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

(11) **EP 2 940 407 A1**

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
04.11.2015 Bulletin 2015/45

(21) Application number: **12891024.7**

(22) Date of filing: **26.12.2012**

(51) Int Cl.:
F25B 47/02 *(2006.01)* ***F24H 1/00*** *(2006.01)*

(86) International application number:
PCT/JP2012/083692

(87) International publication number:
WO 2014/102934 (03.07.2014 Gazette 2014/27)

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

(71) Applicants:
- **Daikin Industries, Ltd.**
  Osaka-shi, Osaka 530-8323 (JP)
- **Daikin Europe N.V.**
  8400 Oostende (BE)

(72) Inventors:
- **CHIKAMI, Hideo**
  Osaka-shi
  Osaka 530-8323 (JP)
- **OCHI, Hiroki**
  Osaka-shi
  Osaka 530-8323 (JP)
- **COESSENS, Tim**
  8400 Oostende (BE)

(74) Representative: **Global IP Europe**
Patentanwaltskanzlei
Pfarrstraße 14
80538 München (DE)

(54) HEAT PUMP HOT WATER HEATER

(57) A heat pump hot water heater (10) includes a refrigerant circuit (20), a water circuit (30) and a control unit (40). The refrigerant circuit includes a first heat exchanger (21) configured to cause heat exchange between air and refrigerant, a second heat exchanger (25) configured to cause heat exchange between the refrigerant and water, and a compressor (22) configured to compress the refrigerant. The water circuit includes the second heat exchanger and a water supply mechanism (31) configured to supply the water to the second heat exchanger. The control unit is configured to control the refrigerant circuit and the water circuit so as to perform a defrosting operation of the first heat exchanger. The refrigerant circuit is capable of switching between a forward cycle operation and a reverse cycle operation. At least either in starting the defrosting operation or during performing the defrosting operation, the control unit is configured to determine a possibility of freezing of the water in the water circuit and select to perform either the forward cycle operation or the reverse cycle operation so as to perform the defrosting operation.

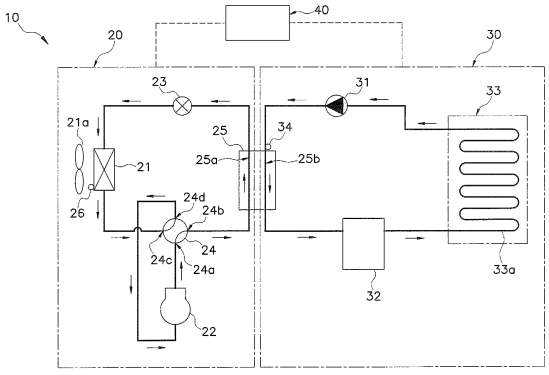

FIG. 1

EP 2 940 407 A1

Description

TEHCNICAL FIELD

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

BACKGROUND ART

[0002] A hot water dispenser, a hot water heater and so forth, in which a heat pump system is utilized, have been conventionally used. For example, Patent Literature 1 (JP 2010-181104 A) discloses a hot water dispenser as a heat pump device equipped with a refrigerant circuit and a water circuit. The refrigerant circuit is a type of circuit composed of a compressor, an outdoor heat exchanger and an indoor heat exchanger, and makes refrigerant circulate therethrough. The water circuit is a type of circuit sharing the indoor heat exchanger with the refrigerant circuit, and makes water flow therethrough. In the refrigerant circuit, the refrigerant, compressed to have high temperature in the compressor, is heat-exchanged with the water and cooled down in the indoor heat exchanger, and is reduced in pressure, and then is heat-exchanged with outdoor air and heated in the outdoor heat exchanger. The water, flowing through the water circuit, is heat-exchanged with the refrigerant and heated in the indoor heat exchanger.

[0003] In a heat pump device equipped with the outdoor heat exchanger in which the outdoor air and the refrigerant are heat-exchanged as with the aforementioned hot water dispenser, there is a possibility that when the temperature of the outdoor air is low, frost is attached to the outdoor heat exchanger and this results in degradation in operating efficiency. In this case, the heat pump device performs a defrosting operation for melting the frost attached to the outdoor heat exchanger. For example, the heat pump device performs a reverse cycle operation for causing the refrigerant to circulate through the refrigerant circuit in a direction opposite to that in a normal operation. Accordingly, the refrigerant, compressed to have high temperature in the compressor, flows into the outdoor heat exchanger, and the outdoor heat exchanger is defrosted.

SUMMARY OF THE INVENTION

<Technical Problem>

[0004] However, there is a possibility that the water freezes in the water circuit when the reverse cycle operation-based defrosting is performed for a long period of time under the condition that the temperature of outdoor air is low. A type of heat pump device has been known that is configured to defrost the outdoor heat exchanger by utilizing the heat of hot water remaining in the water circuit in order to prevent water freezing. For example, Patent Literature 1 discloses a heat pump device configured to perform the reverse cycle operation-based defrosting after heat is accumulated in the indoor heat exchanger by feeding hot water, stored in a hot water storage tank connected to the water circuit, to the indoor heat exchanger. On the other hand, Patent Literature 2 (WO 2006/103815) discloses a heat pump device having a mode for performing the reverse cycle operation-based defrosting by utilizing the heat of hot water remaining in the water circuit and a mode for performing defrosting by causing the high-temperature refrigerant discharged from the compressor in the refrigerant circuit to flow through the outdoor heat exchanger, and subsequently, by causing the refrigerant having passed through the outdoor heat exchanger to flow back to the compressor without changing the status quo of the refrigerant.

[0005] However, the aforementioned heat pump devices are required to change either the configuration of the refrigerant circuit or that of the water circuit in order to defrost the outdoor heat exchanger. Additionally, when the outdoor heat exchanger is defrosted by the reverse cycle operation of the refrigerant circuit, there is still a possibility of water freezing in the water circuit under the condition that the temperature of water in the water circuit and the temperature of outdoor air are low.

[0006] It is an object of the present invention to provide a heat pump hot water heater that is capable of preventing water freezing.

<Solution to Problem>

[0007] A heat pump hot water heater according to a first aspect of the present invention includes a refrigerant circuit, a water circuit and a control unit. The refrigerant circuit is a circuit through which refrigerant circulates. The refrigerant circuit includes a first heat exchanger configured to cause heat exchange between air and the refrigerant, a second heat exchanger configured to cause heat exchange between the refrigerant and water, and a compressor configured to compress the refrigerant. The water circuit is a circuit through which the water flows. The water circuit includes the second heat exchanger and a water supply mechanism configured to supply the water to the second heat exchanger. The control unit is configured to control the refrigerant circuit and the water circuit so as to perform a defrosting operation of the first heat exchanger. The refrigerant circuit is capable of switching between a forward cycle operation and a reverse cycle operation. The forward cycle operation causes the refrigerant to sequentially circulate through the compressor, the second heat exchanger, the first heat exchanger and back to the compressor. The reverse cycle operation causes the refrigerant to sequentially circulate through the compressor, the first heat exchanger, the second heat exchanger and back to the compressor. At least either in starting the defrosting operation or during performing the defrosting operation, the control unit is configured to determine a possibility of freezing of the water in the water circuit and select to perform either the forward

cycle operation or the reverse cycle operation so as to perform the defrosting operation.

[0008] The heat pump hot water heater is a heat pump device equipped with the refrigerant circuit and the water circuit that share the second heat exchanger. The refrigerant at high temperature, compressed by the compressor of the refrigerant circuit, is heat-exchanged with the water flowing through the water circuit in the second heat exchanger. In the second heat exchanger, heat is transferred from the refrigerant flowing through the refrigerant circuit to the water flowing through the water circuit. Accordingly, the water flowing through the water circuit is heated, and hot water is produced. The control unit is capable of switching between the forward cycle operation and the reverse cycle operation by controlling the refrigerant circuit. In the forward cycle operation, the high-temperature refrigerant compressed by the compressor flows into the second heat exchanger. In the reverse cycle operation, the high-temperature refrigerant compressed by the compressor flows into the first heat exchanger. Chances are that frost is attached to the first heat exchanger installed in an outdoor space under conditions of low outdoor air temperature. The present heat pump hot water heater is configured to perform the defrosting operation for eliminating the frost attached to the first heat exchanger. The control unit is normally configured to perform the defrosting operation based on the reverse cycle operation. However, the control unit is configured to perform the defrosting operation based on the forward cycle operation when determining that performing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. The forward cycle operation-based defrosting operation is performed by deactivating the water supply mechanism of the water circuit and by increasing the opening degree of an expansion mechanism of the refrigerant circuit. With the deactivation of the water supply mechanism, heat exchange is inhibited in the second heat exchanger, and heat is accumulated in the second heat exchanger. With the increase in opening degree of the expansion mechanism, the heat of the compressor and the second heat exchanger is transferred to the first heat exchanger via the expansion mechanism through the refrigerant. Accordingly, the first heat exchanger is heated and the frost attached to the first heat exchanger is eliminated.

[0009] The present heat pump hot water heater is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation on the basis of the possibility of freezing of the water flowing through the water circuit. In the reverse cycle operation-based defrosting operation, the high-temperature refrigerant compressed by the compressor directly flows into the first heat exchanger. Thus, the frost attached to the first heat exchanger is efficiently eliminated. However, heat exchange is performed in the second heat exchanger such that heat is transferred from the water flowing through the water circuit to the refrigerant flowing through the refrigerant circuit. Thus, when the temperature of the water in the water circuit is low or so forth, there is a possibility that the water in the water circuit freezes and breaks the water circuit. On the other hand, in the forward cycle operation-based defrosting operation, while heat exchange is inhibited in the second heat exchanger, the frost attached to the first heat exchanger is eliminated by the heat of the compressor and the second heat exchanger. Hence, in the forward cycle operation-based defrosting operation, there is no possibility of water freezing in the water circuit. Consequently, the present heat pump hot water heater can prevent water freezing in the defrosting operation.

[0010] A heat pump hot water heater according to a second aspect of the present invention relates to the heat pump hot water heater according to the first aspect, and wherein, when the water flowing into the second heat exchanger has a temperature of lower than or equal to a first temperature in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

[0011] The present heat pump hot water heater is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation in starting the defrosting operation. When the temperature of the water flowing into the second heat exchanger is lower than or equal to a predetermined temperature, the control unit is configured to determine that performing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. In this case, the present heat pump hot water heater is configured to start the forward cycle operation-based defrosting operation.

[0012] A heat pump hot water heater according to a third aspect of the present invention relates to the heat pump hot water heater according to the first or second aspect, and wherein, when the air to be heat-exchanged in the first heat exchanger has a temperature of lower than or equal to a second temperature in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

[0013] The present heat pump hot water heater is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation in starting the defrosting operation. When the temperature of the air to be heat-exchanged in the first heat exchanger is lower than or equal to a predetermined temperature, the control unit is configured to determine that performing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. In this case, the present heat pump hot water heater is configured to start the forward cycle operation-based defrosting operation.

[0014] A heat pump hot water heater according to a fourth aspect of the present invention relates to the heat pump hot water heater according to any of the first to third aspects, and wherein, when the compressor has been deactivated for a first period of time or greater before starting the defrosting operation in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

[0015] The present heat pump hot water heater is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation in starting the defrosting operation. When the normal operation for heating the water in the water circuit based on the forward cycle operation has been deactivated for a predetermined period of time or greater in starting the defrosting operation, the control unit is configured to determine that performing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. In this case, the present heat pump hot water heater is configured to start the forward cycle operation-based defrosting operation.

[0016] A heat pump hot water heater according to a fifth aspect of the present invention relates to the heat pump hot water heater according to any of the first to fourth aspects, and wherein, when the defrosting operation has been previously performed for a second period of time or less in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

[0017] The present heat pump hot water heater is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation in starting the defrosting operation. When the defrosting operation has been previously performed for a predetermined period of time or less, the control unit is configured to determine that performing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. In this case, the present heat pump hot water heater is configured to start the forward cycle operation-based defrosting operation.

[0018] A heat pump hot water heater according to a sixth aspect of the present invention relates to the heat pump hot water heater according to any of the first to fifth aspects, and wherein, when the water flowing into the second heat exchanger has a temperature of lower than or equal to a third temperature during performing the defrosting operation based on the reverse cycle operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

[0019] The present heat pump hot water heater is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation during performing the reverse cycle operation-based defrosting operation. When the temperature of the water flowing into the second heat exchanger is lower than or equal to a predetermined temperature during performing the reverse cycle operation-based defrosting operation, the control unit is configured to determine that continuing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. In this case, the present heat pump hot water heater is configured to terminate the reverse cycle operation-based defrosting operation and start the forward cycle operation-based defrosting operation.

[0020] A heat pump hot water heater according to a seventh aspect of the present invention relates to the heat pump hot water heater according to any of the first to fifth aspects, and wherein, when the water flowing into the second heat exchanger has a temperature of lower than or equal to a fourth temperature during performing the defrosting operation based on the reverse cycle operation, the control unit is configured to select to perform the forward cycle operation.

[0021] The present heat pump hot water heater is configured to select and perform either the normal operation for heating the water in the water circuit based on the forward cycle operation or the reverse cycle operation-based defrosting operation during performing the reverse cycle operation-based defrosting operation. When the temperature of the water flowing into the second heat exchanger is lower than or equal to a predetermined temperature during performing the reverse cycle operation-based defrosting operation, the control unit is configured to determine that continuing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit. In this case, the present heat pump hot water heater is configured to terminate the reverse cycle operation-based defrosting operation and start the forward cycle operation-based normal operation.

<Advantageous Effects of Invention>

[0022] The heat pump hot water heater according to any of the first to seventh aspects of the present invention can prevent water freezing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

FIG. 1 is a circuit configuration diagram of a heat pump hot water heater in a normal operation.

FIG. 2 is a circuit configuration diagram of the heat pump hot water heater in a reverse cycle operation-based defrosting operation.

FIG. 3 is a circuit configuration diagram of the heat pump hot water heater in a forward cycle operation-based defrosting operation.

FIG. 4 is a flowchart showing a routine for determin-

ing a possibility of water freezing in a water circuit when the defrosting operation is started after terminating the normal operation.

FIG. 5 is a flowchart showing a routine for determining the possibility of water freezing in the water circuit when the reverse cycle operation-based defrosting operation is performed.

DESCRIPTION OF EMBODIMENTS

[0024] A heat pump hot water heater according to an embodiment of the present invention will be explained with reference to drawings. The heat pump hot water heater according to the present embodiment is a type of heater that is configured to heat water with use of a heat pump system and to heat air in an indoor space with use of the heat of the produced hot water.

(1) Construction of Heat Pump Hot Water Heater

[0025] A heat pump hot water heater 10 according to the present embodiment is mainly composed of a refrigerant circuit 20, a water circuit 30 and a control unit 40. The refrigerant circuit 20 is a circuit that refrigerant circulates therethrough. The water circuit 30 is a circuit that water circulates therethrough. The refrigerant circuit 20 functions as a heat pump.

(1-1) Refrigerant Circuit

[0026] The refrigerant circuit 20 is a type of refrigerant circuit in which a first heat exchanger 21, a compressor 22, an expansion valve 23, a four-way switch valve 24 and a second heat exchanger 25 are mainly connected to each other. The refrigerant circuit 20 includes a first temperature sensor 26. The refrigerant circulating through the refrigerant circuit 20 is, for instance, R134a.

[0027] The refrigerant circuit 20 is configured to perform either a forward cycle operation or a reverse cycle operation in accordance with the circulation direction of the refrigerant.

[0028] FIGS. 1 and 3 are circuit configuration diagrams of the heat pump hot water heater 10 in the forward cycle operation of the refrigerant circuit 20. FIG. 2 is a circuit configuration diagram of the heat pump hot water heater 10 in the reverse cycle operation of the refrigerant circuit 20. In FIGS. 1 to 3, the flow direction of the refrigerant circulating through the refrigerant circuit 20 is indicated by arrows. The forward cycle operation of the refrigerant circuit 20 is configured to be performed when the heat pump hot water heater 10 performs either a normal operation or a defrosting operation. The reverse cycle operation of the refrigerant circuit 20 is performed when the heat pump hot water heater 10 performs the defrosting operation. The normal operation of the heat pump hot water heater 10 is a type of operation for heating water circulating through the water circuit 30 and utilizing the produced hot water for heating. The defrosting operation of the heat pump hot water heater 10 is a type of operation for eliminating frost attached to the first heat exchanger 21. The refrigerant circuit 20 is capable of switching between the forward cycle operation and the reverse cycle operation.

[0029] The first heat exchanger 21 is a refrigerant-air heat exchanger. In the first heat exchanger 21, heat exchange is performed between the refrigerant circulating through the refrigerant circuit 20 and a heat source. The heat source is, for instance, outdoor air and geothermal heat. In the present embodiment, the heat source is outdoor air. The first heat exchanger 21 is, for instance, a plate fin coil heat exchanger. A fan 21 a is installed in the vicinity of the first heat exchanger 21. The fan 21 a is configured to feed outdoor air to the first heat exchanger 21 and discharge the outdoor air that is heat-exchanged with the refrigerant in the first heat exchanger 21. The first heat exchanger 21 is an outdoor heat exchanger designed to be installed in an outdoor space.

[0030] The compressor 22 is a type of compressor that is configured to suck and compress the refrigerant at low pressure that flows in the refrigerant circuit 20 and discharge the refrigerant at high temperature and high pressure. The compressor 22 is, for instance, a rotary compressor.

[0031] The expansion valve 23 is an electric valve for regulating the flow rate and the pressure of the refrigerant circulating through the refrigerant circuit 20.

[0032] The four-way switch valve 24 is a type of switch valve configured to switch between the forward cycle operation and the reverse cycle operation so as to reverse the direction of the refrigerant circulating through the refrigerant circuit 20. The four-way switch valve 24 has a first port 24a, a second port 24b, a third port 24c and a fourth port 24d. The four-way switch valve 24 is set in either a first communication state or a second communication state. As shown in FIGS. 1 and 3, in the first communication state, the first port 24a and the second port 24b communicate with each other, and simultaneously, the third port 24c and the fourth port 24d communicate with each other. As shown in FIG. 2, in the second communication state, the first port 24a and the third port 24c communicate with each other, and simultaneously, the second port 24b and the fourth port 24d communicate with each other. When the refrigerant circuit 20 performs the forward cycle operation, the four-way switch valve 24 is set in the first communication state. When the refrigerant circuit 20 performs the reverse cycle operation, the four-way switch valve 24 is set in the second communication state.

[0033] The second heat exchanger 25 is a water-refrigerant heat exchanger. In the second heat exchanger 25, heat exchange is performed between the refrigerant circulating through the refrigerant circuit 20 and the water circulating through the water circuit 30. The refrigerant circuit 20 and the water circuit 30 share the second heat exchanger 25. The second heat exchanger 25 has a refrigerant heat exchange part 25a that the refrigerant cir-

culating through the refrigerant circuit 20 passes therethrough and a water heat exchange part 25b that the water circulating through the water circuit 30 passes therethrough. For example, the second heat exchanger 25 is a tornado heat exchanger having a construction that a refrigerant pipe as the refrigerant heat exchange part 25a is helically wound about the outer periphery of a water pipe as the water heat exchange part 25b, and additionally, the water pipe has grooves in the inside thereof. The second heat exchanger 25 is an indoor heat exchanger designed to be installed in a space as a heating target.

[0034] The first temperature sensor 26 is a type of sensor configured to measure the temperature of the outdoor air to be heat-exchanged in the first heat exchanger 21. The first temperature sensor 26 is configured to measure the temperature of the outdoor air to be fed to the first heat exchanger 21 by the fan 21 a or the temperature of the air in the outdoor space that the first heat exchanger 21 is installed. The first temperature sensor 26 is attached to the first heat exchanger 21.

[0035] The configuration of the refrigerant circuit 20 in the forward cycle operation will be explained. The discharge side of the compressor 22 is connected to the first port 24a of the four-way switch valve 24. The second port 24b of the four-way switch valve 24 is connected to the refrigerant heat exchange part 25a of the second heat exchanger 25. The refrigerant heat exchange part 25a of the second heat exchanger 25 is connected to the expansion valve 23. The expansion valve 23 is connected to the first heat exchanger 21. The first heat exchanger 21 is connected to the third port 24c of the four-way switch valve 24. The fourth port 24d of the four-way switch valve 24 is connected to the intake side of the compressor 22.

[0036] An action of the refrigerant circuit 20 in the forward cycle operation will be explained. The forward cycle operation is configured to be performed when the heat pump hot water heater 10 performs the normal operation. The refrigerant in a gaseous state at low pressure is sucked into the compressor 22 and is compressed therein. The compressed refrigerant is discharged from the compressor 22 in a gaseous state at high temperature and high pressure, and is fed to the second heat exchanger 25 via the first and second ports 24a and 24b of the four-way switch valve 24. In the second heat exchanger 25, the refrigerant passes through the refrigerant heat exchange part 25a, whereas the water passes through the water heat exchange part 25b. In the second heat exchanger 25, heat is transferred from the refrigerant at high temperature to the water at low temperature, and thus, heat exchange is performed between the refrigerant and the water. Accordingly, in the second heat exchanger 25, the refrigerant in a gaseous state at high temperature and high pressure is condensed and changed into a liquid state at high pressure. Then, the refrigerant is reduced in pressure when passing through the expansion valve 23, and is changed into a gas-liquid two phase state at low pressure. The refrigerant in the gas-liquid two phase state at low pressure evaporates in the first heat exchanger 21 as a result of heat exchange with the outdoor air, and is changed into a gaseous state at low pressure. Then, the refrigerant passes through the third and fourth ports 24c and 24d of the four-way switch valve 24 and is fed to the compressor 22. The refrigerant circuit 20, performing the forward cycle operation, is configured to supply the heat of the outdoor air through the refrigerant to the water circulating through the water circuit 30 by repeating the aforementioned processing steps.

[0037] It should be noted that the refrigerant circuit 20 is configured to perform either the forward cycle operation or the reverse cycle operation when the heat pump hot water heater 10 performs the defrosting operation. An action of the refrigerant circuit 20 in the reverse cycle operation will be described below.

(1-2) Water Circuit

[0038] The water circuit 30 is a type of circuit in which the second heat exchanger 25, a water supply pump 31, a hot water storage tank 32 and a heating unit 33 are mainly connected to each other. The water circuit 30 includes a second temperature sensor 34. Water circulates the water circuit 30. In the water circuit 30, the water circulates through the water supply pump 31, the second heat exchanger 25, the hot water storage tank 32, the heating unit 33 and back to the water supply pump 31 in this order. In FIGS. 1 and 2, the direction of the water circulating through the water circuit 30 is indicated by arrows.

[0039] The water supply pump 31 is a type of pump configured to feed the water circulating through the water circuit 30 to the water heat exchange part 25b of the second heat exchanger 25.

[0040] The second heat exchanger 25 is a water-refrigerant heat exchanger. As described above, in the second heat exchanger 25, heat exchange is performed between the refrigerant circulating through the refrigerant circuit 20 and the water circulating through the water circuit 30. The water passes through the water heat exchange part 25b so as to be heat-exchanged in the second heat exchanger 25. The inlet of the water heat exchange part 25b is connected to the water supply pump 31 through a pipe. The outlet of the water heat exchange part 25b is connected to the hot water storage tank 32 through a pipe.

[0041] The hot water storage tank 32 is a type of tank for storing the water heated in the second heat exchanger 25. The hot water stored in the hot water storage tank 32 is fed to the heating unit 33. The hot water storage tank 32 may be provided with a keep-warm heater for keeping the warmth of the hot water stored therein.

[0042] The heating unit 33 is installed in a space to be heated by the normal operation of the heat pump hot water heater 10. For example, the heating unit 33 is a floor heating panel to be mounted to the floor surface of a room. The heating unit 33 has a heating pipe 33a that

the hot water heated in the second heat exchanger 25 flows therethrough.

[0043] The second temperature sensor 34 is a type of sensor configured to measure the temperature of the water flowing into the water heat exchange part 25b of the second heat exchanger 25. For example, the second temperature sensor 34 is attached to the pipe in the vicinity of the inlet of the water heat exchange part 25b.

[0044] An action of the water circuit 30 will be explained. The water is fed to the second heat exchanger 25 by the water supply pump 31. In the second heat exchanger 25, heat exchange is performed between the refrigerant and the water by thermal transference from the refrigerant at high temperature to the water at low temperature. Accordingly, the water is heated in the second heat exchanger 25. The water heated in the second heat exchanger 25 is fed to the hot water storage tank 32 as hot water. The hot water stored in the hot water storage tank 32 is supplied to the heating unit 33. In the heating unit 33, the hot water, flowing through the inside of the heating pipe 33a, heats the air in the space in which the heating unit 33 is installed. The water, reduced in temperature after passing through the heating pipe 33a, is fed to the water supply pump 31.

(1-3) Control Unit

[0045] The control unit 40 is a computer for controlling the respective constituent elements of the heat pump hot water heater 10. The control unit 40 is connected to the compressor 22, the expansion valve 23, the four-way switch valve 24, the first temperature sensor 26, the water supply pump 31, the heating unit 33 and the second temperature sensor 34. For example, the control unit 40 is installed in an electric component unit (not shown in the drawings) disposed inside the heat pump hot water heater 10.

[0046] The control unit 40 is capable of activating and deactivating the compressor 22 by regulating the operating frequency of the compressor 22. The control unit 40 is capable of controlling the flow rate of the refrigerant passing through the expansion valve 23 by regulating the opening degree of the expansion valve 23. The control unit 40 is capable of activating and deactivating the water supply pump 31 by controlling the rotational speed of the water supply pump 31. The control unit 40 is capable of regulating the temperature of the space in which the heating unit 33 is installed by regulating the flow rate of the hot water to be fed to the heating unit 33.

[0047] The control unit 40 is capable of switching between the first communication state and the second communication state by controlling the four-way switch valve 24. Put differently, the control unit 40 is capable of switching between the forward cycle operation and the reverse cycle operation by controlling the four-way switch valve 24.

[0048] The control unit 40 is capable of receiving the temperature measured by the first temperature sensor 26 of the refrigerant circuit 20, i.e., the temperature of the air to be heat-exchanged in the first heat exchanger 21. The control unit 40 is capable of receiving the temperature measured by the second temperature sensor 34 of the water circuit 30, i.e., the temperature of the water flowing into the water heat exchange part 25b of the second heat exchanger 25.

[0049] Additionally, the control unit 40 stores information regarding the operation of the heat pump hot water heater 10. For example, the control unit 40 is configured to monitor and store activation timing of the compressor 22 and deactivation timing of the compressor 22. Accordingly, the control unit 40 is capable of calculating, for instance, duration of deactivation of the compressor 22, duration of the normal operation performed by the heat pump hot water heater 10, and duration of the defrosting operation performed by the heat pump hot water heater 10.

(2) Action of Heat Pump Hot Water Heater

(2-1) Explanation of Normal Operation and Defrosting Operation

[0050] The action of the heat pump hot water heater 10 will be explained. The heat pump hot water heater 10 is configured to perform either the normal operation or the defrosting operation. FIG. 1 is a circuit configuration diagram of the heat pump hot water heater 10 performing the normal operation. In the normal operation of the heat pump hot water heater 10, the refrigerant circuit 20 is configured to perform the forward cycle operation. As shown in FIG. 1, the four-way switch valve 24 of the refrigerant circuit 20 is herein set in the first communication state. In the water circuit 30, the water is fed to the second heat exchanger 25 by the water supply pump 31 and is heated in the second heat exchanger 25. Then, hot water is fed to the hot water storage tank 32 and the heating unit 33.

[0051] In the normal operation of the heat pump hot water heater 10, heat exchange, which is thermal transference from the outdoor air to the refrigerant, is performed in the first heat exchanger 21 of the refrigerant circuit 20. Put differently, the heat of the outdoor air to be blown by the fan 21 a is deprived in the first heat exchanger 21. Due to this, chances are that frost is attached to the first heat exchanger 21 under some conditions of low outdoor air temperature such as cold weather places and the winter season. When frost is attached to the first heat exchanger 21, in comparison with a condition that frost is not attached to the first heat exchanger 21, heat exchange efficiency is degraded in the first heat exchanger 21 and then operating efficiency is degraded in the heat pump hot water heater 10. Therefore, for the purpose of inhibiting degradation in operating efficiency under the conditions of low outdoor air temperature, the heat pump hot water heater 10 is required to regularly perform the defrosting operation of eliminating the frost

attached to the first heat exchanger 21. The defrosting operation of the heat pump hot water heater 10 is performed by melting the frost attached to the first heat exchanger 21 with heat.

[0052] In performing the defrosting operation, the heat pump hot water heater 10 is configured to perform it either in the reverse cycle operation of the refrigerant circuit 20 or in the forward cycle operation of the refrigerant circuit 20. FIG. 2 is a circuit configuration diagram of the heat pump hot water heater 10 performing the reverse cycle operation-based defrosting operation. FIG. 3 is a circuit configuration diagram of the heat pump hot water heater 10 performing the forward cycle operation-based defrosting operation.

[0053] The direction of the refrigerant circulating through the refrigerant circuit 20 in the reverse cycle operation is opposite to that of the refrigerant circulating through the refrigerant circuit 20 in the forward cycle operation. Specifically, in the reverse cycle operation, the refrigerant in the refrigerant circuit 20 passes and circulates through the compressor 22, the four-way switch valve 24 (the first port 24a and the third port 24c), the first heat exchanger 21, the expansion valve 23, the second heat exchanger 25, the four-way switch valve 24 (the second port 24b and the fourth port 24d) and back to the compressor 22 in this order.

[0054] Next, explanation will be provided for an action to be performed when the heat pump hot water heater 10 terminates the normal operation and starts the reverse cycle operation-based defrosting operation. First, the control unit 40 deactivates the compressor 22 by zeroing the rotational speed of the compressor 22. The normal operation is terminated by the deactivation of the compressor 22. Next, the control unit 40 switches the four-way switch valve 24 from the first communication state into the second communication state. Subsequently, the control unit 40 starts an operation of the compressor 22 by increasing the rotational speed of the compressor 22 from zero. The defrosting operation of the heat pump hot water heater 10 is started by the activation of the compressor 22. In the defrosting operation, the refrigerant at high temperature, discharged from the compressor 22, flows into the first heat exchanger 21. Additionally, in the defrosting operation, the heat accumulated in the second heat exchanger 25 in the normal operation is supplied to the first heat exchanger 21 through the refrigerant circulating through the refrigerant circuit 20. Accordingly, frost attached to the first heat exchanger 21 melts, and thus, the first heat exchanger 21 is defrosted. It should be noted that the water supply pump 31 of the water circuit 30 is being operated in the reverse cycle operation-based defrosting operation.

[0055] Next, explanation will be provided for an action to be performed when the heat pump hot water heater 10 terminates the normal operation and starts the forward cycle operation-based defrosting operation. First, the control unit 40 deactivates the water supply pump 31 by zeroing the rotational speed of the water supply pump 31. Water supply to the second heat exchanger 25 is stopped by the deactivation of the water supply pump 31. Next, the control unit 40 increases the opening degree of the expansion valve 23. Additionally, the control unit 40 maintains the four-way switch valve 24 in the first communication state. Put differently, similarly to the normal operation, the refrigerant at high temperature, discharged from the compressor 22, is supplied to the second heat exchanger 25 in the forward cycle operation-based defrosting operation. In the second heat exchanger 25, the water is not passing through the water heat exchange part 25b, and thus, heat exchange between the refrigerant and the water is inhibited in the second heat exchanger 25. Due to this, the heat of the refrigerant at high temperature supplied from the compressor 22 is accumulated in the second heat exchanger 25. As a result, the temperature of the second heat exchanger 25 is increased. Additionally, the temperature of the compressor 22 is also increased by the operation of the compressor 22. The heat accumulated in the compressor 22 and the second heat exchanger 25 is supplied to the first heat exchanger 21 via the expansion valve 23 through the refrigerant circulating through the refrigerant circuit 20. Accordingly, frost attached to the first heat exchanger 21 melts, and thus, the first heat exchanger 21 is defrosted.

(2-2) Explanation of Determining Water Freezing Probability

[0056] In the heat pump hot water heater 10, the control unit 40 is configured to determine a possibility of water freezing in the water circuit 30 and select to perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation. The control unit 40 is configured to perform the forward cycle operation-based defrosting operation when determining that the water circuit 30 has a possibility of water freezing. The control unit 40 is configured to perform the reverse cycle operation-based defrosting operation when determining that the water circuit 30 has no possibility of water freezing.

[0057] The control unit 40 determines the possibility of water freezing in the water circuit 30 at least either in the timing of terminating the normal operation and starting the defrosting operation or during performing the reverse cycle operation-based defrosting operation.

[0058] FIG. 4 is a flowchart showing a routine that the control unit 40 determines the possibility of water freezing in the water circuit 30 in the timing of terminating the normal operation and starting the defrosting operation. The routine is composed of Steps S11 to S15. In Step S11, the control unit 40 terminates the normal operation. In Step S12, the control unit 40 determines the possibility of water freezing in the water circuit 30. When determining that the water circuit 30 has the possibility of water freezing, the control unit 40 performs processing in Step S13. When determining that the water circuit 30 has no

possibility of water freezing, the control unit 40 performs processing in Step S14. In Step S13, the control unit 40 starts the forward cycle operation-based defrosting operation. In Step S14, the control unit 40 starts the reverse cycle operation-based defrosting operation. In Step S15, the control unit 40 terminates the defrosting operation.

[0059] FIG. 5 is a flowchart showing a routine that the control unit 40 determines the possibility of water freezing in the water circuit 30 during performing the reverse cycle operation-based defrosting operation. The routine is composed of Steps S21 to S25. In Step S21, the control unit 40 terminates the normal operation. In Step S22, the control unit 40 starts the reverse cycle operation-based defrosting operation. In Step S23, the control unit 40 determines the possibility of water freezing in the water circuit 30. When determining that the water circuit 30 has the possibility of water freezing, the control unit 40 performs processing in Step S24. When determining that the water circuit 30 has no possibility of water freezing, the control unit 40 continues the reverse cycle operation-based defrosting operation. In Step S24, the control unit 40 terminates the reverse cycle operation-based defrosting operation and starts the forward cycle operation-based defrosting operation. In Step S25, the control unit 40 terminates the defrosting operation.

[0060] Specifically, the control unit 40 is configured to determine the possibility of water freezing in the water circuit 30 on the basis of any one of six determination criteria to be explained below. Next, the respective determination criteria will be explained.

(2-2-1) First Determination Criterion

[0061] In the first determination criterion, the control unit 40 determines the possibility of water freezing in the water circuit 30 when terminating the normal operation and starting the defrosting operation. The control unit 40 is configured to obtain the temperature of the water flowing into the water heat exchange part 25b of the second heat exchanger 25 from the second temperature sensor 34 of the water circuit 30. When the temperature of the water flowing into the water heat exchange part 25b is lower than or equal to a predetermined temperature, the control unit 40 is configured to deactivate the water supply pump 31, maintain the four-way switch valve 24 in the first communication state, and then, start the forward cycle operation-based defrosting operation. When the temperature of the water flowing into the water heat exchange part 25b is higher than the predetermined temperature, the control unit 40 is configured to switch the four-way switch valve 24 from the first communication state into the second communication state, and then, start the reverse cycle operation-based defrosting operation.

(2-2-2) Second Determination Criterion

[0062] In the second determination criterion, the control unit 40 is configured to determine the possibility of water freezing in the water circuit 30 when terminating the normal operation and starting the defrosting operation. The control unit 40 is configured to obtain the temperature of the air to be heat-exchanged in the first heat exchanger 21 from the first temperature sensor 26 of the refrigerant circuit 20. When the temperature of the air to be heat-exchanged in the first heat exchanger 21 is lower than or equal to a predetermined temperature, the control unit 40 is configured to deactivate the water supply pump 31, maintain the four-way switch valve 24 in the first communication state, and then start the forward cycle operation-based defrosting operation. When the temperature of the air to be heat-exchanged in the first heat exchanger 21 is higher than the predetermined temperature, the control unit 40 is configured to switch the four-way switch valve 24 from the first communication state into the second communication state, and then start the reverse cycle operation-based defrosting operation.

(2-2-3) Third Determination Criterion

[0063] In the third determination criterion, the control unit 40 is configured to determine the possibility of water freezing in the water circuit 30 when terminating the normal operation and starting the defrosting operation. The control unit 40 is configured to obtain information regarding the operation of the compressor 22 of the refrigerant circuit 20. When the compressor 22 has been successively deactivated for a predetermined period of time or greater before starting the defrosting operation, the control unit 40 is configured to deactivate the water supply pump 31, maintain the four-way switch valve 24 in the first communication state, and then start the forward cycle operation-based defrosting operation. When the compressor 22 has been successively deactivated for less than the predetermined period of time before starting the defrosting operation, the control unit 40 is configured to switch the four-way switch valve 24 from the first communication state into the second communication state, and then start the reverse cycle operation-based defrosting operation.

(2-2-4) Fourth Determination Criterion

[0064] In the fourth determination criterion, the control unit 40 is configured to determine the possibility of water freezing in the water circuit 30 when terminating the normal operation and starting the defrosting operation. The control unit 40 is configured to obtain information regarding the defrosting operation of the heat pump hot water heater 10. When the defrosting operation has been previously performed for a predetermined period of time or less, the control unit 40 is configured to deactivate the water supply pump 31, maintain the four-way switch valve 24 in the first communication state, and then start the forward cycle operation-based defrosting operation. When the defrosting operation has been previously per-

formed for more than the predetermined period of time, the control unit 40 is configured to switch the four-way switch valve 24 from the first communication state into the second communication state, and then start the reverse cycle operation-based defrosting operation.

(2-2-5) Fifth Determination Criterion

[0065] In the fifth determination criterion, the control unit 40 is configured to determine the possibility of water freezing in the water circuit 30 during performing the reverse cycle operation-based defrosting operation after terminating the normal operation. The control unit 40 is configured to obtain the temperature of the water flowing into the water heat exchange part 25b of the second heat exchanger 25 from the second temperature sensor 34 of the water circuit 30. When the temperature of the water flowing into the water heat exchange part 25b is lower than or equal to a predetermined temperature, the control unit 40 is configured to deactivate the water supply pump 31 of the water circuit 30, switch the four-way switch valve 24 from the second communication state into the first communication state, and then start the forward cycle operation-based defrosting operation. When the temperature of the water flowing into the water heat exchange part 25b is higher than the predetermined temperature, the control unit 40 continues the reverse cycle operation-based defrosting operation.

(2-2-6) Sixth Determination Criterion

[0066] In the sixth determination criterion, the control unit 40 is configured to determine the possibility of water freezing in the water circuit 30 during performing the reverse cycle operation-based defrosting operation after terminating the normal operation. The control unit 40 is configured to obtain the temperature of the water flowing into the water heat exchange part 25b of the second heat exchanger 25 from the second temperature sensor 34 of the water circuit 30. When the temperature of the water flowing into the water heat exchange part 25b is lower than or equal to a predetermined temperature, the control unit 40 is configured to switch the four-way switch valve 24 from the second communication state into the first communication state in order to terminate the defrosting operation, and then start a forward cycle operation-based normal operation. When the temperature of the water flowing into the water heat exchange part 25b is higher than the predetermined temperature, the control unit 40 continues the reverse cycle operation-based defrosting operation.

(3) Features of Heat Pump Hot Water Heater

[0067] The present heat pump hot water heater 10 is a heat pump device equipped with the refrigerant circuit 20 and the water circuit 30 that share the second heat exchanger 25. The refrigerant at high temperature, compressed by the compressor 22 of the refrigerant circuit 20, is heat-exchanged with the water flowing through the water circuit 30 in the second heat exchanger 25. In the second heat exchanger 25, heat is transferred from the refrigerant flowing through the refrigerant heat exchange part 25a to the water flowing through the water heat exchange part 25b. Accordingly, the water flowing through the water circuit 30 is heated, and hot water is produced. The hot water herein produced is temporarily stored in the hot water storage tank 32, and is utilized for heating of the indoor space by the heating unit 33.

[0068] The control unit 40 is capable of switching between the forward cycle operation and the reverse cycle operation by controlling the four-way switch valve 24 of the refrigerant circuit 20. Chances are that frost is attached to the first heat exchanger 21 under conditions of low outdoor air temperature. The heat pump hot water heater 10 is capable of performing the defrosting operation for eliminating the frost attached to the first heat exchanger 21. The control unit 40 is normally configured to perform the reverse cycle operation-based defrosting operation. However, the control unit 40 is configured to perform the forward cycle operation-based defrosting operation when determining that performing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit 30. The forward cycle operation-based defrosting operation is performed by deactivating the water supply pump 31 of the water circuit 30 and by increasing the opening degree of the expansion valve 23 of the refrigerant circuit 20. With the deactivation of the water supply pump 31, heat exchange is inhibited in the second heat exchanger 25, and heat is accumulated in the second heat exchanger 25. With the increase in opening degree of the expansion valve 23, the heat accumulated in the compressor 22 and the second heat exchanger 25 is transferred to the first heat exchanger 21 via the expansion valve 23 through the refrigerant. Accordingly, the first heat exchanger 21 is heated and the frost attached to the first heat exchanger 21 is eliminated.

[0069] The present heat pump hot water heater 10 is configured to select and perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation on the basis of the possibility of freezing of the water flowing through the water circuit 30.

[0070] In the reverse cycle operation-based defrosting operation, the refrigerant at high temperature compressed by the compressor 22 directly flows into the first heat exchanger 21. Thus, the frost attached to the first heat exchanger 21 is efficiently eliminated. However, in the reverse cycle operation-based defrosting operation, heat exchange is performed in the second heat exchanger 25 such that heat is transferred from the water flowing through the water circuit 30 to the refrigerant flowing through the refrigerant circuit 20. Thus, when the temperature of the water flowing into the second heat exchanger 25 is low, the temperature of the water to be

heat-exchanged in the second heat exchanger 25 falls and this could result in water freezing. When freezing, water increases in volume. Hence, there is a possibility that when the water in the water circuit 30 freezes in the pipe of the water circuit 30, the pipe is broken due to increase in pressure inside the pipe. On the other hand, in the forward cycle operation-based defrosting operation, heat exchange is inhibited in the second heat exchanger 25, and the frost attached to the first heat exchanger 21 is eliminated by the heat accumulated in the compressor 22 and the second heat exchanger 25. Hence, there is no possibility of water freezing in the water circuit 30. Consequently, the heat pump hot water heater 10 can prevent water freezing in the defrosting operation.

[0071] The control unit 40 of the heat pump hot water heater 10 is configured to determine the possibility of water freezing in the water circuit 30 on the basis of the first to sixth determination criteria and is configured to select to perform either the forward cycle operation-based defrosting operation or the reverse cycle operation-based defrosting operation.

[0072] When the temperature of the water flowing into the second heat exchanger 25 is lower than or equal to a predetermined temperature in starting the defrosting operation, the control unit 40 is configured to determine that, based on the first determination criterion, performing the reverse cycle operation-based defrosting operation could result in water freezing in the water circuit 30. In the configuration, the heat pump hot water heater 10 is capable of preventing water freezing in the water circuit 30 by terminating the normal operation and starting the forward cycle operation-based defrosting operation.

[0073] On the other hand, when the temperature of the air to be heat-exchanged in the first heat exchanger 21 is lower than or equal to a predetermined temperature in starting the defrosting operation, the control unit 40 is configured to determine that, based on the second determination criterion, performing the reverse cycle operation-based defrosting operation could result in water freezing in the water circuit 30. In the configuration, the heat pump hot water heater 10 is capable of preventing water freezing in the water circuit 30 by terminating the normal operation and starting the forward cycle operation-based defrosting operation.

[0074] But then, when the normal operation for heating the water in the water circuit 30 based on the forward cycle operation has been deactivated for a predetermined period of time or greater in starting the defrosting operation, the control unit 40 is configured to determine that, based on the third determination criterion, performing the reverse cycle operation-based defrosting operation could result in water freezing in the water circuit 30. In the configuration, the heat pump hot water heater 10 is capable of preventing water freezing in the water circuit 30 by terminating the normal operation and starting the forward cycle operation-based defrosting operation.

[0075] Then again, when the defrosting operation has been previously performed for a predetermined period of time or less in starting the defrosting operation, the control unit 40 is configured to determine that, based on the fourth determination criterion, performing the reverse cycle operation-based defrosting operation could result in water freezing in the water circuit 30. In the configuration, the heat pump hot water heater 10 is capable of preventing water freezing in the water circuit 30 by terminating the normal operation and starting the forward cycle operation-based defrosting operation.

[0076] Then again, when the temperature of the water flowing into the second heat exchanger 25 is lower than or equal to a predetermined temperature during performing the reverse cycle operation-based defrosting operation, the control unit 40 is configured to determine that, based on the fifth determination criterion, continuing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit 30. In the configuration, the heat pump hot water heater 10 is configured to terminate the reverse cycle operation-based defrosting operation and start the forward cycle operation-based defrosting operation.

[0077] Then again, when the temperature of the water flowing into the second heat exchanger 25 is lower than or equal to a predetermined temperature during performing the reverse cycle operation-based defrosting operation, the control unit 40 is configured to determine that, based on the sixth determination criterion, continuing the reverse cycle operation-based defrosting operation could result in freezing of the water flowing through the water circuit 30. In the configuration, the heat pump hot water heater 10 is configured to terminate the reverse cycle operation-based defrosting operation and start the forward cycle operation-based normal operation.

[0078] In the forward cycle operation-based defrosting operation, the temperature of the water flowing into the second heat exchanger 25 does not fall. Hence, the possibility of water freezing in the water circuit 30 is low. However, the temperature of the first heat exchanger 21 does not easily rise until a sufficient amount of heat is accumulated in the second heat exchanger 25. Hence, a longer time will be required for defrosting the first heat exchanger 21. Due to the above, when performing only the forward cycle operation-based defrosting operation, the heat pump hot water heater 10 degrades in average heating performance. On the other hand, when performing only the reverse cycle operation-based defrosting operation, the heat pump hot water heater 10 has the possibility of water freezing in the water circuit 30. The heat pump hot water heater 10 according to the present embodiment is configured to select to perform either the reverse cycle operation-based defrosting operation or the forward cycle operation-based defrosting operation in accordance with the possibility of water freezing in the water circuit 30. Accordingly, the heat pump hot water heater 10 is capable of preventing water freezing in the water circuit 30 and is also capable of reliably achieving required average heating performance.

(4) Modifications

[0079] Specific configurations of the embodiment of the present invention can be changed without departing from the scope of the present invention. Modifications applicable to the embodiment of the present invention will be hereinafter explained.

(4-1) Modification A

[0080] In the present embodiment, the control unit 40 of the heat pump hot water heater 10 is configured to determine the possibility of water freezing in the water circuit 30 on the basis of any one of the first to sixth determination criteria. However, the control unit 40 may be configured to select two or more of the first to sixth determination criteria and determine the possibility of water freezing in the water circuit 30 on the basis of combination of the selected determination criteria.

[0081] For example, in terminating the normal operation and starting the defrosting operation, the heat pump hot water heater 10 may be configured to start the defrosting operation on the basis of the first and second determination criteria. In this case, the control unit 40 may be configured to start the forward cycle operation-based defrosting operation when either of the following conditions is fulfilled: that the temperature of the water flowing into the water heat exchange part 25b is lower than or equal to a predetermined temperature; and that the temperature of the air to be heat-exchanged in the first heat exchanger 21 is lower than or equal to another predetermined temperature. In addition, in this case, the control unit 40 may be configured to start the forward cycle operation-based defrosting operation when the both of the following conditions are fulfilled: that the temperature of the water flowing into the water heat exchange part 25b is lower than or equal to the predetermined temperature; and that the temperature of the air to be heat-exchanged in the first heat exchanger 21 is lower than or equal to the another predetermined temperature.

[0082] Alternatively, in terminating the normal operation and starting the defrosting operation, the heat pump hot water heater 10 may be configured to start the defrosting operation on the basis of the first determination criterion. Moreover, during performing the reverse cycle operation-based defrosting operation, the heat pump hot water heater 10 may be configured to terminate the reverse cycle operation-based defrosting operation and start the forward cycle operation-based defrosting operation on the basis of the fifth determination criterion.

(4-2) Modification B

[0083] During performing the forward cycle operation-based defrosting operation, the heat pump hot water heater 10 may be configured to terminate the forward cycle operation-based defrosting operation and start the reverse cycle operation-based defrosting operation.

[0084] For example, the control unit 40 may be configured to start the reverse cycle operation-based defrosting operation on the basis of the fifth determination criterion. Specifically, when the temperature of the water flowing into the water heat exchange part 25b is higher than a predetermined temperature during performing the forward cycle operation-based defrosting operation, the control unit 40 may be configured to start the reverse cycle operation-based defrosting operation by activating the water supply pump 31 of the water circuit 30 and switching the four-way switch valve 24 from the first communication state into the second communication state. When the temperature of the water flowing into the water heat exchange part 25b is herein lower than or equal to the predetermined temperature, the control unit 40 is configured to continue the forward cycle operation-based defrosting operation.

[0085] Moreover, in the present modification, when the forward cycle operation-based defrosting operation has been performed for more than a predetermined period of time, the control unit 40 may be configured to determine that the possibility of water freezing in the water circuit 30 becomes zero and to start the reverse cycle operation-based defrosting operation by activating the water supply pump 31 of the water circuit 30 and switching the four-way switch valve 24 from the first communication state into the second communication state.

INDUSTRIAL APPLICABILITY

[0086] The heat pump hot water heater according to the present invention is capable of preventing water freezing.

REFERENCE SIGNS LIST

[0087]

10 Heat pump hot water heater
20 Refrigerant Circuit
21 First heat exchanger
22 Compressor
25 Second heat exchanger
30 Water circuit
31 Water supply pump (water supply mechanism)
40 Control unit

CITATION LIST

PATENT LITERATURE

[0088]

PTL 1: Japan Laid-open Patent Application Publication No. 2010-181104
PTL 2: International Patent Application Publication No. WO2006/103815

Claims

1. A heat pump hot water heater (10), comprising:

a refrigerant circuit (20) through which refrigerant is to circulate, the refrigerant circuit including a first heat exchanger (21), a second heat exchanger (25) and a compressor (22), the first heat exchanger being configured to cause heat exchange between air and the refrigerant, the second heat exchanger being configured to cause heat exchange between the refrigerant and water, the compressor being configured to compress the refrigerant;
a water circuit (30) through which the water is to flow, the water circuit including the second heat exchanger and a water supply mechanism (31), the water supply mechanism being configured to supply the water to the second heat exchanger; and
a control unit (40) being configured to control the refrigerant circuit and the water circuit so as to perform a defrosting operation of the first heat exchanger, wherein
the refrigerant circuit is capable of switching between

a forward cycle operation causing the refrigerant to sequentially circulate through the compressor, the second heat exchanger, the first heat exchanger and back to the compressor, and
a reverse cycle operation causing the refrigerant to sequentially circulate through the compressor, the first heat exchanger, the second heat exchanger and back to the compressor, and

at least either in starting the defrosting operation or during performing the defrosting operation, the control unit is configured to determine a possibility of freezing of the water in the water circuit and select to perform either the forward cycle operation or the reverse cycle operation so as to perform the defrosting operation.

2. The heat pump hot water heater according to claim 1, wherein
when the water flowing into the second heat exchanger has a temperature of lower than or equal to a first temperature in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

3. The heat pump hot water heater according to claim 1 or 2, wherein
when the air to be heat-exchanged in the first heat exchanger has a temperature of lower than or equal to a second temperature in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

4. The heat pump hot water heater according to any one of claims 1 to 3, wherein
when the compressor has been deactivated for a first period of time or greater before starting the defrosting operation in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

5. The heat pump hot water heater according to any one of claims 1 to 4, wherein
when the defrosting operation has been previously performed for a second period of time or less in starting the defrosting operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

6. The heat pump hot water heater according to any one of claims 1 to 5, wherein
when the water flowing into the second heat exchanger has a temperature of lower than or equal to a third temperature during performing the defrosting operation based on the reverse cycle operation, the control unit is configured to select to perform the forward cycle operation and deactivate the water supply mechanism.

7. The heat pump hot water heater according to any one of claims 1 to 5, wherein
when the water flowing into the second heat exchanger has a temperature of lower than or equal to a fourth temperature during performing the defrosting operation based on the reverse cycle operation, the control unit is configured to select to perform the forward cycle operation.

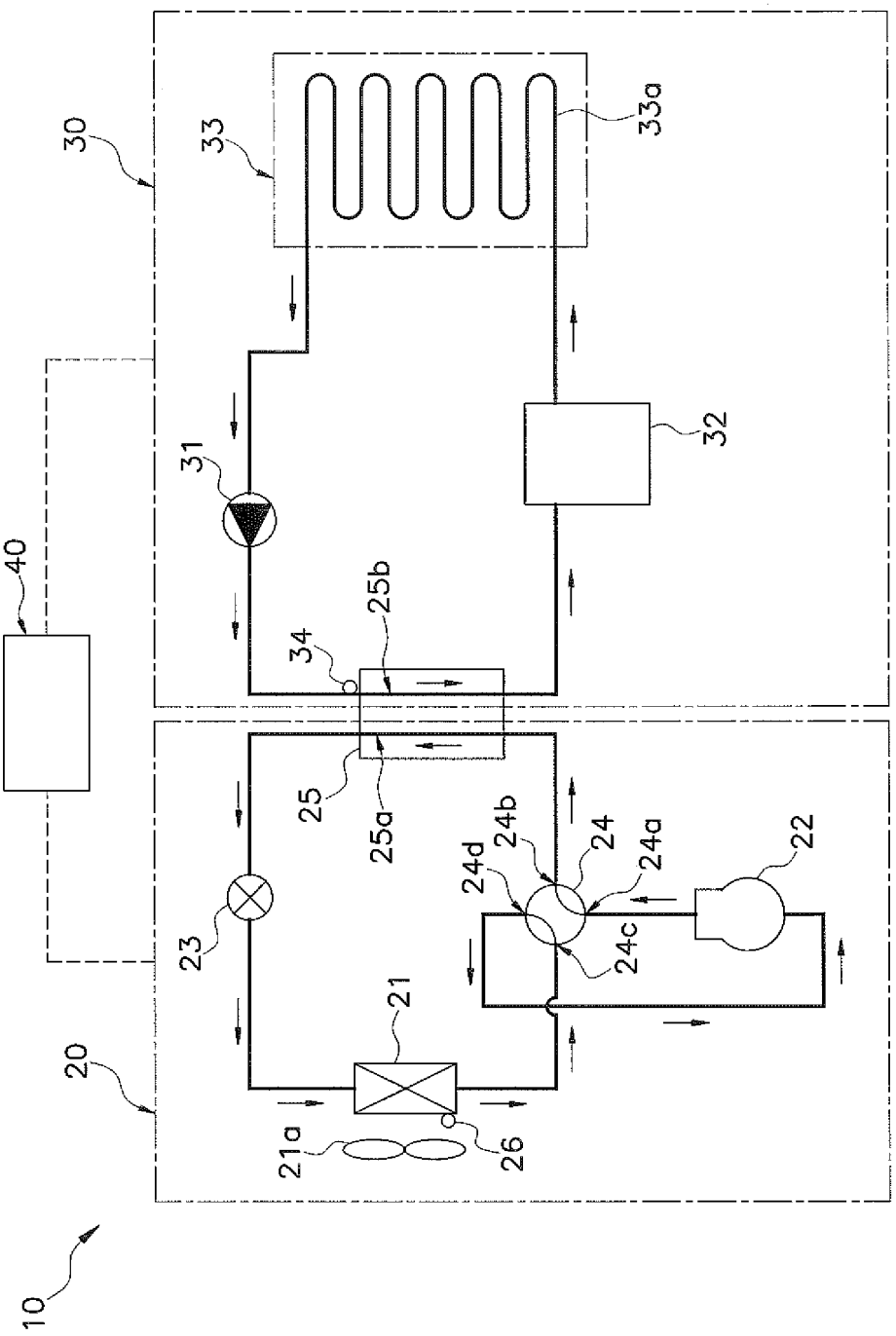
10
20
21
21a
22
23
24
24a
24b
24c
24d
25
25a
25b
26
30
31
32
33
33a
34
40

FIG. 1

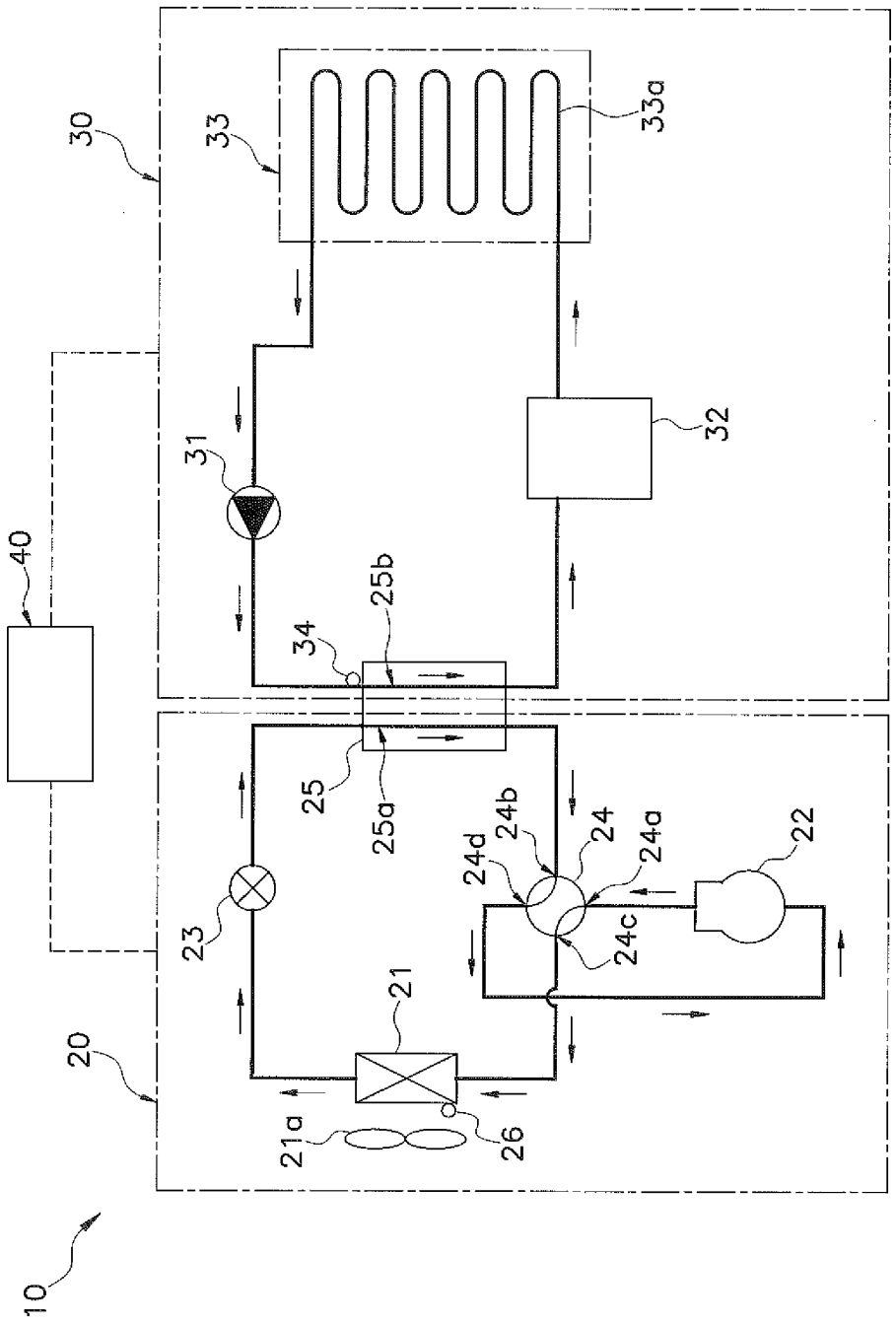
10
20
21
21a
22
23
24
24a
24b
24c
24d
25
25a
25b
26
30
31
32
33
33a
34
40

FIG. 2

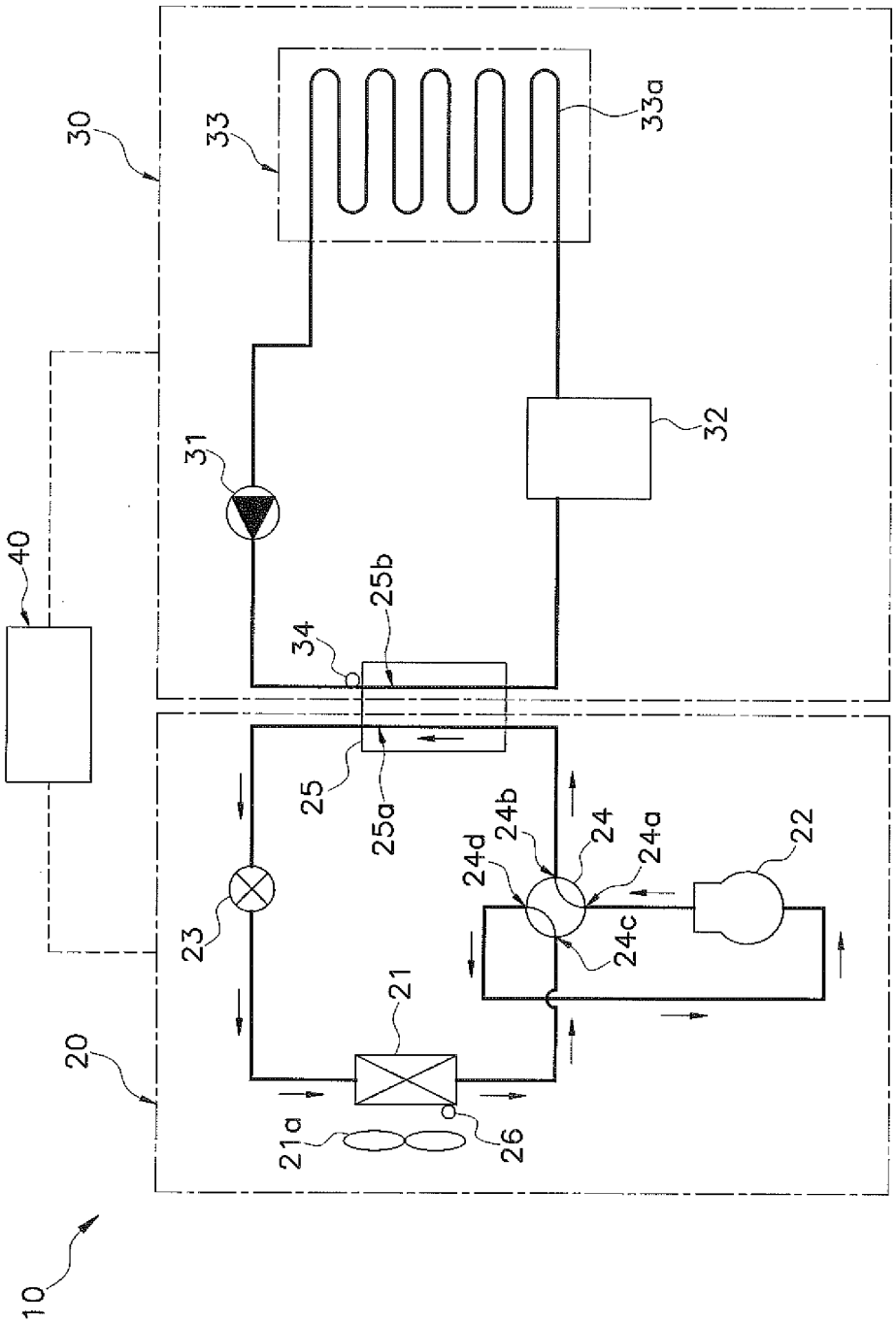
30
33
33a
31
32
40
34
25b
25
25a
24b
24
24a
24d
22
24c
23
21
20
21a
26
10

FIG. 3

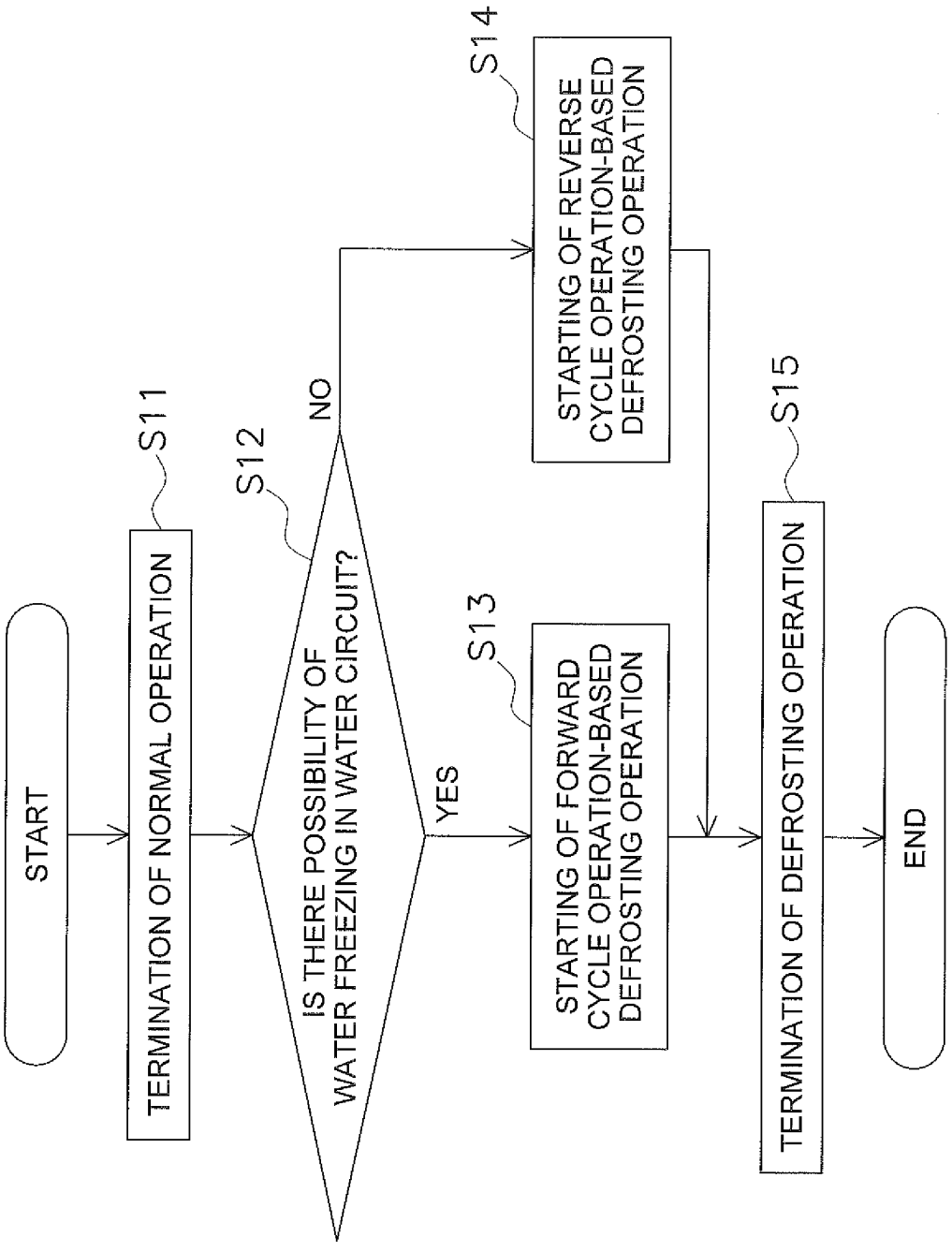
START
TERMINATION OF NORMAL OPERATION
S11
IS THERE POSSIBILITY OF WATER FREEZING IN WATER CIRCUIT?
S12
YES
NO
STARTING OF FORWARD CYCLE OPERATION-BASED DEFROSTING OPERATION
S13
STARTING OF REVERSE CYCLE OPERATION-BASED DEFROSTING OPERATION
S14
TERMINATION OF DEFROSTING OPERATION
S15
END

FIG. 4

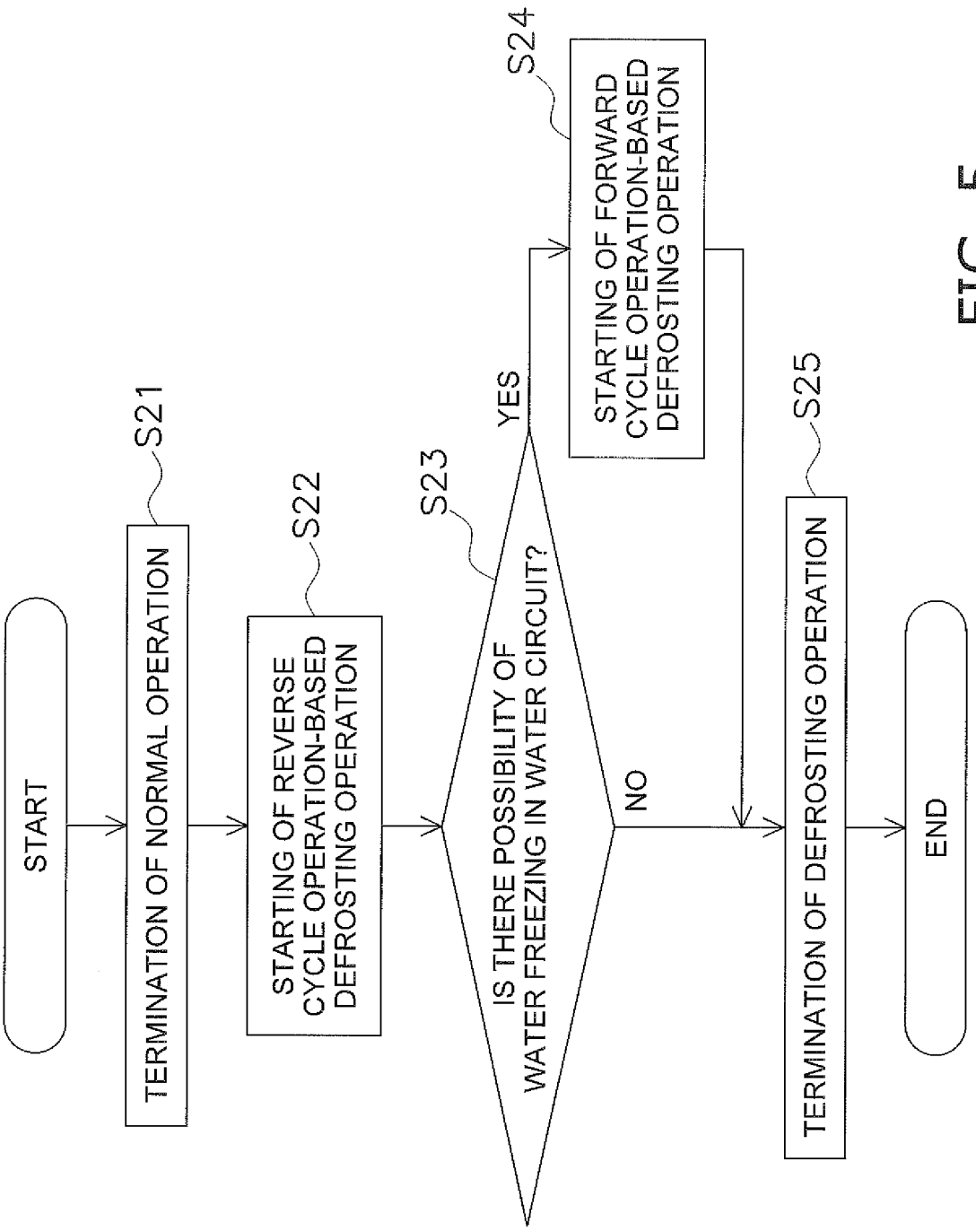
START
TERMINATION OF NORMAL OPERATION
S21
STARTING OF REVERSE CYCLE OPERATION-BASED DEFROSTING OPERATION
S22
IS THERE POSSIBILITY OF WATER FREEZING IN WATER CIRCUIT?
S23
YES
NO
STARTING OF FORWARD CYCLE OPERATION-BASED DEFROSTING OPERATION
S24
TERMINATION OF DEFROSTING OPERATION
S25
END

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/083692

A. CLASSIFICATION OF SUBJECT MATTER
F25B47/02(2006.01)i, *F24H1/00*(2006.01)i

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)
F25B47/02, F24H1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2013
Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

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.
A	WO 2011/092802 A1 (Mitsubishi Electric Corp.), 04 August 2011 (04.08.2011), paragraphs [0023] to [0025] & EP 2530410 A1	1-7
A	JP 2003-090653 A (Denso Corp.), 28 March 2003 (28.03.2003), paragraph [0040] (Family: none)	1-7
A	JP 62-213654 A (Hitachi, Ltd.), 19 September 1987 (19.09.1987), page 2, upper left column, lines 3 to 13; lower left column, lines 13 to 20 (Family: none)	1-7

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"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)
"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
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 February, 2013 (21.02.13)	05 March, 2013 (05.03.13)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- JP 2010181104 A **[0002] [0088]**
- WO 2006103815 A **[0004] [0088]**