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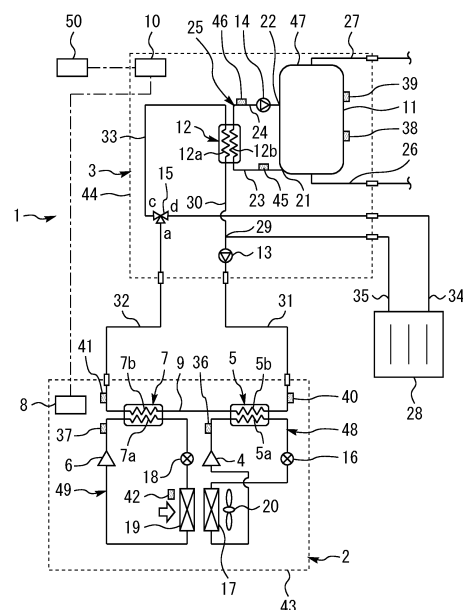
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(54) HEAT PUMP DEVICE AND HOT WATER SUPPLY SYSTEM

(57) A heat pump apparatus according to the present disclosure is a heat pump apparatus for supplying heat for hot water storage operation to raise a temperature of water in a hot water storage tank. The heat pump apparatus includes a constant speed compressor, a first heat exchanger for exchanging heat between refrigerant compressed by the constant speed compressor and a heat medium, a variable speed compressor, and a second heat exchanger for exchanging heat between refrigerant compressed by the variable speed compressor and the heat medium downstream of the first heat exchanger. A hot water supply system according to the present disclosure includes the heat pump apparatus, the hot water storage tank, and a water heat exchanger for exchanging heat between the heat medium flowed out of the heat pump apparatus and water stored in the hot water storage tank.

FIG. 1



Description

Technical Field

[0001] The present disclosure relates to a heat pump apparatus and a hot water supply system.

Background Art

[0002] PTL 1 below discloses a heat pump water heater including a first refrigerant circuit configured by sequentially connecting a first compressor, a first water heat exchanger, a first depressurizing mechanism, and a first heat-source-side heat exchanger, a second refrigerant circuit configured by sequentially connecting a second compressor, a second water heat exchanger, a second depressurizing mechanism, and a second heat-source-side heat exchanger, and a hot water supply circuit for heating low-temperature water by the first water heat exchanger to obtain medium-temperature water and then further heating this medium-temperature water by the second water heat exchanger to output high-temperature water.

Citation List

Patent Literature

[0003] [PTL 1] JP 2004-233010 A

Summary of the Invention

Problems to be solved by the Invention

[0004] When a heat pump inlet temperature which is a temperature of water flowing into the first water heat exchanger rises in a case where hot water storage operation of storing hot water in a hot water storage tank is performed by the heat pump water heater disclosed in PTL 1, the temperature of water heated by the first water heat exchanger rises further, and the water flows into the second water heat exchanger. Then, the second refrigerant circuit increases in condensation pressure. As a result, the condensation pressure of the second refrigerant circuit exceeds a design pressure, and the second compressor might stop. This makes a behavior of the water heater unstable.

[0005] The present disclosure has been made to solve problems as described above and has an object to provide a heat pump apparatus and a hot water supply system that enable hot water storage operation to be performed stably even when the heat pump inlet temperature rises.

Solution to Problem

[0006] A heat pump apparatus according to the present disclosure is for supplying heat for hot water storage

operation to raise a temperature of water in a hot water storage tank, the heat pump apparatus includes: a constant speed compressor; a first heat exchanger for exchanging heat between refrigerant compressed by the constant speed compressor and a heat medium; a variable speed compressor; and a second heat exchanger for exchanging heat between refrigerant compressed by the variable speed compressor and the heat medium downstream of the first heat exchanger.

[0007] A hot water supply system according to the present disclosure includes: the heat pump apparatus; the hot water storage tank; and a water heat exchanger for exchanging heat between the heat medium flowed out of the heat pump apparatus and water stored in the hot water storage tank.

[0008] A hot water supply system according to the present disclosure includes: the heat pump apparatus; the hot water storage tank; an outgoing water path for causing water flowed out of the hot water storage tank to flow into the first heat exchanger of the heat pump apparatus as the heat medium; and a return water path for causing the water which is the heat medium flowed out of the second heat exchanger of the heat pump apparatus to flow into the hot water storage tank.

Advantageous Effect of the Invention

[0009] According to the present disclosure, a heat pump apparatus and a hot water supply system that enable hot water storage operation to be performed stably even when the heat pump inlet temperature rises can be provided.

Brief Description of Drawings

[0010]

Fig. 1 a diagram illustrating a heat pump apparatus according to a first embodiment and a hot water supply system 1 including the same.

Fig. 2 is a functional block diagram of the hot water supply system according to the first embodiment.

Fig. 3 a flowchart illustrating an example of processing executed before a hot water storage operation is started.

Fig. 4 is a flowchart illustrating an example of processing executed by a first controller and a second controller while the hot water storage operation in which both a constant speed compressor and an inverter compressor are actuated is executed.

Fig. 5 is a flowchart illustrating an example of processing executed by the first controller during the hot water storage operation.

Fig. 6 is a diagram illustrating changes in a rotation speed of the constant speed compressor, changes in a rotation speed of the inverter compressor, and changes in a temperature of a heat medium during the hot water storage operation.

Fig. 7 is a diagram illustrating a hot water supply system according to a second embodiment.

Fig. 8 is a diagram illustrating a hot water supply system according to a third embodiment.

Description of Embodiments

[0011] Hereinafter, embodiments will be described with reference to the drawings. Common or corresponding elements in the respective drawings are denoted by the same reference numerals, and description thereof will be simplified or omitted. In the following description, the expression "water" or "hot water" shall in principles indicate liquid water and include cold water to boiling water.

First Embodiment

[0012] Fig. 1 is a diagram illustrating a heat pump apparatus 2 according to a first embodiment and a hot water supply system 1 including the same. The hot water supply system 1 includes the heat pump apparatus 2 and a tank unit 3. In the illustrated example, the heat pump apparatus 2 is separate from the tank unit 3.

[0013] A hot water storage tank 11, a water heat exchanger 12, a heat medium pump 13, a water pump 14, and a flow path switching valve 15 are provided in an enclosure 44 of the tank unit 3.

[0014] Operation of raising the temperature of water in the hot water storage tank 11 is called "hot water storage operation". The heat pump apparatus 2 can supply heat for the hot water storage operation. The heat pump apparatus 2 in the present embodiment supplies a heated, liquid heat medium to the tank unit 3. In the present disclosure, liquid to be used as the heat medium may be water or may be brine other than water.

[0015] The heat pump apparatus 2 is arranged outside a room. The tank unit 3 is arranged outside or inside the room. Combination of the heat pump apparatus 2 with the tank unit 3 constitutes the hot water supply system 1. The heat pump apparatus 2 may not only be connected to the tank unit 3 manufactured by the same manufacturer as the manufacturer of the heat pump apparatus 2 to constitute the hot water supply system 1, but also may be connected to the tank unit 3 manufactured by a manufacturer different from the manufacturer of the heat pump apparatus 2 to constitute the hot water supply system 1.

[0016] A constant speed compressor 4, a first heat exchanger 5, an inverter compressor 6, a second heat exchanger 7, and a first controller 8 are provided in an enclosure 43 of the heat pump apparatus 2. The constant speed compressor 4 is driven rotatably by an electric motor. The constant speed compressor 4 rotates at a constant speed all the time during operation. The constant speed compressor 4 may be one that rotates at a fixed speed in accordance with a frequency of an AC power supply such as a commercial power supply. The first controller 8 controls operation and stop of the con-

stant speed compressor 4.

[0017] The first heat exchanger 5 exchanges heat between refrigerant compressed by the constant speed compressor 4 and the heat medium. The first heat exchanger 5 includes a primary flow path 5a and a secondary flow path 5b. Heat is exchanged between the refrigerant passing through the primary flow path 5a and the heat medium passing through the secondary flow path 5b.

[0018] The inverter compressor 6 is driven rotatably by an electric motor. The first controller 8 controls operation and stop of the inverter compressor 6. The first controller 8 can control the inverter compressor 6 such that the rotation speed is variable continuously or in multiple stages through inverter control. The inverter compressor 6 is an example of a variable speed compressor. The variable speed compressor in the present disclosure is not limited to one that is achieved using inverter control. The variable speed compressor in the present disclosure may be of any control system as long as its rotation speed can be changed continuously or in multiple stages.

[0019] The second heat exchanger 7 exchanges heat between refrigerant compressed by the inverter compressor 6 and the heat medium downstream of the first heat exchanger 5. The second heat exchanger 7 includes a primary flow path 7a and a secondary flow path 7b. Heat is exchanged between the refrigerant passing through the primary flow path 7a and the heat medium passing through the secondary flow path 7b. The heat medium flowed out of an outlet of the secondary flow path 5b of the first heat exchanger 5 passes through a passage 9 to flow into an inlet of the secondary flow path 7b of the second heat exchanger 7. As described, the secondary flow path 5b of the first heat exchanger 5 and the secondary flow path 7b of the second heat exchanger 7 are connected in series via the passage 9.

[0020] A first expansion valve 16, a first evaporator 17, a second expansion valve 18, a second evaporator 19, and an air blower 20 are further provided in the enclosure 43 of the heat pump apparatus 2. The constant speed compressor 4, the primary flow path 5a, the first expansion valve 16, and the first evaporator 17 are connected via a refrigerant tube, thereby forming a first refrigerant circuit 48. The inverter compressor 6, the primary flow path 7a, the second expansion valve 18, and the second evaporator 19 are connected via a refrigerant tube, thereby forming a second refrigerant circuit 49.

[0021] In the present disclosure, the material to be used as the refrigerant is not particularly limited, and CO₂, HFC, HC, HFO, or the like, for example, can be used.

[0022] Production of a crack in a refrigerant tube might cause leakage of the refrigerant. In a case where combustible refrigerant such as HC (hydrocarbon) is used, it is desirable to minimize the amount of refrigerant leakage in such an eventuality. The heat pump apparatus 2 of the present embodiment has refrigerant circuits divided into two of the first refrigerant circuit 48 and the second

refrigerant circuit 49. This can reduce the amount of refrigerant in each of the refrigerant circuits. Therefore, the amount of refrigerant leakage in an eventuality is advantageously small.

[0023] As a modification, the heat pump apparatus 2 of the present disclosure may have refrigerant circuits divided into three or may have refrigerant circuits divided into four or more. The heat pump apparatus 2 of the present disclosure should only have at least one constant speed compressor 4 and at least one inverter compressor 6.

[0024] The first expansion valve 16 is equivalent to a depressurizing device for depressurizing and expanding high-pressure refrigerant compressed by the constant speed compressor 4. The first evaporator 17 evaporates the refrigerant on the downstream side of the first expansion valve 16. The first evaporator 17 in the present embodiment causes heat to be exchanged between air outside a room captured from the outside of the heat pump apparatus 2 and the refrigerant.

[0025] The second expansion valve 18 is equivalent to a depressurizing device for depressurizing and expanding high-pressure refrigerant compressed by the inverter compressor 6. The second evaporator 19 evaporates the refrigerant on the downstream side of the second expansion valve 18. The second evaporator 19 in the present embodiment causes heat to be exchanged between air outside the room captured from the outside of the heat pump apparatus 2 and the refrigerant.

[0026] Each of the first evaporator 17 and the second evaporator 19 may be implemented by using a fin-and-tube air heat exchanger, for example.

[0027] In the present embodiment, air outside the room flows through the second evaporator 19 and the first evaporator 17 in series. In other words, when the air blower 20 works, air outside the room having passed through the second evaporator 19 flows so as to further pass through the first evaporator 17. The present embodiment brings about an advantage in that air can be blown to both the first evaporator 17 and the second evaporator 19 by the single air blower 20. There is also an advantage that when a behavior of one of the refrigerant circuits is stopped, reduction in the amount of air to be captured by the heat pump apparatus 2 can be avoided. However, the present disclosure is not limited to the illustrated example, and the first evaporator 17 and the second evaporator 19 may be arranged in parallel and may each be provided with individual air blowers.

[0028] The hot water storage tank 11 is a container for storing hot water. The hot water storage tank 11 is covered with a heat insulating material not illustrated. An outlet 21 is provided in a lower part of the hot water storage tank 11. An inlet 22 is provided for the hot water storage tank 11 at a position above the outlet 21. In the illustrated example, the inlet 22 is located at a position above half the height of the hot water storage tank 11 in terms of the position in the vertical direction. The hot water storage tank 11 has a cylindrical outer shape, for

example.

[0029] The water heat exchanger 12 exchanges heat between the heat medium flowed out of the heat pump apparatus 2 and water stored in the hot water storage tank 11. The water heat exchanger 12 includes a primary flow path 12a and a secondary flow path 12b. Heat is exchanged between the heat medium passing through the primary flow path 12a and water passing through the secondary flow path 12b. A tank outgoing tube 23 connects the outlet 21 to a water inlet of the secondary flow path 12b. A tank return tube 24 connects a water outlet of the secondary flow path 12b to the inlet 22. The water pump 14 is provided in the middle of the tank return tube 24. The tank outgoing tube 23, the secondary flow path 12b, and the tank return tube 24 form a water circuit 25. When the water pump 14 works, water in the water circuit 25 flows.

[0030] The water heat exchanger 12 may be implemented by using a plate heat exchanger, for example.

The plate heat exchanger has a structure that promotes heat transfer. This can minimize a temperature difference between the refrigerant and heat medium in the heat pump apparatus 2 and minimize a temperature difference between the heat medium and water in the water heat exchanger 12. As a result, the hot water storage operation can be performed more efficiently.

[0031] A water supply tube 26 is connected to a lower part of the hot water storage tank 11. The water supply tube 26 extends to the outside of the tank unit 3. Water supplied from a water source such as a water supply, for example, passes through the water supply tube 26 to flow into the hot water storage tank 11. A hot water supply tube 27 is connected to an upper part of the hot water storage tank 11. The hot water supply tube 27 extends to the outside of the tank unit 3. Hot water stored in the hot water storage tank 11 passes through the hot water supply tube 27 to be supplied to a hot water supply terminal such as a shower, tap, or bathtub, for example. When hot water flows out of the hot water storage tank 11 through the hot water supply tube 27, the same quantity of water flows into the hot water storage tank 11 through the water supply tube 26. As a result, the hot water storage tank 11 is maintained in a full water state.

[0032] As in the illustrated example, a room-heating device 28 for heating a room may be connected to the tank unit 3. In the following description, operation of circulating the heat medium to the room-heating device 28 will be referred to as room-heating operation. The room-heating device 28 is installed in the room. The room-heating device 28 may include at least one of a floor heating panel installed under the floor, a radiator, a panel heater, and a fan convector installed on a wall surface in the room, for example.

[0033] A passage 30 connects an outlet of the primary flow path 12a of the water heat exchanger 12 to an intake of the heat medium pump 13. A branch portion 29 is formed in the middle of the passage 30. The flow path switching valve 15 is a valve for switching a circuit in

which the heat medium flows. The flow path switching valve 15 has an a port which is an inlet, a c port which is an outlet, and a d port which is an outlet.

[0034] A passage 31 and a passage 32 connect the heat pump apparatus 2 to the tank unit 3. The passage 31 connects a discharge outlet of the heat medium pump 13 to an inlet of the secondary flow path 5b of the first heat exchanger 5. The passage 32 connects an outlet of the secondary flow path 7b of the second heat exchanger 7 to the a port of the flow path switching valve 15. The passage 31 and the passage 32 pass through the outside of the enclosure 43 of the heat pump apparatus 2 and the outside of the enclosure 44 of the tank unit 3. An installation place of the heat pump apparatus 2 may be distant from an installation place of the tank unit 3. A passage 33 connects the c port of the flow path switching valve 15 to an inlet of the primary flow path 12a of the water heat exchanger 12.

[0035] A passage 34 and a passage 35 connect the room-heating device 28 to the tank unit 3. The passage 34 connects the d port of the flow path switching valve 15 to a heat medium inlet of the room-heating device 28. The passage 35 connects a heat medium outlet of the room-heating device 28 to the branch portion 29.

[0036] A first discharge temperature sensor 36 is arranged on the refrigerant tube between the constant speed compressor 4 and the first heat exchanger 5. The first discharge temperature sensor 36 senses a temperature of the refrigerant discharged from the constant speed compressor 4. A second discharge temperature sensor 37 is arranged on the refrigerant tube between the inverter compressor 6 and the second heat exchanger 7. The second discharge temperature sensor 37 senses a temperature of the refrigerant discharged from the inverter compressor 6.

[0037] A temperature of water in the hot water storage tank 11 is called a "stored hot water temperature". It is desirable that at least one stored hot water temperature sensor for sensing the stored hot water temperature should be arranged on the hot water storage tank 11. It is also desirable that at least one stored hot water temperature sensor should be located at a position of a height between the outlet 21 and the inlet 22. In the illustrated example, a lower-part stored hot water temperature sensor 38 is provided at a position of a height between the outlet 21 and the inlet 22. In addition, in the illustrated example, an upper-part stored hot water temperature sensor 39 is further provided at a position above the outlet 21. A stored hot water temperature in an upper part in the hot water storage tank 11 can be sensed by the upper-part stored hot water temperature sensor 39.

[0038] In the following description, a temperature of the heat medium flowing into the heat pump apparatus 2 will be referred to as a "heat pump inlet temperature". The heat pump inlet temperature is equivalent to a temperature of the heat medium flowing into the secondary flow path 5b of the first heat exchanger 5. A temperature of the heat medium flowing out of the heat pump apparatus 2

will be referred to as a "heat pump outlet temperature". The heat pump outlet temperature is equivalent to a temperature of the heat medium flowing out of the secondary flow path 7b of the second heat exchanger 7.

[0039] The heat pump apparatus 2 further includes a heat pump inlet temperature sensor 40, a heat pump outlet temperature sensor 41, and an outside air temperature sensor 42. The heat pump inlet temperature sensor 40 installed on the passage 31 is equivalent to heat pump inlet temperature obtaining means for sensing the heat pump inlet temperature. The heat pump outlet temperature sensor 41 installed on the passage 32 is equivalent to heat pump outlet temperature sensing means for sensing the heat pump outlet temperature. The outside air temperature sensor 42 senses an outside air temperature which is a temperature of air outside the room.

[0040] A temperature of water flowing out of the outlet 21 of the hot water storage tank 11 to the tank outgoing tube 23 will be referred to as a "tank outflow temperature". The tank outflow temperature is equivalent to a temperature of water flowing into the secondary flow path 12b of the water heat exchanger 12. A tank outflow temperature sensor 45 installed on the tank outgoing tube 23 senses the tank outflow temperature.

[0041] A temperature of water passing through the tank return tube 24 and flowing into the hot water storage tank 11 through the inlet 22 will be referred to as a "tank inflow temperature". The tank inflow temperature is equivalent to a temperature of water flowing out of the secondary flow path 12b of the water heat exchanger 12 to the tank return tube 24. A tank inflow temperature sensor 46 installed on the tank return tube 24 senses the tank inflow temperature.

[0042] In the present embodiment, the hot water storage tank 11 has an uppermost part 47. The uppermost part 47 is equivalent to a portion above the inlet 22 in the hot water storage tank 11. An inlet of the hot water supply tube 27 is positioned in the uppermost part 47. The hot water supply tube 27 is configured to take out hot water in the uppermost part 47. Hot water in the uppermost part 47 passes through the hot water supply tube 27 to be supplied to the outside.

[0043] In the illustrated example, a second controller 10 is arranged in the enclosure 44 of the tank unit 3. As a modification, the second controller 10 may be arranged outside the enclosure 44, or the second controller 10 may be provided integrally with the heat pump apparatus 2.

[0044] The first controller 8 and the second controller 10 are connected such that bidirectional data communication can be made by wire or wirelessly. The first controller 8 and the second controller 10 are equivalent to control circuitry or control means for controlling a behavior of the hot water supply system 1. At least one of the first controller 8 and the second controller 10 may have a timer function of managing the time. At least one of the first controller 8 and the second controller 10 may have a calendar function of managing the date.

[0045] In the present embodiment, the first controller 8 and the second controller 10 cooperate to control the behavior of the hot water supply system 1. The present disclosure is not limited to a configuration in which a plurality of controllers cooperate to control the behavior of the hot water supply system 1 as in the illustrated example, and a configuration in which the behavior of the hot water supply system 1 is controlled by a single controller may be adopted.

[0046] The hot water supply system 1 of the present embodiment includes a remote controller 50. The remote controller 50 and the second controller 10 are connected such that bidirectional data communication can be made by wire or wirelessly. The remote controller 50 and the second controller 10 may communicate with each other via a local area network or the Internet. The remote controller 50 may be installed in a room. The remote controller 50 has a function of accepting user's operation concerning an operation behavior command, changing of a set value, and others. The remote controller 50 is equivalent to a human interface. Although illustration is omitted, the remote controller 50 may be equipped with a display that displays information concerning the state of the hot water supply system 1, an operation unit such as a switch to be operated by a user, a speaker, a microphone, and the like. The hot water supply system 1 may include a plurality of remote controllers 50 installed at difference places.

[0047] A configuration may be adopted in which a mobile device such as a smartphone or tablet terminal, for example, can be used as a human interface of the hot water supply system 1 instead of the remote controller 50 or in addition to the remote controller 50. Although the following description mainly provides an example in which the remote controller 50 is used as a representative of the human interface, every processing through use of the remote controller 50 can be replaced by processing through use of the above-described mobile device in the present disclosure.

[0048] Fig. 2 is a functional block diagram of the hot water supply system 1 according to the first embodiment. As illustrated in Fig. 2, each of the constant speed compressor 4, the inverter compressor 6, the first expansion valve 16, the second expansion valve 18, the air blower 20, the first discharge temperature sensor 36, the second discharge temperature sensor 37, the heat pump inlet temperature sensor 40, the heat pump outlet temperature sensor 41, and the outside air temperature sensor 42 is electrically connected to the first controller 8. Each of the heat medium pump 13, the water pump 14, the flow path switching valve 15, the lower-part stored hot water temperature sensor 38, the upper-part stored hot water temperature sensor 39, the tank outflow temperature sensor 45, and the tank inflow temperature sensor 46 is electrically connected to the second controller 10.

[0049] Each of functions of the first controller 8 may be achieved by processing circuitry. The processing circuitry of the first controller 8 may include at least one processor

8a and at least one memory 8b. The at least one processor 8a may read out and execute a program saved in the at least one memory 8b to achieve each of the respective functions of the first controller 8. The processing circuitry of the first controller 8 may include at least one piece of dedicated hardware.

[0050] Each of functions of the second controller 10 may be achieved by processing circuitry. The processing circuitry of the second controller 10 may include at least one processor 10a and at least one memory 10b. The at least one processor 10a may read out and execute a program saved in the at least one memory 10b to achieve each of the respective functions of the second controller 10. The processing circuitry of the second controller 10 may include at least one piece of dedicated hardware.

[0051] The second controller 10 may be capable of controlling the heat medium pump 13 such that the rotation speed is variable through inverter control, for example. The second controller 10 may be capable of controlling the water pump 14 such that the rotation speed is variable through inverter control, for example.

[0052] The hot water supply system 1 can execute hot water storage operation. The first controller 8 and the second controller 10 control the hot water storage operation. Hereinafter, a behavior example during the hot water storage operation will be described.

[0053] In the hot water storage operation, at least one of the constant speed compressor 4 and the inverter compressor 6, the heat medium pump 13, the water pump 14, and the air blower 20 are actuated. In addition, in the flow path switching valve 15, the a port communicates with the c port, and the d port is closed. Herein, the hot water storage operation in which both the constant speed compressor 4 and the inverter compressor 6 are actuated will be described.

[0054] The refrigerant compressed by the constant speed compressor 4 to be raised in temperature and pressure flows into the primary flow path 5a of the first heat exchanger 5. The refrigerant flowing in the primary flow path 5a is cooled by the heat medium flowing in the secondary flow path 5b. The refrigerant having passed through the primary flow path 5a is depressurized by the first expansion valve 16 to be low-temperature, low-pressure refrigerant. This low-temperature, low-pressure refrigerant flows into the first evaporator 17. In the first evaporator 17, heat is exchanged between air outside the room having passed through the second evaporator 19, guided by the air blower 20, and the low-temperature, low-pressure refrigerant. The refrigerant evaporates by being heated in the first evaporator 17 by air outside the room. The evaporated refrigerant is sucked in the constant speed compressor 4. A refrigerating cycle by the first refrigerant circuit 48 is thus formed.

[0055] The heat medium heated in the first heat exchanger 5 under the heat of the refrigerant passes through the passage 9 to flow into the secondary flow path 7b of the second heat exchanger 7. The refrigerant compressed by the inverter compressor 6 to be raised in

temperature and pressure flows into the primary flow path 7a of the second heat exchanger 7. The refrigerant flowing in the primary flow path 7a is cooled by the heat medium flowing in the secondary flow path 7b. The refrigerant having passed through the primary flow path 7a is depressurized by the second expansion valve 18 to be low-temperature, low-pressure refrigerant. This low-temperature, low-pressure refrigerant flows into the second evaporator 19. In the second evaporator 19, heat is exchanged between air outside the room guided by the air blower 20 and the low-temperature, low-pressure refrigerant. The refrigerant evaporates by being heated in the second evaporator 19 by air outside the room. The evaporated refrigerant is sucked in the inverter compressor 6. A refrigerating cycle by the second refrigerant circuit 49 is thus formed.

[0056] The heat medium having passed through the first heat exchanger 5 is further heated in the second heat exchanger 7 under the heat of the refrigerant. The heat medium flowed out of the second heat exchanger 7 passes through the passage 32, the flow path switching valve 15, and the passage 33 to flow into the primary flow path 12a of the water heat exchanger 12. The heat medium having passed through the primary flow path 12a passes through the passage 30, the heat medium pump 13, and the passage 31 to return to the first heat exchanger 5. A circuit in which the heat medium thus circulates passing through the first heat exchanger 5 and the water heat exchanger 12 will be hereinafter referred to as a "heat medium circuit".

[0057] Water in the lower part of the hot water storage tank 11 passes through the outlet 21 and the tank outgoing tube 23 to flow into the secondary flow path 12b of the water heat exchanger 12. In the water heat exchanger 12, water flowing in the secondary flow path 12b is heated by the heat medium flowing in the primary flow path 12a. The heated water passes through the tank return tube 24 and the inlet 22 to flow into the upper part of the hot water storage tank 11.

[0058] The second controller 10 makes the rotation speed of the water pump 14 relatively high such that the flow rate of water flowing in the water circuit 25 becomes relatively high. As a result, in the hot water storage tank 11, water is heated to a substantially uniform temperature without a temperature boundary layer being formed over a range from the height of the inlet 22 to which the tank return tube 24 is connected to the height of the outlet 21 to which the tank outgoing tube 23 is connected. In addition, hot water passing through the tank return tube 24 and the inlet 22 to flow into the hot water storage tank 11 rises to a position above the inlet 22 by buoyancy. As a result, the whole water in the hot water storage tank 11 is heated to a substantially uniform temperature. However, in a case where hot water having a temperature higher than the temperature of water heated in the water heat exchanger 12 remains in the uppermost part 47 of the hot water storage tank 11, the high-temperature hot water may continue to remain in the

uppermost part 47.

[0059] In the hot water storage operation of the present embodiment, the temperature of water in the hot water storage tank 11 gradually rises by means of repeated circulation of water stored in the hot water storage tank 11 to the water heat exchanger 12 by the water circuit 25. Thus, each of the tank outflow temperature and the tank inflow temperature rises continuously from the start of the hot water storage operation to the completion of the hot water storage operation. In addition, the heat pump inlet temperature rises continuously from the start of the hot water storage operation to the completion of the hot water storage operation.

[0060] When an upper-part stored hot water temperature sensed by the upper-part stored hot water temperature sensor 39 falls below a predetermined threshold value while the hot water storage operation is not executed, the first controller 8 and the second controller 10 may start the hot water storage operation. When the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 reaches a predetermined target stored hot water temperature while the hot water storage operation is executed, the first controller 8 and the second controller 10 may terminate the hot water storage operation.

[0061] By adjusting the rotation speed of the inverter compressor 6 by the first controller 8, a heating capacity of the second heat exchanger 7 during the hot water storage operation can be adjusted. The heating capacity of the second heat exchanger 7 refers to the amount of heat that the heat medium receives from the refrigerant in the second heat exchanger 7 per unit time. The unit of the heating capacity is W (watt), for example. As the rotation speed of the inverter compressor 6 is higher, the heating capacity of the second heat exchanger 7 is higher.

[0062] Since the rotation speed of the constant speed compressor 4 cannot be adjusted, a heating capacity of the first heat exchanger 5 cannot be adjusted during operation of the constant speed compressor 4. The heating capacity of the first heat exchanger 5 refers to the amount of heat that the heat medium receives from the refrigerant in the first heat exchanger 5 per unit time. The heating capacity of the whole heat pump apparatus 2 is the sum of the heating capacity of the first heat exchanger 5 and heating capacity of the second heat exchanger 7.

[0063] The present embodiment enables the heating capacity of the whole heat pump apparatus 2 to be adjusted by adjusting the rotation speed of the inverter compressor 6. In addition, since there is no need to provide an inverter device for the constant speed compressor 4, the heat pump apparatus 2 can be reduced in size and cost.

[0064] According to the present embodiment, the flow path of the heat medium in the first heat exchanger 5 and the flow path of the heat medium in the second heat exchanger 7 are connected in series. Thus, the total amount of the heat medium flowing in the heat medium circuit flows into each of the first heat exchanger 5 and the

second heat exchanger 7. This causes the flow velocity of the heat medium in the first heat exchanger 5 and the flow velocity of the heat medium in the second heat exchanger 7 to be higher than in a configuration in which the flow path of the heat medium in the first heat exchanger 5 and the flow path of the heat medium in the second heat exchanger 7 are connected in parallel, which results in improved heat transfer coefficient.

[0065] In a case where either one of a behavior of the first refrigerant circuit 48 having the first heat exchanger 5 and a behavior of the second refrigerant circuit 49 having the second heat exchanger 7 is stopped in the configuration in which the flow path of the heat medium in the first heat exchanger 5 and the flow path of the heat medium in the second heat exchanger 7 are connected in parallel, a valve for closing the flow path of the heat medium passing through the heat exchanger of the stopped refrigerant circuit is required. In contrast, the series connection as in the present embodiment is advantageous in that the valve is not required.

[0066] While the hot water storage operation of the present embodiment is executed, the heat pump inlet temperature rises continuously as described earlier. When the heat pump inlet temperature rises, the condensation pressure of the first refrigerant circuit 48 rises, and the condensation pressure of the second refrigerant circuit 49 also rises. According to the present embodiment, the rotation speed of the inverter compressor 6 is lowered in a case where the condensation pressure of the second refrigerant circuit 49 is increased, so that the condensation pressure of the second refrigerant circuit 49 can be prevented from rising, and the condensation pressure of the second refrigerant circuit 49 can be adjusted so as not to exceed the design pressure. Therefore, the hot water storage operation can be performed stably. In addition, since the flow path of the heat medium in the first heat exchanger 5 is located on the upstream side of the flow path of the heat medium in the second heat exchanger 7, the temperature of the heat medium flowing in the first heat exchanger 5 is lower than the temperature of the heat medium flowing in the second heat exchanger 7. Therefore, the condensation pressure is relatively less likely to rise in the first refrigerant circuit 48 even if the rotation speed of the constant speed compressor 4 cannot be adjusted. Consequently, it is advantageous in preventing the condensation pressure of the first refrigerant circuit 48 from rising, which enables the hot water storage operation to be performed more stably.

[0067] During the hot water storage operation, the first controller 8 may adjust an opening of the first expansion valve 16 such that a discharge temperature of the constant speed compressor 4 sensed by the first discharge temperature sensor 36 becomes equal to a predetermined temperature. As the opening of the first expansion valve 16 is larger, the flow rate of the refrigerant in the first refrigerant circuit 48 increases, and the discharge temperature of the constant speed compressor 4 decreases.

During the hot water storage operation, the first controller 8 may adjust an opening of the second expansion valve 18 such that a discharge temperature of the inverter compressor 6 sensed by the second discharge temperature sensor 37 becomes equal to a predetermined temperature. As the opening of the second expansion valve 18 is larger, the flow rate of the refrigerant in the second refrigerant circuit 49 increases, and the discharge temperature of the inverter compressor 6 decreases.

[0068] During the hot water storage operation, the second controller 10 may fix the rotation speed of the heat medium pump 13 at such a rotation speed that the flow rate of the heat medium flowing in the heat medium circuit becomes equal to a predetermined value. Alternatively, the second controller 10 may adjust the rotation speed of the heat medium pump 13 such that a difference between the heat pump outlet temperature sensed by the heat pump outlet temperature sensor 41 and the heat pump inlet temperature sensed by the heat pump inlet temperature sensor 40 becomes equal to a target temperature difference.

[0069] During the hot water storage operation, the second controller 10 may fix the rotation speed of the water pump 14 at such a rotation speed that the flow rate of water flowing in the water circuit 25 becomes equal to a predetermined value. Alternatively, the second controller 10 may adjust the rotation speed of the water pump 14 such that a difference between the tank inflow temperature sensed by the tank inflow temperature sensor 46 and the tank outflow temperature sensed by the tank outflow temperature sensor 45 becomes equal to a target temperature difference.

[0070] In the present embodiment, the first controller 8 or the second controller 10 may estimate the heat pump inlet temperature using information about the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38. In this case, the first controller 8 or the second controller 10 is equivalent to heat pump inlet temperature obtaining means for estimating the heat pump inlet temperature. As described earlier, during the hot water storage operation, the temperature of water in the hot water storage tank 11 at the height between the outlet 21 and the inlet 22 is uniform. Thus, the lower-part stored hot water temperature and the tank outflow temperature are equivalent. A difference between the temperature of the heat medium flowing out of the primary flow path 12a of the water heat exchanger 12 and the tank outflow temperature which is the temperature of water flowing into the secondary flow path 12b will be hereinafter referred to as a "primary/secondary temperature difference". The primary/secondary temperature difference is determined by heat exchange performance of the water heat exchanger 12, the flow rate of the heat medium in the heat medium circuit, and the flow rate of water in the water circuit 25. Thus, the first controller 8 or the second controller 10 can previously estimate the primary/secondary temperature difference and previously save the primary/secondary temperature dif-

ference as a fixed value. If the amount of heat dissipated from the passage 31 is small, it is considered that the heat pump inlet temperature is substantially equal to the temperature of the heat medium flowing out of the primary flow path 12a of the water heat exchanger 12. From the foregoing, the first controller 8 or the second controller 10 can estimate the heat pump inlet temperature by adding the primary/secondary temperature difference previously saved to the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38. In the case where the first controller 8 or the second controller 10 can estimate the heat pump inlet temperature, the heat pump apparatus 2 may not include the heat pump inlet temperature sensor 40.

[0071] In the present embodiment, the first controller 8 and the second controller 10 receive information about the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 before starting the hot water storage operation, and in a case where the lower-part stored hot water temperature before starting the hot water storage operation is lower than a reference, actuate both the inverter compressor 6 and the constant speed compressor 4 to start the hot water storage operation, and in a case where the lower-part stored hot water temperature before starting the hot water storage operation is more than or equal to the reference, actuate the inverter compressor 6 to start the hot water storage operation without actuating the constant speed compressor 4.

[0072] Fig. 3 is a flowchart illustrating an example of processing executed before the hot water storage operation is started. The flowchart of Fig. 3 is executed before the first controller 8 activates the constant speed compressor 4 and the inverter compressor 6. When the second controller 10 determines that start conditions for the hot water storage operation are satisfied, it is determined in step S101 in Fig. 3 whether the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 is less than a first predetermined temperature. This first predetermined temperature is equivalent to the above-described reference. The value of the first predetermined temperature may be approximately 40°C, for example. If the lower-part stored hot water temperature is less than the first predetermined temperature, the process proceeds into step S102, and setting is made so as to operate both the constant speed compressor 4 and the inverter compressor 6 in the hot water storage operation to be started. In contrast, if the lower-part stored hot water temperature is more than or equal to the first predetermined temperature, the process proceeds into step S103, and setting is made so as to operate the inverter compressor 6 in the hot water storage operation to be started without operating the constant speed compressor 4.

[0073] Suppose that both the constant speed compressor 4 and the inverter compressor 6 are actuated to start the hot water storage operation when the lower-part stored hot water temperature before the hot water

storage operation is started is more than or equal to the first predetermined temperature. When the lower-part stored hot water temperature before the hot water storage operation is started is more than or equal to the first predetermined temperature, the heat pump inlet temperature rises immediately after the hot water storage operation is started. Since the heat medium is heated in the first heat exchanger 5, the temperature of the heat medium flowing into the second heat exchanger 7 becomes higher than the heat pump inlet temperature. Since the heating capacity of the first heat exchanger 5 cannot be adjusted, the temperature of the heat medium flowing into the second heat exchanger 7 becomes significantly higher than the heat pump inlet temperature. When the temperature of the heat medium flowing into the second heat exchanger 7 becomes high, the condensation pressure of the second refrigerant circuit 49 cannot be lowered even if the rotation speed of the inverter compressor 6 is lowered, so that the condensation pressure of the second refrigerant circuit 49 might exceed the design pressure. As a result, after the hot water storage operation is started, the inverter compressor 6 might stop suddenly after short-time operation, resulting in an unstable behavior of the heat pump apparatus 2. When the inverter compressor 6 stops after short-time operation, the behavior of the second refrigerant circuit 49 will stop before a refrigeration machine oil discharged from the inverter compressor 6 immediately after activation goes round the second refrigerant circuit 49 and returns to the inverter compressor 6. Thus, next time the inverter compressor 6 is activated, the amount of the refrigeration machine oil in the inverter compressor 6 might be insufficient, which causes a lubrication failure.

[0074] In contrast, according to the present embodiment, when the lower-part stored hot water temperature before the hot water storage operation is started is more than or equal to the first predetermined temperature, the inverter compressor 6 is actuated to start the hot water storage operation without actuating the constant speed compressor 4. Thus, the heat medium flows into the second heat exchanger 7 without being heated in the first heat exchanger 5, so that the temperature of the heat medium flowing into the second heat exchanger 7 is low. Therefore, the condensation pressure of the second refrigerant circuit 49 is less likely to rise, which can more reliably prevent such a situation that the inverter compressor 6 suddenly stops, and the hot water storage operation can be performed stably. In addition, occurrence of a shortage of the refrigeration machine oil in the inverter compressor 6 as described above can be prevented more reliably.

[0075] According to the present embodiment, it can be determined whether to operate the constant speed compressor 4 using the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 before the hot water storage operation is started. This brings about an advantage in that the heat medium pump 13 and the water pump 14 do not need to

be operated when it is determined whether the constant speed compressor 4 needs to be activated.

[0076] While the hot water storage operation is executed, the first controller 8 may adjust the rotation speed of the inverter compressor 6 such that the heat pump outlet temperature sensed by the heat pump outlet temperature sensor 41 does not exceed an upper limit value. In other words, the first controller 8 may gradually lower the rotation speed of the inverter compressor 6 while the hot water storage operation is executed such that the heat pump outlet temperature does not exceed the upper limit value. This enables the heating capacity of the heat pump apparatus 2 to be maximized within a possible operation range.

[0077] When the heat pump inlet temperature reaches the reference while the hot water storage operation in which both the inverter compressor 6 and the constant speed compressor 4 are actuated is executed, the first controller 8 may stop the constant speed compressor 4 and leave the inverter compressor 6 actuated. When the constant speed compressor 4 is stopped, the heat medium flows into the second heat exchanger 7 without being heated by the first heat exchanger 5. Thus, the temperature of the heat medium flowing into the second heat exchanger 7 is low. As a result, the condensation pressure of the second refrigerant circuit 49 can be prevented from rising, which can reliably prevent such a situation that the condensation pressure of the second refrigerant circuit 49 from exceeding the design pressure so that the inverter compressor 6 stops. Therefore, the hot water storage operation can be continued stably. Thereafter, in a case where the heat pump inlet temperature rises further, the first controller 8 can further continue the hot water storage operation while preventing the condensation pressure of the second refrigerant circuit 49 from rising by lowering the rotation speed of the inverter compressor 6. The hot water storage operation can thus be performed until the heat pump inlet temperature reaches a higher temperature. As a result, the temperature in the hot water storage tank 11 at the time when the hot water storage operation is terminated can be made higher.

[0078] An example of processing in which the first controller 8 and the second controller 10 determine to stop the constant speed compressor 4 and stop the inverter compressor 6 during the hot water storage operation will now be described. Fig. 4 is a flowchart illustrating an example of processing executed by the first controller 8 and the second controller 10 while the hot water storage operation in which both the constant speed compressor 4 and the inverter compressor 6 are actuated is executed. The first controller 8 and the second controller 10 execute the flowchart in Fig. 4 after setting both the constant speed compressor 4 and the inverter compressor 6 to operate to start the hot water storage operation in step S102 in Fig. 3.

[0079] In step S201 in Fig. 4, the first controller 8 continues operation of the inverter compressor 6 and operation of the constant speed compressor 4. In this

state, in step S202, the first controller 8 determines whether the heat pump inlet temperature is more than or equal to a second predetermined temperature. This second predetermined temperature is equivalent to the aforementioned reference. The value of the second predetermined temperature may be approximately 53°C, for example. Note that the value of the heat pump inlet temperature used by the first controller 8 in step S202 may be a value sensed by the heat pump inlet temperature sensor 40 or may be a value estimated by adding the primary/secondary temperature difference to the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38.

[0080] In a case where the heat pump inlet temperature has not reached the second predetermined temperature in step S202, the process returns to step S201, and operation of the inverter compressor 6 and operation of the constant speed compressor 4 are continued.

[0081] When the heat pump inlet temperature is more than or equal to the second predetermined temperature in step S202, the first controller 8 stops the constant speed compressor 4 in step S203, and continues operation of the inverter compressor 6 in step S204. The heat pump apparatus 2 thus transitions into operation in which operation of the first refrigerant circuit 48 stops, and the heat medium is heated only by the second refrigerant circuit 49.

[0082] Subsequently, in step S205, the first controller 8 determines whether the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 is more than or equal to the target stored hot water temperature. In a case where the lower-part stored hot water temperature has not reached the target stored hot water temperature, the process returns to step S204, and operation of the inverter compressor 6 is continued.

[0083] When the lower-part stored hot water temperature reaches the target stored hot water temperature, the process proceeds from step S205 into step S206, and the first controller 8 stops the inverter compressor 6. Then, in step S207, the first controller 8 stops the heat medium pump 13 and the water pump 14. The hot water storage operation is thereby terminated (step S208).

[0084] In a case where the heat pump apparatus 2 is installed at a position distant from the tank unit 3, and the passage 31 is large in length, it takes time from a rise in the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 to a rise in the heat pump inlet temperature. Thus, if the heat pump inlet temperature is estimated by adding the primary/secondary temperature difference to the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38, a rise in the heat pump inlet temperature can be sensed before the heat pump inlet temperature actually rises. Thus, in a case where the first controller 8 determines to stop the constant speed compressor 4 using the heat pump inlet temperature estimated from the lower-part stored hot

water temperature in step S202 and step S203 described above, a rise in the heat pump inlet temperature can be sensed at an earlier stage, and the constant speed compressor 4 can be stopped. This brings about an advantage in that such a case in which the heat pump inlet temperature suddenly rises can also be reliably dealt with.

[0085] The tank unit 3 may not include the lower-part stored hot water temperature sensor 38. In a case where the lower-part stored hot water temperature sensor 38 is not provided, the lower-part stored hot water temperature can be sensed by operating the water pump 14 for a short time to sense the temperature of water flowing out through the outlet 21 of the hot water storage tank 11 by the tank outflow temperature sensor 45 before the refrigerant circuit of the heat pump apparatus 2 is activated.

[0086] The tank unit 3 may include neither the lower-part stored hot water temperature sensor 38 nor the tank outflow temperature sensor 45. In a case where neither the lower-part stored hot water temperature sensor 38 nor the tank outflow temperature sensor 45 is provided, the heat medium pump 13 and the water pump 14 should only be operated for a short time to sense the heat pump inlet temperature by the heat pump inlet temperature sensor 40 before the refrigerant circuit of the heat pump apparatus 2 is activated. Before starting the hot water storage operation, the heat pump apparatus 2 may determine whether to activate the constant speed compressor 4 using the thus sensed heat pump inlet temperature.

[0087] An example in which the first controller 8 adjusts the rotation speed of the inverter compressor 6 in accordance with the heat pump outlet temperature will now be described with reference to Fig. 5 and Fig. 6. Fig. 5 is a flowchart illustrating an example of processing executed by the first controller 8 during the hot water storage operation. Fig. 6 is a diagram illustrating changes in the rotation speed of the constant speed compressor 4, changes in the rotation speed of the inverter compressor 6, and changes in the temperature of the heat medium during the hot water storage operation. In the following description, the temperature of the heat medium between the first heat exchanger 5 and the second heat exchanger 7 will be referred to as an "intermediate temperature". In other words, the intermediate temperature is the temperature of the heat medium flowing out of the first heat exchanger 5 and flowing into the second heat exchanger 7. Herein, description will be given assuming that the amount of heat dissipated from tubes and the like in which the heat medium flows is negligible for ease of description.

[0088] When the hot water storage operation is started at time T1 in Fig. 6, and the constant speed compressor 4 and the inverter compressor 6 are activated, the heat medium is heated by the first heat exchanger 5, so that the intermediate temperature becomes higher than the heat pump inlet temperature. In addition, when the heat medium is further heated by the second heat exchanger

7, the heat pump outlet temperature becomes higher than the intermediate temperature. After the start of the hot water storage operation, the first controller 8 may operate the inverter compressor 6 at a highest rotation speed or may operate the inverter compressor 6 at a rotation speed which is lower than the highest rotation speed and which provides high operation efficiency.

[0089] After the start of the hot water storage operation, the first controller 8 continues operation of the constant speed compressor 4 and the inverter compressor 6 in step S301 in Fig. 5. Then, in step S302, the first controller 8 determines whether the heat pump outlet temperature sensed by the heat pump outlet temperature sensor 41 has reached a heat pump outlet temperature upper limit value. In the case where the heat pump outlet temperature has not reached the heat pump outlet temperature upper limit value, the process returns to step S301, and operation of the constant speed compressor 4 and the inverter compressor 6 is continued.

[0090] As illustrated in Fig. 6, the heat pump outlet temperature gradually rises after time T1 and reaches the heat pump outlet temperature upper limit value at time T2. When the heat pump outlet temperature reaches the heat pump outlet temperature upper limit value in step S302 in Fig. 5, the first controller 8 adjusts the heat pump outlet temperature in step S303 by lowering the rotation speed of the inverter compressor 6 such that the heat pump outlet temperature does not exceed the heat pump outlet temperature upper limit value. Note that the heat pump outlet temperature upper limit value is previously saved in the first controller 8 as such a value that the condensation pressure of the second refrigerant circuit 49 does not exceed the design pressure. The heat pump outlet temperature upper limit value may be approximately 60°C, for example.

[0091] When the temperature of water in the hot water storage tank 11 rises further after time T2 in Fig. 6, the intermediate temperature also rises further. Thus, the first controller 8 lowers the rotation speed of the inverter compressor 6 with time. The process proceeds from step S303 into step S304, and the first controller 8 determines whether the rotation speed of the inverter compressor 6 has decreased to a lower limit value. In a case where the rotation speed of the inverter compressor 6 is still higher than the lower limit value, the process returns to step S303.

[0092] In Fig. 6, a state in which the rotation speed of the inverter compressor 6 has been lowered to the lower limit value is brought about at time T3. When the rotation speed of the inverter compressor 6 is lowered to the lower limit value, the process proceeds from step S304 into step S305, and the first controller 8 stops the constant speed compressor 4. As illustrated in Fig. 6, after the constant speed compressor 4 is stopped at time T3, the heat medium is no longer heated in the first heat exchanger 5. Thus, the intermediate temperature becomes equal to the heat pump inlet temperature. The heat pump

inlet temperature at this time becomes equal to the aforementioned second predetermined temperature.

[0093] The process proceeds from step S305 into step S306, and the first controller 8 increases the rotation speed of the inverter compressor 6. Then, in step S307, the first controller 8 continues operation of the inverter compressor 6. As described, when the rotation speed of the inverter compressor 6 is lowered to the lower limit value while the hot water storage operation in which both the inverter compressor 6 and the constant speed compressor 4 are actuated is executed, the first controller 8 stops the constant speed compressor 4 and continues actuating the inverter compressor 6. This can make the time during which both the constant speed compressor 4 and the inverter compressor 6 are operated as long as possible. In addition, the first controller 8 increases the rotation speed of the inverter compressor 6 when stopping the constant speed compressor 4 while the hot water storage operation in which both the inverter compressor 6 and the constant speed compressor 4 are actuated is executed. This can minimize a decrease in the heat pump outlet temperature after the constant speed compressor 4 is stopped. Therefore, low-temperature water can be prevented from flowing into the inlet 22 of the hot water storage tank 11 during the hot water storage operation.

[0094] After time T3 in Fig. 6, following a further rise in the heat pump inlet temperature, the heat pump outlet temperature also rises further. The process proceeds from step S307 into step S308, and the first controller 8 determines whether the heat pump outlet temperature sensed by the heat pump outlet temperature sensor 41 has reached the heat pump outlet temperature upper limit value. In the case where the heat pump outlet temperature has not reached the heat pump outlet temperature upper limit value, the process returns to step S307, and operation of the inverter compressor 6 is continued.

[0095] As illustrated in Fig. 6, after time T3, the heat pump outlet temperature gradually rises and reaches the heat pump outlet temperature upper limit value at time T4. When the heat pump outlet temperature reaches the heat pump outlet temperature upper limit value in step S308, the first controller 8 adjusts the heat pump outlet temperature in step S309 by lowering the rotation speed of the inverter compressor 6 such that the heat pump outlet temperature does not exceed the heat pump outlet temperature upper limit value. Then, in step S310, the first controller 8 determines whether the lower-part stored hot water temperature sensed by the lower-part stored hot water temperature sensor 38 has reached the target stored hot water temperature. In a case where the lower-part stored hot water temperature has not reached the target stored hot water temperature, the process returns to step S309. When the lower-part stored hot water temperature reaches the target stored hot water temperature, the process proceeds from step S310 into step S311, and the first controller 8 stops the inverter compressor 6. Then, in step S312, the first controller 8 stops the heat medium pump 13 and the water pump 14. The

hot water storage operation is thereby terminated (step S313, time T5 in Fig. 6).

[0096] As described above, in the present embodiment, the first controller 8 lowers and adjusts the rotation speed of the inverter compressor 6 such that the heat pump outlet temperature does not exceed the upper limit value while the hot water storage operation is executed. This enables the heating capacity of the heat pump apparatus 2 to be maximized within a possible operation range. Therefore, the time required for the hot water storage operation can be minimized.

[0097] Room-heating operation of the hot water supply system 1 will now be described. The first controller 8 and the second controller 10 control the room-heating operation. The first controller 8 and the second controller 10 control a behavior during the room-heating operation as will be described below. One or both of the constant speed compressor 4 and the inverter compressor 6 and the heat medium pump 13 are driven. The water pump 14 is stopped. In the flow path switching valve 15, the a port communicates with the d port, and the c port is closed. The behavior of the heat pump apparatus 2 is identical or similar to that in the hot water storage operation. The heat medium heated in the heat pump apparatus 2 by refrigerant passes through the passage 32, the flow path switching valve 15, and the passage 34 to flow into the room-heating device 28. The room-heating device 28 heats a room using heat of the heat medium. The temperature of the heat medium decreases during passage through the room-heating device 28. The heat medium decreased in temperature passes through the passage 35, the branch portion 29, the heat medium pump 13, and the passage 31 to return to the heat pump apparatus 2. A circuit in which the heat medium thus circulates passing through the heat pump apparatus 2 and the room-heating device 28 will be hereinafter referred to as a "room-heating circuit".

[0098] In the present embodiment, the room-heating operation and the hot water storage operation can be switched by switching between the room-heating circuit and the heat medium circuit by the flow path switching valve 15. The flow path switching valve 15 is thus equivalent to a switching valve for switching between the room-heating operation and the hot water storage operation.

Second Embodiment

[0099] A second embodiment will now be described with reference to Fig. 7. Different points from the aforementioned first embodiment will be mainly described, and description in common will be simplified or omitted. Elements common or corresponding to the aforementioned elements will be denoted by the same reference characters. Fig. 7 is a diagram illustrating a hot water supply system 51 according to the second embodiment. The hot water supply system 51 includes the heat pump apparatus 2 and a tank unit 52. The heat pump apparatus 2 included in the hot water supply system 51 is identical or

similar to the heat pump apparatus 2 of the first embodiment. Hereinafter, the tank unit 52 will be described mainly in terms of different points from the tank unit 3 of the first embodiment, and description of common points will be simplified or omitted.

[0100] The tank unit 52 is different from the tank unit 3 in that the water heat exchanger 12, the water pump 14, the water circuit 25, the tank outflow temperature sensor 45, and the tank inflow temperature sensor 46 are not provided. The tank unit 52 includes a water heat exchanger 53 arranged in the hot water storage tank 11. A heat medium tube 54 included in the water heat exchanger 53 has a shape wound in helical or coil form around a central axis of the hot water storage tank 11. The water heat exchanger 53 is submerged in the hot water storage tank 11. In terms of the position in the vertical direction, the center of the water heat exchanger 53 is located at a position below the center of the hot water storage tank 11.

[0101] The water heat exchanger 53 has an inlet 55 and an outlet 56. The inlet 55 is located at a position above the outlet 56. The inlet passage 58 connects the c port of the flow path switching valve 15 to the inlet 55 of the water heat exchanger 53. An outlet passage 57 connects the outlet 56 of the water heat exchanger 53 to the intake of the heat medium pump 13.

[0102] In the illustrated example, the heat medium tube 54 of the water heat exchanger 53 is arranged without being in contact with an inner wall surface of the hot water storage tank 11. As a modification, the heat medium tube 54 of the water heat exchanger 53 may be in contact with the inner wall surface of the hot water storage tank 11.

[0103] During the hot water storage operation through use of the tank unit 52, the heat medium heated in the heat pump apparatus 2 passes through the passage 32, the flow path switching valve 15, the inlet passage 58, and the inlet 55 to flow into the heat medium tube 54 of the water heat exchanger 53. The heat medium having passed through the heat medium tube 54 of the water heat exchanger 53 passes through the outlet 56, the outlet passage 57, the heat medium pump 13, and the passage 31 to return to the heat pump apparatus 2. In the water heat exchanger 53, heat is exchanged between the heat medium flowing in the heat medium tube 54 and water in the hot water storage tank 11 in contact with an outer wall of the heat medium tube 54, so that water is heated. Water in contact with the outer wall of the heat medium tube 54 rises by buoyancy when heated. As a result, a flow circulating by natural convection is formed in the hot water storage tank 11. Therefore, similarly to the case of the tank unit 3, the whole water in the hot water storage tank 11 is heated to a substantially uniform temperature. However, in a case where high-temperature hot water remains in the uppermost part 47 of the hot water storage tank 11, the high-temperature hot water may continue to remain in the uppermost part 47.

[0104] Although illustration is omitted, the hot water supply system according to the present disclosure may include a tank unit of a type in which a heat medium tube

included in the water heat exchanger is in contact with the outer wall of the hot water storage tank 11. Such a tank unit will be hereinafter referred to as an "external coil type". In the tank unit of the external coil type, the heat medium tube included in the water heat exchanger is wound in helical or coil form on the outer circumference of the hot water storage tank 11. The wall of the hot water storage tank 11 is heated by heat of the heat medium flowing in the heat medium tube in contact with the outer wall of the hot water storage tank 11. When heat is transferred from the inner wall of the hot water storage tank 11 to water in contact with the inner wall, water in the hot water storage tank 11 is heated. When water in contact with the inner wall of the hot water storage tank 11 is heated to float upward, natural convection is produced. The heat pump apparatus 2 according to the present disclosure can also be used in connection with the tank unit of the external coil type.

[0105] According to the second embodiment described above, effects identical or similar to those of the first embodiment can be exerted.

Third Embodiment

[0106] A third embodiment will now be described with reference to Fig. 8. Different points from the aforementioned first embodiment will be mainly described, and common description will be simplified or omitted. Elements common or corresponding to the aforementioned elements will be denoted by the same reference characters. Fig. 8 is a diagram illustrating a hot water supply system 61 according to the third embodiment. The hot water supply system 61 includes the heat pump apparatus 2 and a tank unit 62. The heat pump apparatus 2 included in the hot water supply system 61 is identical or similar to the heat pump apparatus 2 of the first embodiment. Hereinafter, the tank unit 62 will be described mainly in terms of different points from the tank unit 3 of the first embodiment, and description of common points will be simplified or omitted.

[0107] The tank unit 62 is different from the tank unit 3 in that the water heat exchanger 12, the water pump 14, the water circuit 25, the passage 30, the passage 33, the tank outflow temperature sensor 45, and the tank inflow temperature sensor 46 are not provided. The tank unit 62 includes a tank outgoing tube 63 and a tank return tube 64. The tank outgoing tube 63 connects the outlet 21 of the hot water storage tank 11 to the intake of the heat medium pump 13. The tank return tube 64 connects the c port of the flow path switching valve 15 to the inlet 22 of the hot water storage tank 11.

[0108] In the hot water supply system 61, heat is exchanged directly between water stored in the hot water storage tank 11 and refrigerant in the heat pump apparatus 2. The tank outgoing tube 63 and the passage 31 are equivalent to an outgoing water path for causing water flowed out of the outlet 21 of the hot water storage tank 11 to flow into the first heat exchanger 5 of the heat

pump apparatus 2 as a heat medium. The passage 32 and the tank return tube 64 are equivalent to a return water path for causing water which is the heat medium flowed out of the second heat exchanger 7 of the heat pump apparatus 2 to flow into the hot water storage tank 11 through the inlet 22.

[0109] In the hot water storage operation of the hot water supply system 61, water flowed out of the outlet 21 of the hot water storage tank 11 passes through the tank outgoing tube 63 and the passage 31 to flow into the heat pump apparatus 2. Water flowed into the heat pump apparatus 2 is heated during passage through the first heat exchanger 5 and the second heat exchanger 7. Water heated in the heat pump apparatus 2 passes through the passage 32 and the tank return tube 64 to flow into the hot water storage tank 11 through the inlet 22. Such a water circuit will be hereinafter referred to as a "hot water storage circuit".

[0110] During the hot water storage operation of the hot water supply system 61, the second controller 10 may make the rotation speed of the heat medium pump 13 relatively high such that the flow rate of water flowing in the hot water storage circuit becomes relatively high. In that occasion, water is heated to a substantially uniform temperature in the hot water storage tank 11 without a temperature boundary layer being formed over a range from the height of the inlet 22 to the height of the outlet 21, as in the first embodiment.

[0111] Alternatively, during the hot water storage operation of the hot water supply system 61, the second controller 10 may make the rotation speed of the heat medium pump 13 relatively low such that the flow rate of water flowing in the hot water storage circuit becomes relatively low. In that occasion, high-temperature water flowed through the inlet 22 accumulates in the upper part in the hot water storage tank 11. A temperature boundary layer is formed between this high-temperature water and low-temperature water in the lower part in the hot water storage tank 11. In the hot water supply system 61 that performs the hot water storage operation of forming such a temperature boundary layer in the hot water storage tank 11, the inlet 22 may be arranged in the uppermost part 47 of the hot water storage tank 11.

[0112] According to the third embodiment described above, effects identical or similar to those of the first embodiment can be exerted.

Reference Signs List

[0113]

1	hot water supply system
2	heat pump apparatus
3	tank unit
4	constant speed compressor
5	first heat exchanger
5a	primary flow path
5b	secondary flow path

6	inverter compressor
7	second heat exchanger
7a	primary flow path
7b	secondary flow path
5 8	first controller
8a	processor
8b	memory
9	passage
10	second controller
10 10a	processor
10b	memory
11	hot water storage tank
12	water heat exchanger
12a	primary flow path
15 12b	secondary flow path
13	heat medium pump
14	water pump
15	flow path switching valve
16	first expansion valve
20 17	first evaporator
18	second expansion valve
19	second evaporator
20	air blower
21	outlet
25 22	inlet
23	tank outgoing tube
24	tank return tube
25	water circuit
26	water supply tube
30 27	hot water supply tube
28	room-heating device
29	branch portion
30	passage
31	passage
35 32	passage
33	passage
34	passage
35	passage
36	first discharge temperature sensor
40 37	second discharge temperature sensor
38	lower-part stored hot water temperature sensor
39	upper-part stored hot water temperature sensor
40	heat pump inlet temperature sensor
41	heat pump outlet temperature sensor
45 42	outside air temperature sensor
43	enclosure
44	enclosure
45	tank outflow temperature sensor
46	tank inflow temperature sensor
50 47	uppermost part
48	first refrigerant circuit
49	second refrigerant circuit
50	remote controller
51	hot water supply system
55 52	tank unit
53	water heat exchanger
54	heat medium tube
55	inlet

- 56 outlet
- 57 outlet passage
- 58 inlet passage
- 61 hot water supply system
- 62 tank unit
- 63 tank outgoing tube
- 64 tank return tube

Claims

1. A heat pump apparatus for supplying heat for hot water storage operation to raise a temperature of water in a hot water storage tank, the heat pump apparatus comprising:

a constant speed compressor;
a first heat exchanger for exchanging heat between refrigerant compressed by the constant speed compressor and a heat medium;
a variable speed compressor; and
a second heat exchanger for exchanging heat between refrigerant compressed by the variable speed compressor and the heat medium downstream of the first heat exchanger.

2. The heat pump apparatus according to claim 1, further comprising control means capable of receiving information about a stored hot water temperature which is the temperature of water in the hot water storage tank, wherein
the control means is configured to actuate both the variable speed compressor and the constant speed compressor to start the hot water storage operation in a case where the stored hot water temperature before the hot water storage operation is started is lower than a reference, and actuate the variable speed compressor to start the hot water storage operation without actuating the constant speed compressor in a case where the stored hot water temperature before the hot water storage operation is started is more than or equal to the reference.

3. The heat pump apparatus according to claim 1, further comprising:

heat pump outlet temperature sensing means for sensing a heat pump outlet temperature which is a temperature of the heat medium flowing out of the heat pump apparatus; and
control means configured to adjust a rotation speed of the variable speed compressor such that the heat pump outlet temperature does not exceed an upper limit value while the hot water storage operation is executed.

4. The heat pump apparatus according to claim 1, further comprising:

heat pump inlet temperature obtaining means for sensing or estimating a heat pump inlet temperature which is a temperature of the heat medium flowing into the heat pump apparatus; and

control means configured to stop the constant speed compressor and continue actuating the variable speed compressor when the heat pump inlet temperature reaches a reference while the hot water storage operation in which both the variable speed compressor and the constant speed compressor are actuated is executed.

5. The heat pump apparatus according to claim 4, wherein the heat pump inlet temperature obtaining means is configured to estimate the heat pump inlet temperature using information about a stored hot water temperature which is the temperature of water in the hot water storage tank.

6. The heat pump apparatus according to claim 1, further comprising control means configured to stop the constant speed compressor and continue actuating the variable speed compressor when a rotation speed of the variable speed compressor decreases to a lower limit value while the hot water storage operation in which both the variable speed compressor and the constant speed compressor are actuated is executed.

7. The heat pump apparatus according to claim 1, further comprising control means configured to increase a rotation speed of the variable speed compressor when stopping the constant speed compressor while the hot water storage operation in which both the variable speed compressor and the constant speed compressor are actuated is executed.

8. The heat pump apparatus according to any one of claims 1 to 7, wherein the refrigerant is a combustible refrigerant.

9. A hot water supply system comprising:

the heat pump apparatus according to any one of claims 1 to 7;
the hot water storage tank; and
a water heat exchanger for exchanging heat between the heat medium flowed out of the heat pump apparatus and water stored in the hot water storage tank.

10. The hot water supply system according to claim 9, comprising:

an outlet provided for the hot water storage tank;
a tank outgoing tube for connecting the outlet to a water inlet of the water heat exchanger pro-

vided outside the hot water storage tank;
an inlet provided for the hot water storage tank at
a position above the outlet;
a tank return tube for connecting a water outlet of
the water heat exchanger to the inlet; 5
a stored hot water temperature sensor installed
in the hot water storage tank at a position of a
height between the outlet and the inlet; and
control means configured to estimate a heat
pump inlet temperature which is a temperature 10
of the heat medium flowing into the heat pump
apparatus using a result sensed by the stored
hot water temperature sensor.

11. A hot water supply system comprising: 15

the heat pump apparatus according to any one
of claims 1 to 7;
the hot water storage tank;
an outgoing water path for causing water flowed 20
out of the hot water storage tank to flow into the
first heat exchanger of the heat pump apparatus
as the heat medium; and
a return water path for causing the water which is 25
the heat medium flowed out of the second heat
exchanger of the heat pump apparatus to flow
into the hot water storage tank.

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FIG. 1

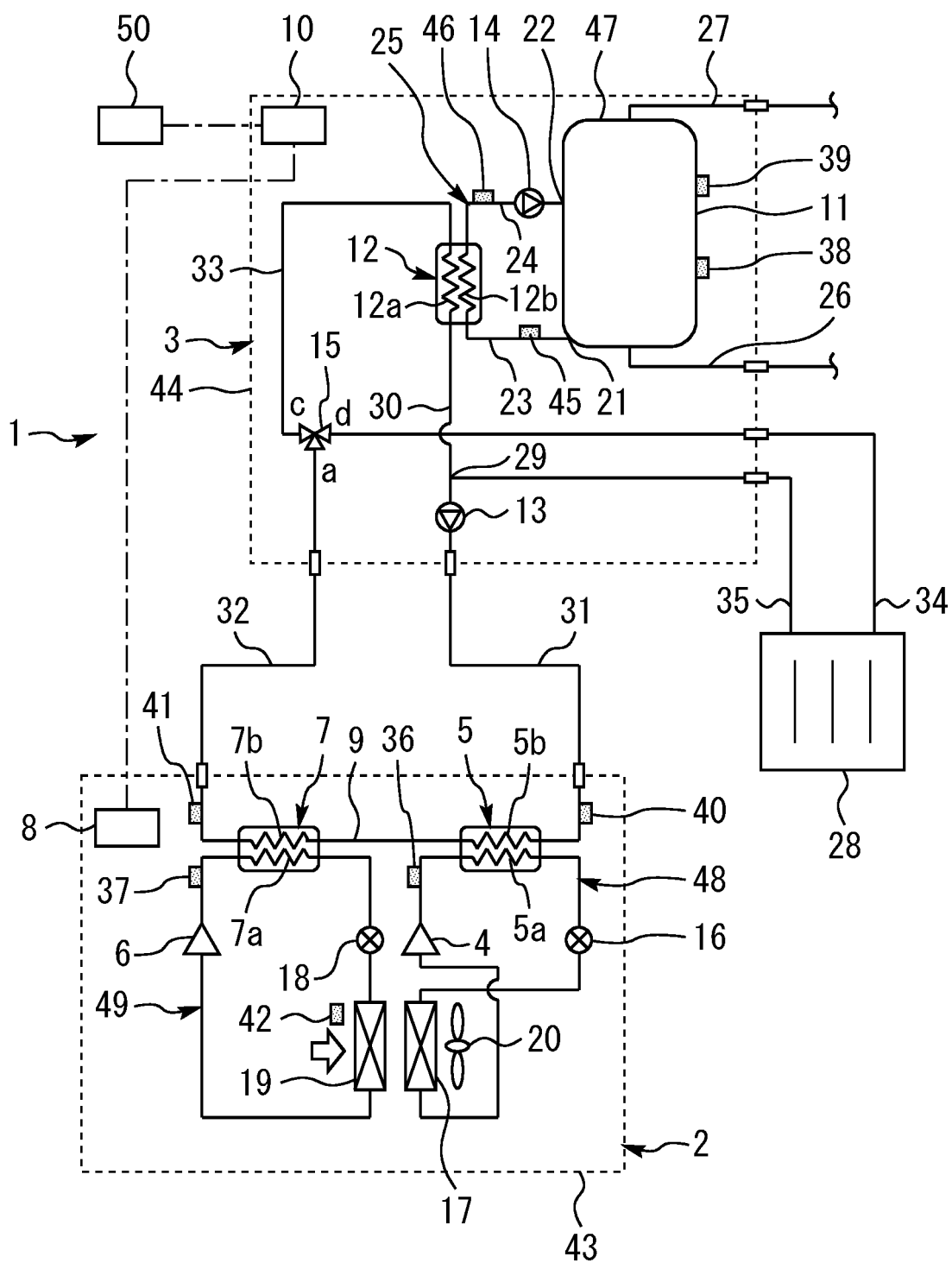


FIG. 2

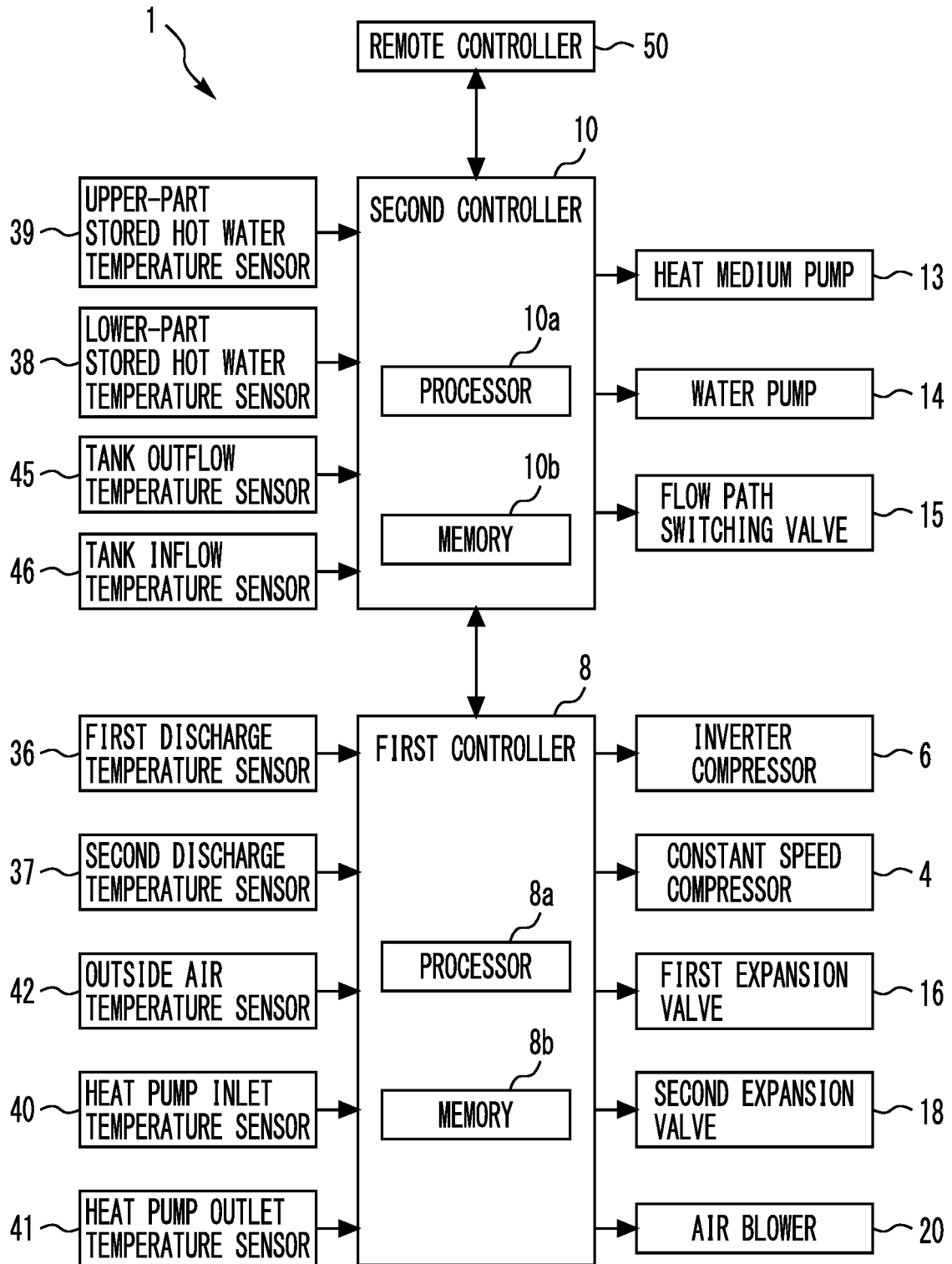


FIG. 3

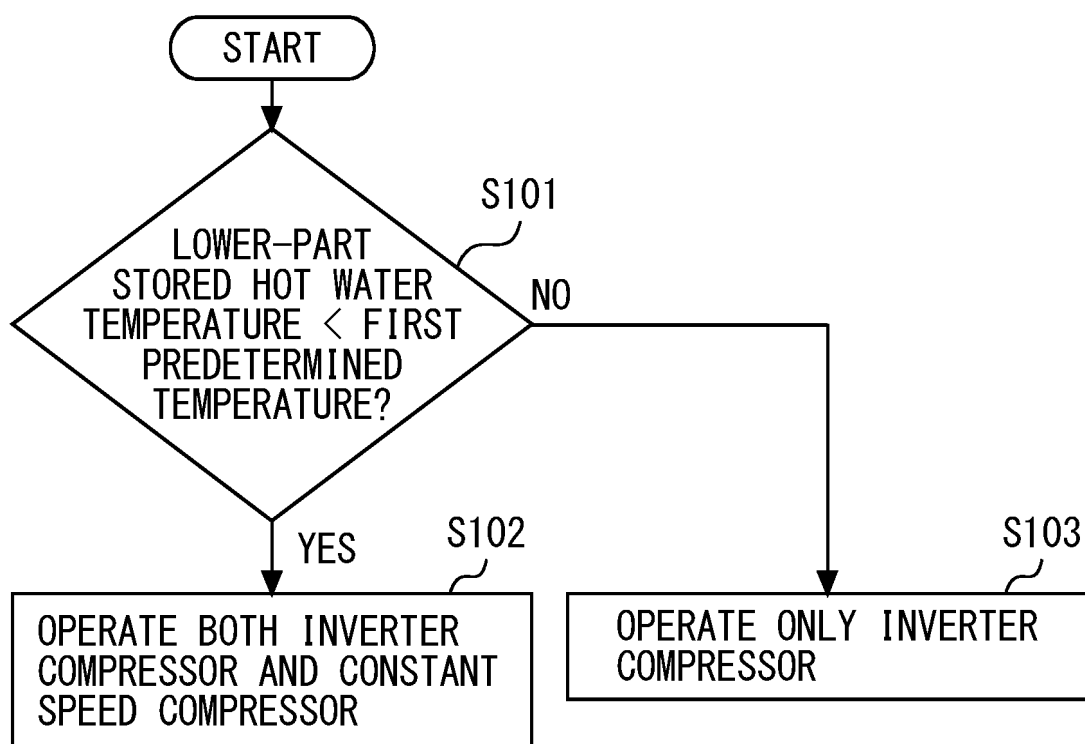


FIG. 4

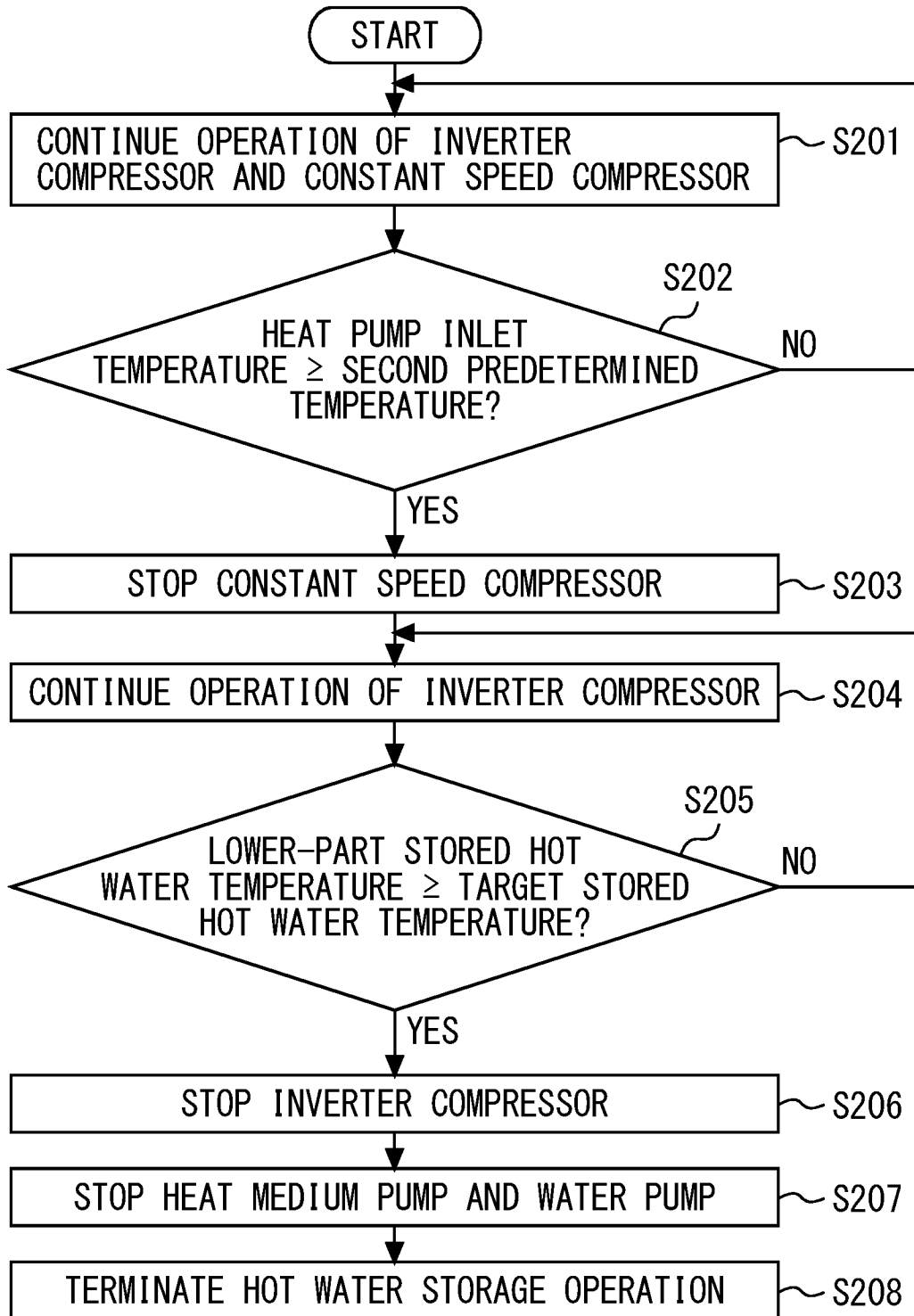


FIG. 5

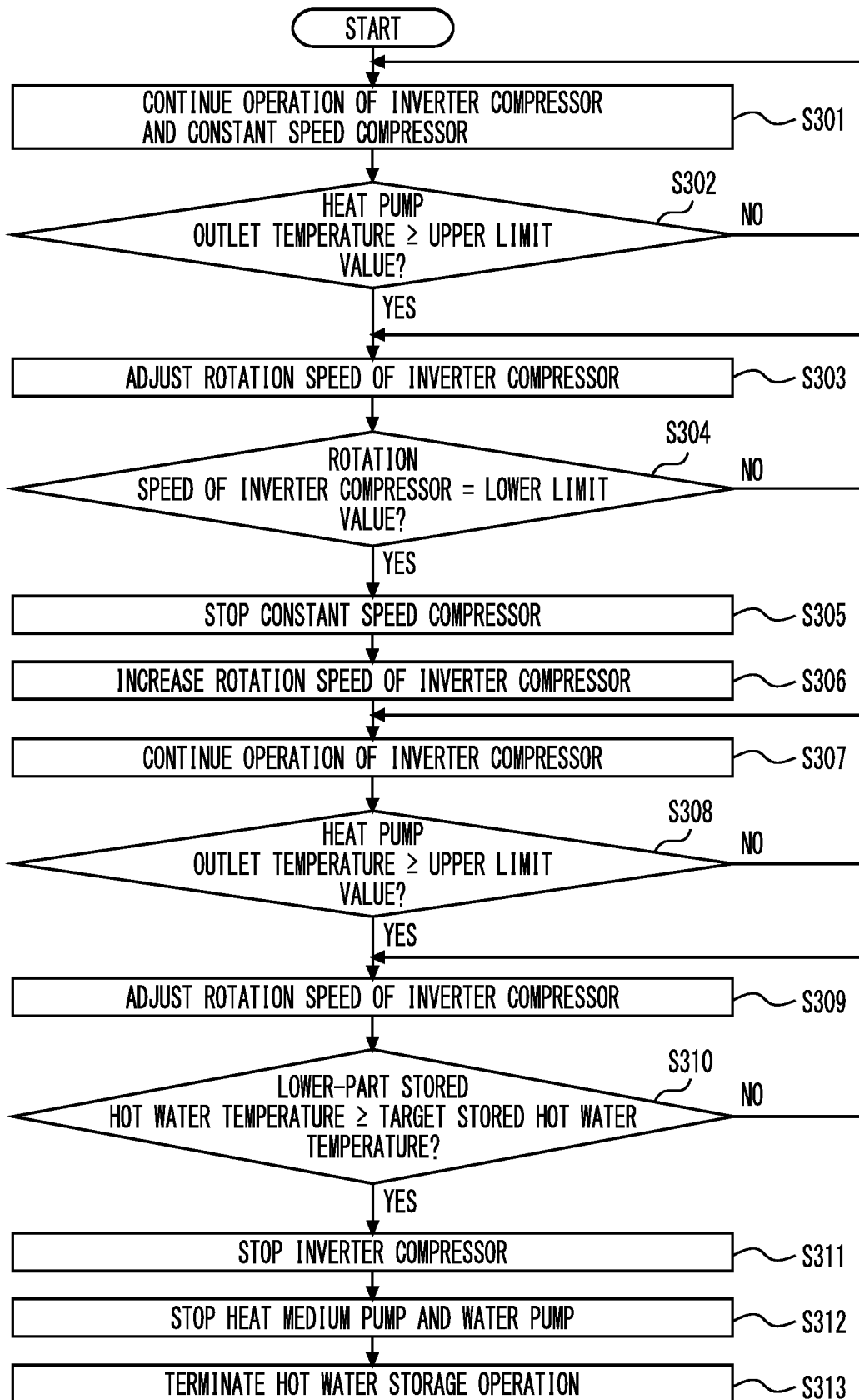


FIG. 6

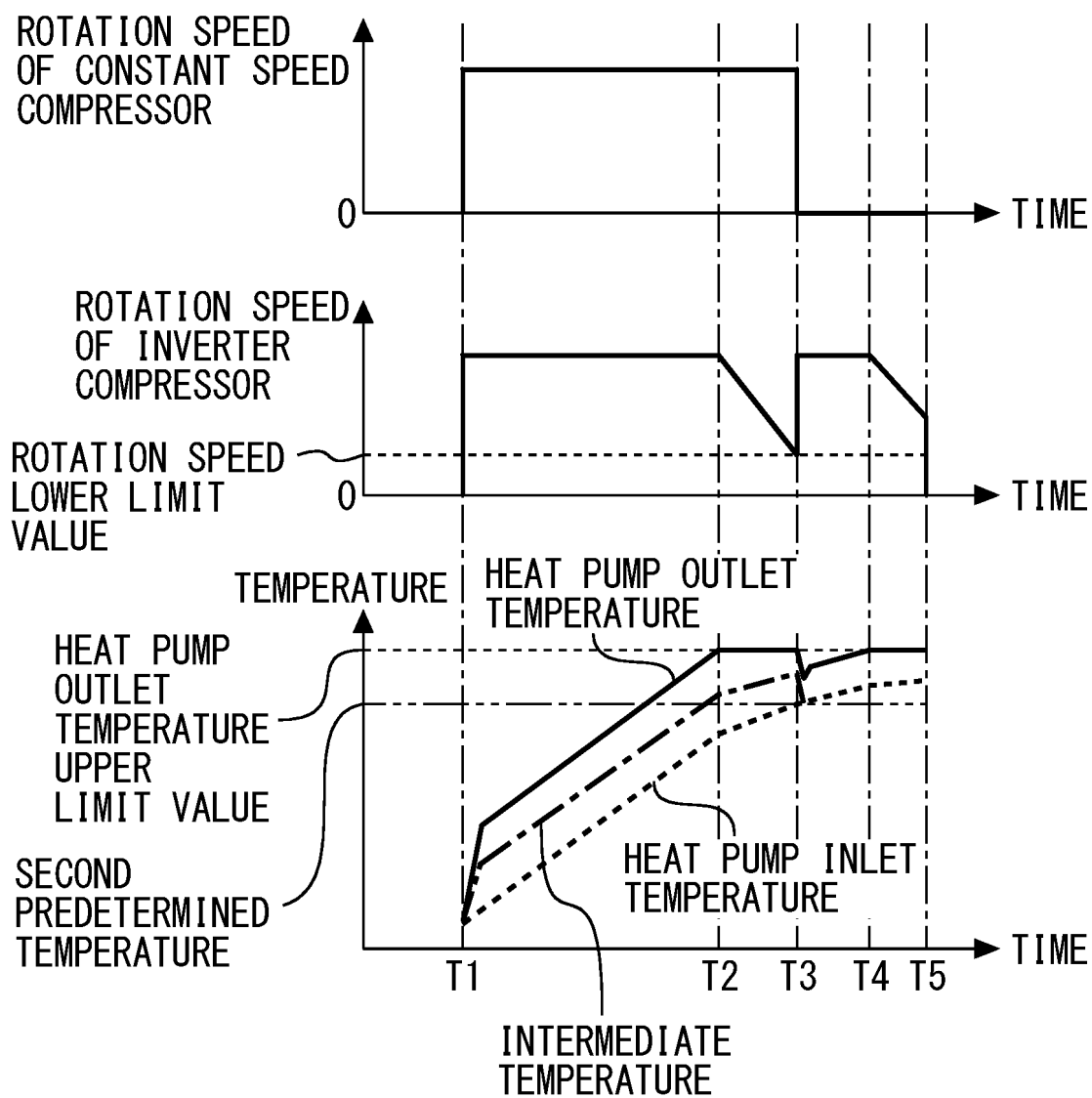


FIG. 7

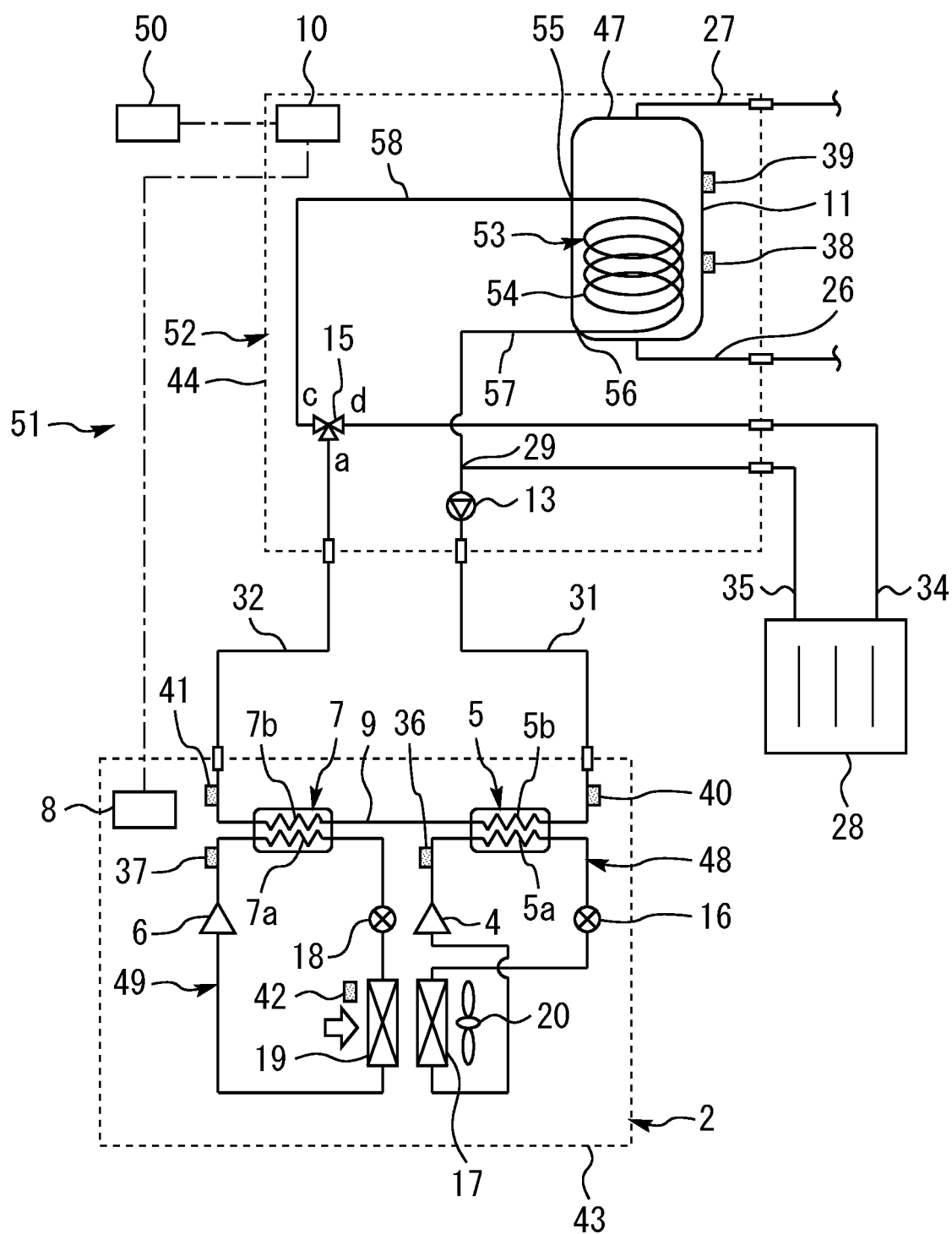
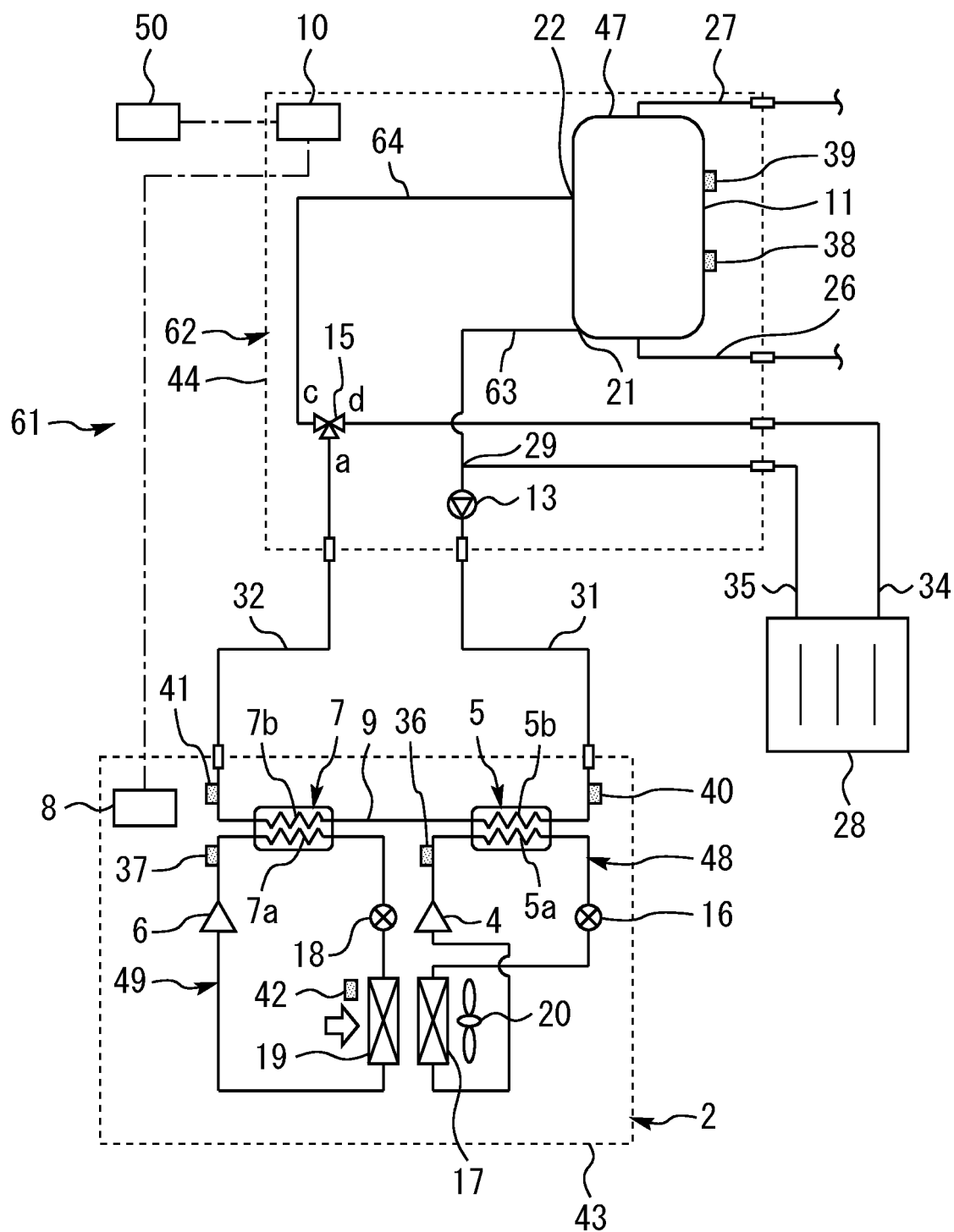


FIG. 8



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/019087

A. CLASSIFICATION OF SUBJECT MATTER

F24H 4/02(2022.01)i; **F24H 15/215**(2022.01)i; **F24H 15/219**(2022.01)i; **F24H 15/38**(2022.01)i
 FI: F24H4/02 G; F24H15/215; F24H15/219; F24H15/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F24H4/00-4/06; F24H15/00-15/493; F25B1/00; F25B6/04; F25B30/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2022
 Registered utility model specifications of Japan 1996-2022
 Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2004-233010 A (DAIKIN IND., LTD.) 19 August 2004 (2004-08-19) paragraphs [0021]-[0034], fig. 6	1, 3, 8-9, 11 2, 4-7, 10
Y A	JP 2013-530375 A (BLACK DIAMOND TECHNOLOGIES LTD.) 25 July 2013 (2013-07-25) paragraphs [0053]-[0067], fig. 1	1, 3, 8-9, 11 2, 4-7, 10
Y	JP 2016-166715 A (RINNAI CORP.) 15 September 2016 (2016-09-15) paragraphs [0028], [0040]-[0041], [0054], fig. 1, 3	3, 8-9, 11

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 08 June 2022	Date of mailing of the international search report 21 June 2022
Name and mailing address of the ISA/JP Japan Patent Office (ISA/JP) 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915 Japan	Authorized officer Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/JP2022/019087

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2004-233010 A	19 August 2004	(Family: none)	
JP 2013-530375 A	25 July 2013	WO 2012/005608 A1 specification, page 12, line 1 to page 14, line 33, fig. 1 GB 2493888 A AU 2011274655 A1 NZ 603962 A	
JP 2016-166715 A	15 September 2016	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004233010 A [0003]