature sensor provided in the water storage tank, and a controller for controlling an operation of at least the fan. The radiator is configured such that the refrigerant pipe is wound around a periphery of the water storage tank. As compared to when a temperature of the hot water in the water storage tank is low, a rotation speed of the fan is lower when the temperature of the hot water in the water storage tank is high.

[0013] Under a condition where a temperature of water in the water storage tank is high, and thus pressure in a high pressure side of the refrigerant circuit easily increases, a rotation speed of the fan is therefore lowered, and thus an evaporating capability is lowered. As a result, pressure in the high pressure side of the refrigerant circuit can be prevented from increasing excessively.

[0014] Particularly, in a second aspect of the present disclosure in accordance with the first aspect of the present disclosure, the heat pump water heater further includes an ambient temperature sensor for detecting an ambient temperature, wherein as compared to when an ambient temperature is low, an amount of reduction when a rotation speed of the fan is lowered is greater when the ambient temperature is high.

[0015] Since an endothermic energy amount in the evaporator is greater as an ambient temperature is higher, by increasing an amount of reduction in rotation speed of the fan when an ambient temperature is relatively higher, the endothermic energy amount in the evaporator is reduced to lower an evaporating capability. Therefore, an excessive increase in pressure in the high pressure side of the refrigerant circuit can further reliably be suppressed.

[0016] Particularly, in a third aspect of the present disclosure in accordance with the first or second aspect of the present disclosure, the heat pump water heater further includes a discharge temperature sensor for detecting a temperature of a refrigerant discharged from the compressor, and an ambient temperature sensor for detecting an ambient temperature. The decompressor is an electronic expansion valve. The electronic expansion valve has a degree of opening controlled such that a temperature of the refrigerant discharged from the compressor reaches a target discharge temperature determined based on a temperature of hot water in the water storage tank and an ambient temperature.

[0017] The refrigerant taken from the evaporator into the compressor can therefore be optimized (dryness 1) to make the refrigerant circuit highly efficient. Excessive increases in temperature of the refrigerant discharged from the compressor, and pressure in the high pressure side of the refrigerant circuit can further reliably be suppressed.

[0018] An exemplary embodiment of the present disclosure will be described below with reference to the drawings. This exemplary embodiment does not intend to limit the present disclosure.

EXEMPLARY EMBODIMENT

[0019] FIG. 1 is a schematic view illustrating an outline configuration of a heat pump water heater according to this exemplary embodiment. As shown in FIG. 1, heat pump water heater 100 includes refrigerant circuit 80 in which compressor 1, radiator 4, decompressor 3, and evaporator 2 are sequentially connected in a loop by refrigerant pipe 81, and water storage tank 6 for storing hot water. For a refrigerant circulating in refrigerant circuit 80, a Freon (registered trademark) refrigerant such as R410A, R407C, R134a, and R32, or a natural refrigerant such as carbon dioxide can be used. In this exemplary embodiment, a Freon (registered trademark) refrigerant is used, and refrigerant circuit 80 is operated such that pressure in a high pressure side is kept in a subcritical state.

[0020] For decompressor 3, an electronic expansion valve for which a degree of opening can freely be adjusted, or a capillary tube may be used. In this exemplary embodiment, an electronic expansion valve is used.

[0021] For radiator 4, refrigerant pipe 81 is spirally wound around a periphery of water storage tank 6. The hot, highly pressurized refrigerant discharged from compressor 1 flows into the refrigerant pipe constituting radiator 4 to radiate heat toward hot water in water storage tank 6, to thereby heat the hot water in water storage tank 6.

[0022] Near evaporator 2, fan 7 for blowing air toward evaporator 2 is provided. A rotation speed of fan 7 can freely be adjusted. Near evaporator 2, ambient temperature sensor 11 for detecting an ambient temperature is also provided. Discharge temperature sensor 12 for detecting a temperature of the refrigerant discharged from compressor 1 is also provided.

[0023] Water storage tank 6 is connected with water supply pipe 8 for supplying water to water storage tank 6, and hot water discharge pipe 9 for discharging hot water in water storage tank 6. Water supply pipe 8 is connected to a lower portion of water storage tank 6, and hot water discharge pipe 9 is connected to an upper por-

tion of water storage tank 6.

[0024] At approximately a center in a height direction of water storage tank 6, tank temperature sensor 10 for detecting a temperature of hot water in water storage tank 6 (or a temperature of an exterior of water storage tank 6) is provided. A plurality of tank temperature sensors 10 may be provided at predetermined intervals in the height direction of water storage tank 6.

[0025] Controller 13 controls a heating operation for heating hot water in water storage tank 6. Based on temperatures detected by tank temperature sensor 10 and ambient temperature sensor 11, controller 13 controls at least one of a rotation speed of compressor 1, a degree of opening of the electronic expansion valve that is decompressor 3, and a rotation speed of fan 7. Heat pump water heater 100 may be provided with other sensors.

[0026] In a heating operation, the hot, highly pressurized refrigerant discharged from compressor 1 enters into radiator 4, radiates heat toward hot water in water storage tank 6, and condenses wholly or partially. The refrigerant discharged from radiator 4 is decompressed by the electronic expansion valve that is decompressor 3, and enters into evaporator 2.

[0027] In evaporator 2, the refrigerant exchanges heat with air blown by fan 7 to evaporate. The refrigerant is then taken again into compressor 1. This operation is repeated to heat the hot water in water storage tank 6.

[0028] The refrigerant pipe constituting radiator 4 is preferably configured such that the refrigerant flows from the upper portion of the exterior of water storage tank 6 toward the lower portion. In other words, in radiator 4, the relatively hot refrigerant is preferably present in the upper portion of the exterior of water storage tank 6. Into water storage tank 6, cold water flows from the lower portion through water supply pipe 8. Hot water in water storage tank 6 is discharged from hot water discharge pipe 9.

[0029] A temperature of the lower portion of water storage tank 6 is therefore relatively lower. In a configuration in which the refrigerant flows from the upper portion of the exterior of water storage tank 6 toward the lower portion, in radiator 4, the refrigerant radiates heat toward cold water in water storage tank 6 at a lower area of water storage tank 6. In radiator 4, an Enthalpy difference therefore increases. As a result, in evaporator 2, an endothermic energy amount of the refrigerant increases, and thus heating efficiency required as the heat pump device increases.

[0030] A temperature of the hot water in water storage tank 6 (a tank temperature) gradually increases upon start of a heating operation, as shown in FIG. 2. As the tank temperature rises, pressure in the high pressure side of refrigerant circuit 80 increases accordingly.

[0031] When the tank temperature rises, a difference in temperature between the refrigerant and a heating target (hot water in water storage tank 6) in radiator 4 decreases, and thus a heat exchange amount is reduced. The refrigerant is therefore discharged from radiator 4 without fully radiating heat, and thus evaporating pressure and condensing pressure (pressure in the high pressure side) are increased. The pressure in the high pressure side might exceed an upper limit pressure specified as an operation range for refrigerant circuit 80.

[0032] In particular, in heat pump water heater 100 according to this exemplary embodiment in which refrigerant pipe 81 is wound around the periphery of water storage tank 6 to constitute radiator 4, a heating target (hot water in water storage tank 6) cannot be flown in radiator 4, and a rise in tank temperature directly affects an increase in pressure in the high pressure side, thus remarkably increasing the pressure in the high pressure side. An excessive increase in pressure in the high pressure side due to a rise in tank temperature therefore needs to be prevented.

[0033] In the present disclosure, as shown in FIG. 2, controller 13 lowers, in a heating operation, a rotation speed of fan 7 in accordance with a temperature of hot water in water storage tank 6. In other words, as compared to when a temperature detected by tank temperature sensor 10 is low, controller 13 performs a control such that an amount of reduction in rotation speed of the fan is increased when the temperature detected by tank temperature sensor 10 is high. In evaporator 2, an endothermic energy amount of the refrigerant is therefore reduced, and accordingly pressure in the high pressure side of refrigerant circuit 80 is lowered.

[0034] When a temperature detected by tank temperature sensor 10 reaches a predetermined temperature (for example, 50°C), controller 13 lowers a rotation speed of the fan, and then, each time a temperature detected by tank temperature sensor 10 exceeds the predetermined temperature, controller 13 gradually lowers a rotation speed of fan 7. As shown in FIGS. 4A and 4B, while pressure in the high pressure side of refrigerant circuit 80 is kept below upper limit pressure, a heating operation can therefore be executed to heat hot water to a set temperature.

[0035] When a plurality of tank temperature sensors 10 are provided, controller 13 preferably lowers a rotation speed of fan 7 in accordance with a temperature detected by tank temperature sensors 10 provided at a lower area.

[0036] As described above, controller 13 performs a control such that a rotation speed of fan 7 is lowered when a temperature of hot water in tank 6 exceeds a predetermined temperature, and, as a temperature of hot water in tank 6 further rises, an amount of reduction in rotation speed of fan 7 is increased.

[0037] Controller 13 lowers a rotation speed of fan 7 when a temperature detected by tank temperature sensor 10 reaches the predetermined temperature. An amount of reduction at that time may be changed in accordance with an ambient temperature detected by ambient temperature sensor 11.

[0038] In other words, as shown in FIGS. 3A and 3B, as compared to when an ambient temperature is low, controller 13 increases an amount of reduction in rotation

speed of fan 7 when the ambient temperature is high. Since an endothermic energy amount in evaporator 2 is greater as an ambient temperature is higher, by increasing an amount of reduction in rotation speed of fan 7 when an ambient temperature is relatively higher, the endothermic energy amount in evaporator 2 is reduced to lower an evaporating capability. Therefore, an excessive increase in pressure in the high pressure side of refrigerant circuit 80 can further reliably be suppressed.

[0039] As described above, as an ambient temperature rises, controller 13 may perform a control such that an amount of reduction in rotation speed of fan 7 is increased.

[0040] Next, a method for determining a target discharge temperature for a temperature of a refrigerant discharged from compressor 1 will now be described. Based on a temperature of hot water in water storage tank 6, which is detected by tank temperature sensor 10, and an ambient temperature detected by ambient temperature sensor 11, a target discharge temperature set beforehand in controller 13 is determined. Controller 13 controls a degree of opening for the electronic expansion valve that is decompressor 3 such that a temperature detected by discharge temperature sensor 12 reaches the target discharge temperature.

[0041] The target discharge temperature set beforehand in controller 13 is set so as to be higher as a temperature of hot water in water storage tank 6 and an ambient temperature are higher, and such that a refrigerant taken from evaporator 2 into compressor 1 is optimized (dryness 1).

[0042] In refrigerant circuit 80 with an operation specification where pressure in a high pressure side is kept in a subcritical state, pressure in the high pressure side and a temperature of hot water in water storage tank 6 have a correlation. Pressure in the high pressure side of refrigerant circuit 80 can therefore be estimated based on a temperature of hot water in water storage tank 6. An optimal target discharge temperature can then be calculated from an optimal state (dryness 1) of the refrigerant taken from evaporator 2 into compressor 1. As described above, a target discharge temperature is set beforehand in controller 13.

[0043] The refrigerant taken from evaporator 2 into compressor 1 can therefore be optimized (dryness 1) to make refrigerant circuit 80 highly efficient. Excessive increases in temperature of the refrigerant discharged from compressor 1 and pressure in the high pressure side of refrigerant circuit 80 can further reliably be suppressed.

[0044] In a refrigerant circuit mounted with electronic-type decompressor 3 for which a degree of opening can be adjusted for suppressing excessive pressure, an increase in pressure in the high pressure side of refrigerant circuit 80 can be suppressed by only increasing a degree of opening for the electronic expansion valve. However, as compared to an adjustment of pressure in the high pressure side of refrigerant circuit 80 through a reduction in rotation speed of fan 7, an adjustment range for pressure in the high pressure side of refrigerant circuit 80 is narrower, and thus an effect for suppressing higher pressure cannot fully be demonstrated. When decompressor 3 such as a capillary tube or a thermo-sensitive or pressure-sensitive expansion valve is mounted, an effect for suppressing higher pressure cannot be achieved.

[0045] Therefore, in this exemplary embodiment, controller 13 controls an operation of at least one of compressor 1, an electronic expansion valve that is decompressor 3, and fan 7 such that a temperature of refrigerant discharged from compressor 1 reaches a target discharge temperature, as well as adjusts pressure in the high pressure side of refrigerant circuit 80 to make refrigerant circuit 80 highly efficient. Excessive increases in temperature of the refrigerant discharged from compressor 1 and pressure in the high pressure side of refrigerant circuit 80 are further reliably be suppressed.

[0046] According to the present disclosure, pressure in a high pressure side of a refrigerant circuit at the time of a heating operation can be prevented from increasing, and thus the present disclosure can be applied to home and business use heat pump water heaters.

Claims

1. A heat pump water heater comprising:

a refrigerant circuit in which a compressor, a radiator, a decompressor, and an evaporator are connected in a loop by a refrigerant pipe;
a fan for blowing air toward the evaporator;
a water storage tank for storing hot water;
a tank temperature sensor provided in the water storage tank; and
a controller for controlling an operation of at least the fan,
wherein the radiator is configured such that the refrigerant pipe is wound around a periphery of the water storage tank, and
as compared to when a temperature of the hot water in the water storage tank is low, a rotation speed of the fan is lower when the temperature of the hot water in the water storage tank is high.

2. The heat pump water heater according to claim 1, further comprising an ambient temperature sensor for detecting an ambient temperature,
wherein as compared to when the ambient temperature is low, an amount of reduction when a rotation speed of the fan is lowered is greater when the ambient temperature is high.

3. The heat pump water heater according to claim 1 or 2, further comprising:

a discharge temperature sensor for detecting a temperature of a refrigerant discharged from the

compressor; and
an ambient temperature sensor for detecting an ambient temperature,
wherein the decompressor is an electronic expansion valve, the electronic expansion valve having a degree of opening being controlled such that the temperature of the refrigerant discharged from the compressor reaches a target discharge temperature determined based on a temperature of the hot water in the water storage tank and the ambient temperature.

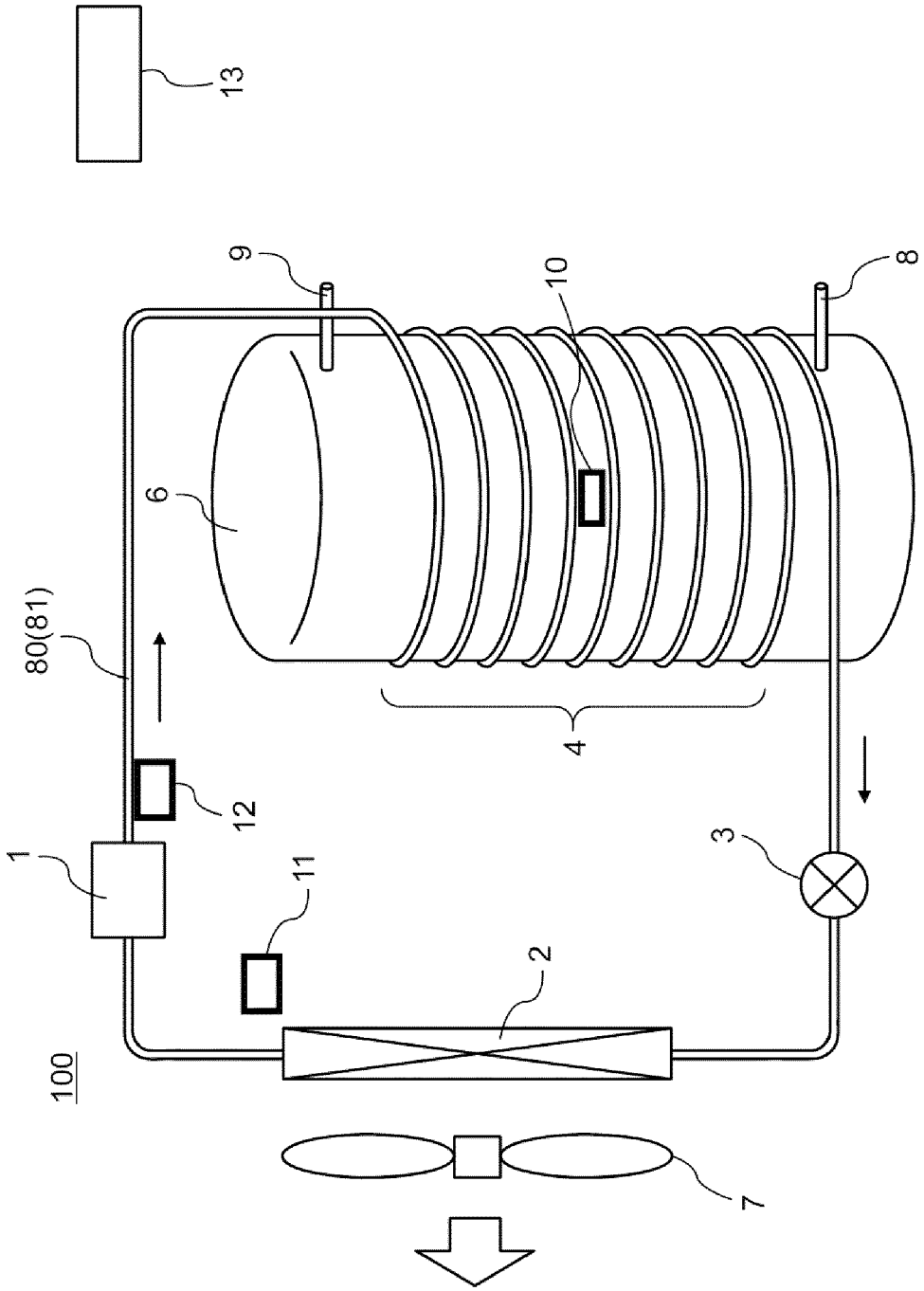


FIG. 1

FIG. 2

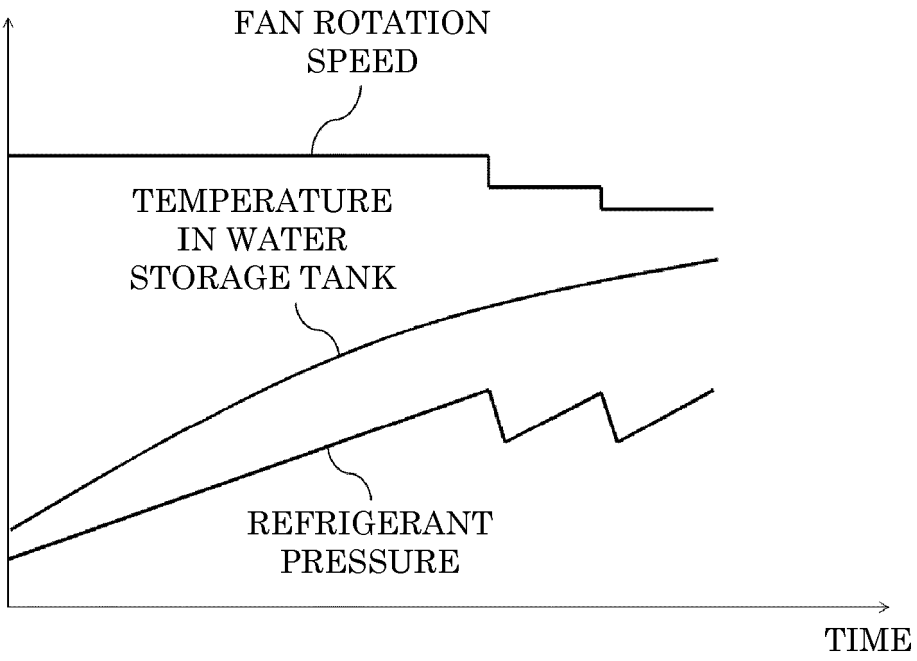

FAN ROTATION SPEED
TEMPERATURE IN WATER STORAGE TANK
REFRIGERANT PRESSURE
TIME

FIG. 3A

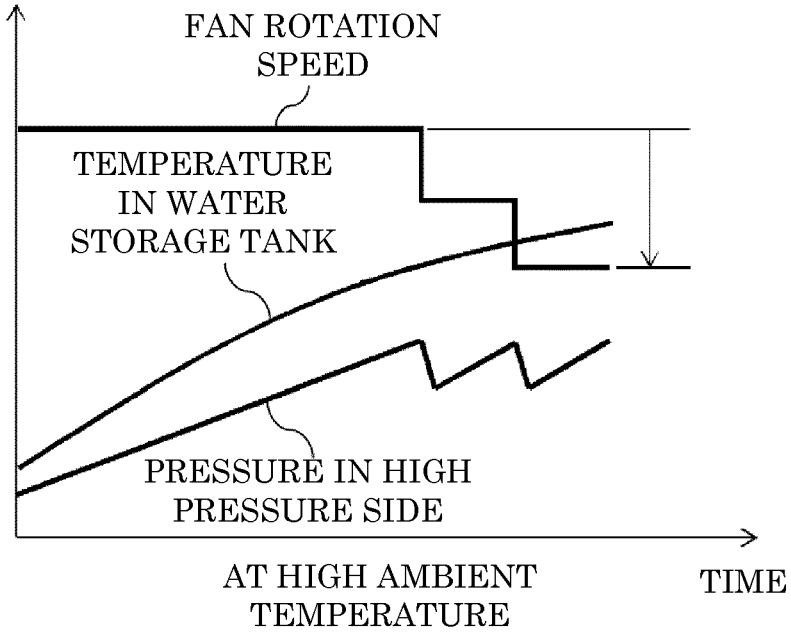

FAN ROTATION SPEED
TEMPERATURE IN WATER STORAGE TANK
PRESSURE IN HIGH PRESSURE SIDE
AT HIGH AMBIENT TEMPERATURE
TIME

FIG. 3B

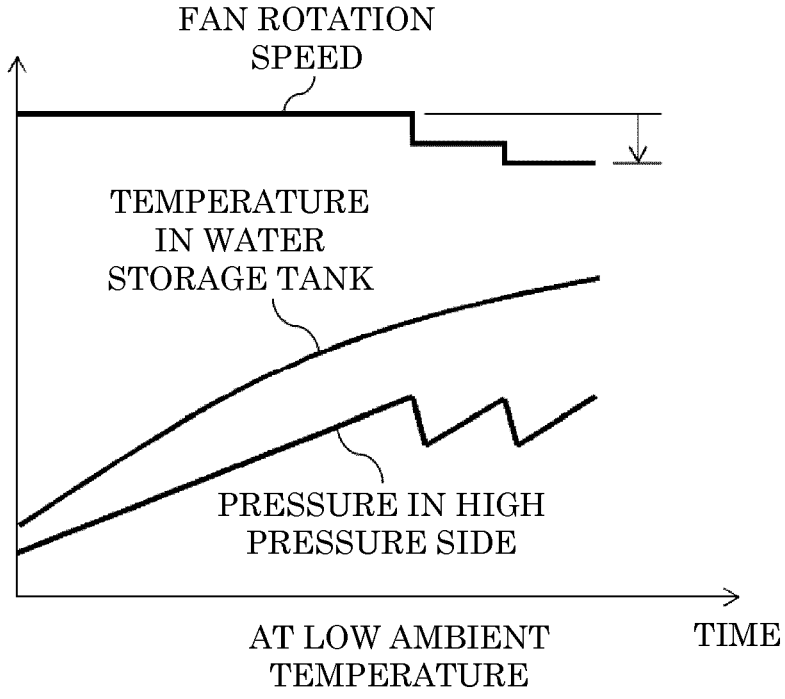

FAN ROTATION SPEED
TEMPERATURE IN WATER STORAGE TANK
PRESSURE IN HIGH PRESSURE SIDE
AT LOW AMBIENT TEMPERATURE
TIME

FIG. 4A

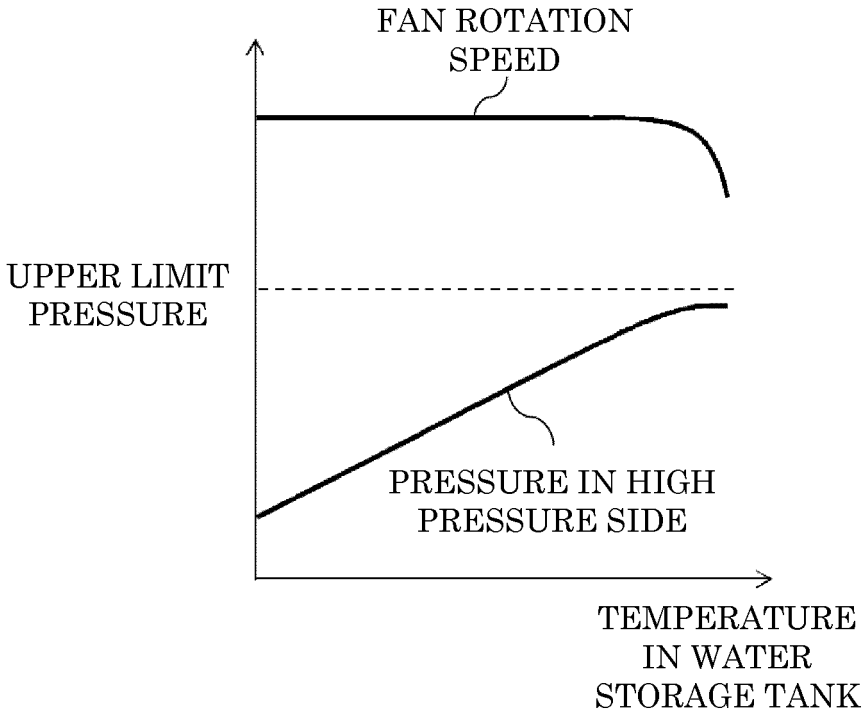

FAN ROTATION SPEED
UPPER LIMIT PRESSURE
PRESSURE IN HIGH PRESSURE SIDE
TEMPERATURE IN WATER STORAGE TANK

FIG. 4B

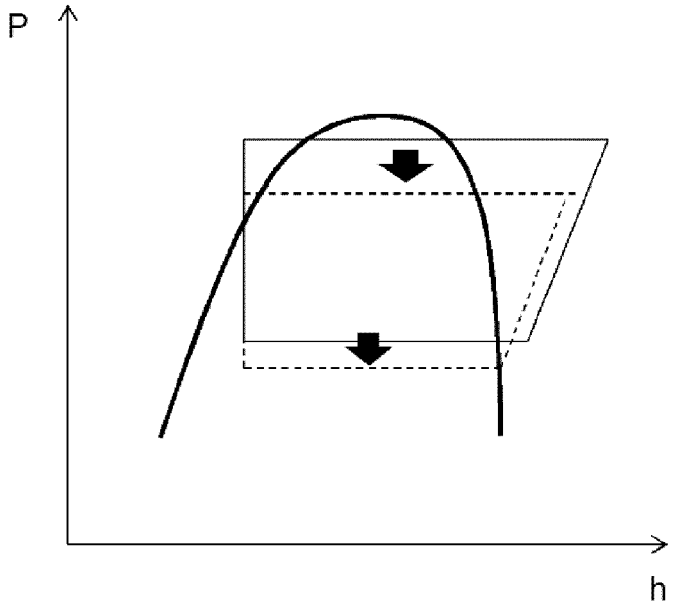
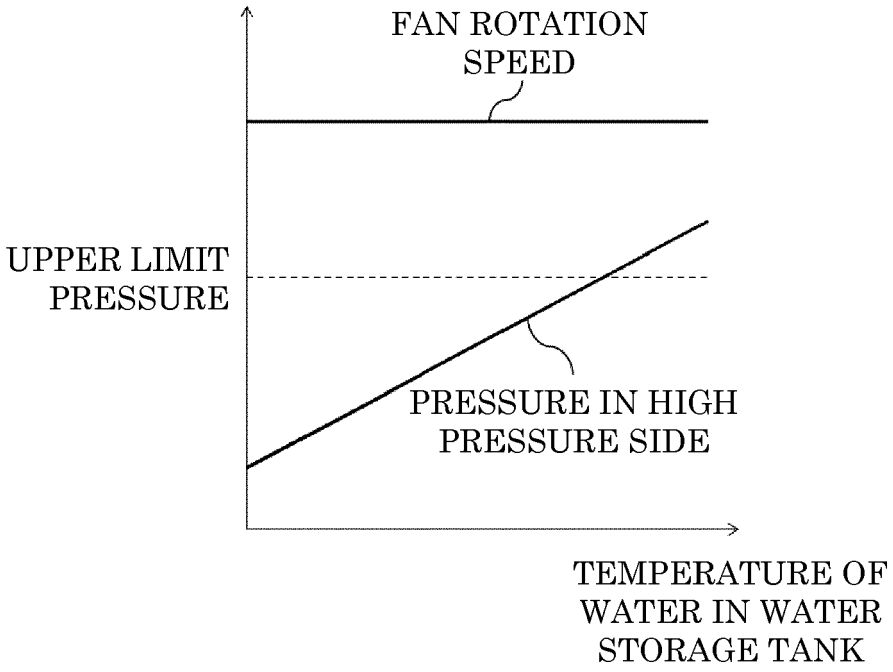

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FIG. 5


FAN ROTATION SPEED
UPPER LIMIT PRESSURE
PRESSURE IN HIGH PRESSURE SIDE
TEMPERATURE OF WATER IN WATER STORAGE TANK

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 6005

DOCUMENTS CONSIDERED TO BE RELEVANT

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	30 November 2017	García Moncayo, O

CATEGORY OF CITED DOCUMENTS

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30-11-2017

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