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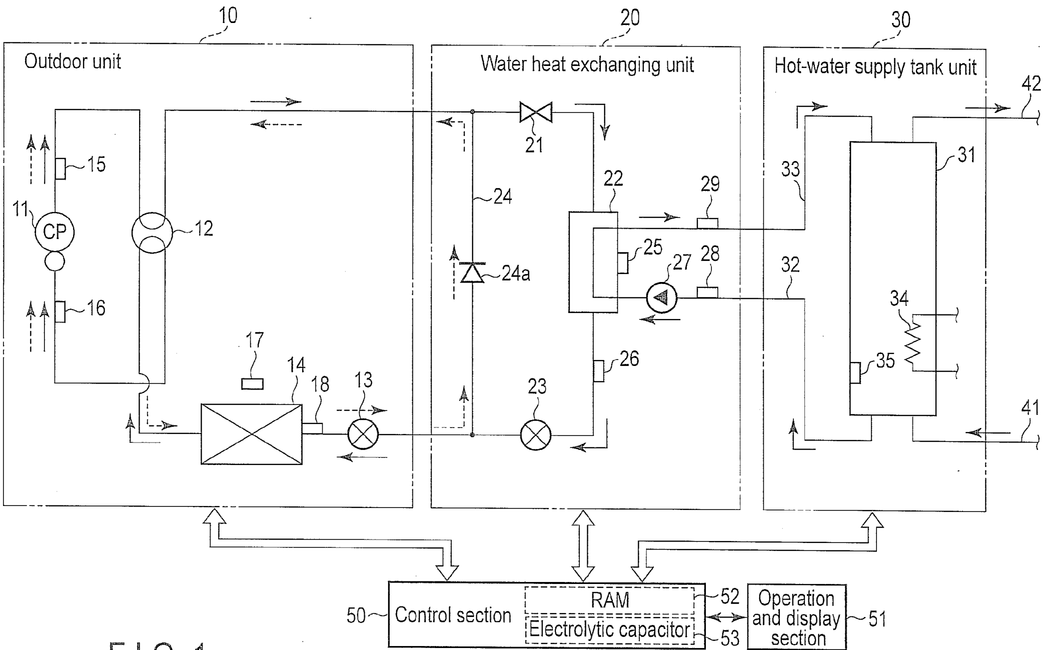
(54) **Hot-Water Supply Apparatus And Control Method Of The Same**

(57) According to one embodiment, a hot-water supply apparatus includes a hot-water supply tank (31), a heat-pump type refrigeration cycle, a bypass (24), a circulating pump (27), a refrigerant temperature sensor (26) and a control section (50). The circulating pump (27) circulates water in the supply-water tank (31) after making the water pass through the water heat exchanger (22). The refrigerant temperature sensor (26) detects a temperature of the refrigerant when the refrigerant flows between the water heat exchanger (22) and the open/close valve (23). The control section (50) performs a defrosting operation of defrosting the outdoor heat exchanger (14) by activating a defrosting circuit, and also configured to operate the circulating pump (27) in a case where the temperature detected by the refrigerant temperature sensor (26) lowers to be less than a set value during the defrosting operation.



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Description

FIELD

[0001] Embodiments described herein relate generally to a hot-water supply apparatus and a control method of the same, which heats water in a tank with a heat-pump type refrigeration cycle.

BACKGROUND

[0002] A hot-water supply apparatus is known which comprises a tank and heats water in the tank with a heat-pump type refrigeration cycle, as can be seen from disclosure of, e.g., Jpn. Pat. Appln. KOKAI Publication No. 2003-222391.

[0003] The heat-pump type refrigeration cycle activates a heating circuit in which refrigerant having a high temperature discharged from a compressor passes through a four-way valve, a water heat exchanger, a pressure reducing unit, an outdoor heat exchanger and the four-way valve, and returns to the compressor. When the above heating circuit is activated, it causes water in the tank to pass through the water heat exchanger and be circulated, thereby supplying hot water into the tank.

[0004] However, in the hot-water supply apparatus, if outside air temperature lowers, frost gradually forms on the outdoor heat exchanger to reduce the amount of heat absorbed from outside air and also the amount of heat to be added to water.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

FIG. 1 is a view for showing each of structures according to embodiments;
FIG. 2 is a flowchart of a control according to a first embodiment;
FIG. 3 is a view for showing a relationship between a temperature detected by a refrigerant temperature sensor in each of the embodiments and a plurality of zones set for the detected temperature;
FIG. 4 is a view for showing conditions for setting the number of revolutions of a circulating pump in each of the embodiments;
FIG. 5 is a view for showing a relationship between a temperature detected by a temperature sensor in each of the embodiments and a plurality of zones set for the detected temperature;
FIG. 6 is a view for showing conditions for correcting the number of revolutions of the circulating pump in each of the embodiments; and
FIG. 7 is a flowchart of a control in the second embodiment.

DETAILED DESCRIPTION

[0006] In general, according to one embodiment, a hot-water supply apparatus includes: a hot-water supply tank; a heat-pump type refrigeration cycle which comprises a compressor configured to compress and discharge refrigerant, and in which the compressor, a four-way valve, a water heat exchanger, an open/close valve, a pressure reducing unit and an outdoor heat exchanger are connected in this order; a bypass connected between the open/close valve and the pressure reducing unit and between the four-way valve and the water heat exchanger; a circulating pump configured to circulate water in the supply-water tank after making the water pass through the water heat exchanger; a refrigerant temperature sensor configured to detect a temperature of the refrigerant when the refrigerant flows between the water heat exchanger and the open/close valve; and a control section configured to perform a defrosting operation of defrosting the outdoor heat exchanger by activating a defrosting circuit in which the refrigerant discharged from the compressor flows through the four-way valve, the outdoor heat exchanger, the pressure reducing unit, the bypass and the four-way valve and returns to the compressor, and also configured to operate the circulating pump in a case where the temperature detected by the refrigerant temperature sensor lowers to be less than a set value during the defrosting operation.

[1] First embodiment

[0007] A hot-water supply apparatus according to a first embodiment will be explained.

[0008] The hot-water supply apparatus, as shown in FIG. 1, comprises an outdoor unit 10, a water heat exchanging unit 20 and a hot-water supply tank unit 30, which are connected to each other by pipes specific for those units. Also, a control section 50 is connected to the outdoor unit 10, the water heat exchanging unit 20 and the hot-water supply tank unit 30. To the control section 50, an operation and display section 51 is connected.

[0009] The outdoor unit 10 and the water heat exchanging unit 20 are connected as described above to provide a heat-pump type refrigeration cycle.

[0010] A compressor 11 is provided to discharge refrigerant after sucking therein and compressing the refrigerant. To a discharge portion of the compressor 11, a four-way valve 12 and one end of a water heat exchanger 22 are connected by a pipe specific for them, with an open/close valve, e.g., a two-way valve 21, interposed between the four-way valve 12 and the water heat exchanger 22. To the other end of the water heat exchanger 22, one end of an outdoor heat exchanger 14 is connected by a pipe specific for them, with a pulse motor valve (PMV) 23 and a pressure reducing unit, e.g., an electrical expansion valve 13, interposed between the water heat exchanger 22 and the outdoor heat exchanger 14. The other end of the outdoor heat exchanger 14 is connected to an intake port of the compressor 11 by a pipe specific for them, with the four-way valve 12 interposed between the outdoor heat exchanger 14 and the compressor 11.

[0011] When a heat operation is performed, i.e., a heating circuit is activated, as indicated by arrows of solid lines, refrigerant (gas refrigerant) having a high temperature discharged from the compressor 11 passes through the four-way valve 12 and the two-way valve 21 to flow into the water heat exchanger 22. In the water heat exchanger 22, the refrigerant is liquefied by heat exchange between the refrigerant and water. The liquefied refrigerant passes through the pulse motor valve 23 and the electrical expansion valve 13 (e.g., a pulse motor valve) to flow into the outdoor heat exchanger 14. In the outdoor heat exchanger 14, the refrigerant is gasified by absorbing heat from outside air in the outdoor heat exchanger 14. After passing through the four-way valve 12, the gasified refrigerant is sucked in the compressor 11. In such a manner, when the heating circuit is activated, water passing through the water heat exchanger 22 is heated.

[0012] The two-way valve 21 is an electromagnetic type of two-way valve which is opened by supplying power to the two-way valve 21, and closed by stopping supplying of the power thereto. To be more specific, the two-way valve 21 is opened when the above heating circuit is activated, and closed to stop flowing of the refrigerant into the water heat exchanger 22 at a pipe for gas in the heat-pump type refrigeration cycle when a defrosting circuit is activated which will be described later. The degree of opening of the pulse motor valve 23 is continuously varied in accordance with the number of drive voltage pulses. The pulse motor valve 23 is totally opened when the heating circuit is activated, and totally closed to stop flowing of the refrigerant into the water heat exchanger 22 at a pipe for liquid in the heat-pump type of refrigeration circuit when the defrosting circuit is activated.

[0013] In the above heat-pump type refrigeration cycle, a bypass 24 for the defrosting circuit, which includes a check valve 24a, is provided to extend from a pipe for liquid between the pulse motor valve 23 and the electrical expansion valve 13 to a pipe for gas between the four-way valve 12 and the two-way valve 21.

[0014] When the four-way valve 12 is switched, the two-way valve 21 is closed, and the pulse motor valve 23 is totally closed, as indicated by arrows of broken lines, the refrigerant discharged from the compressor 11 passes through the four-way valve 12 to directly flow into the outdoor heat exchanger 14. After passing through the outdoor heat exchanger 14, the refrigerant passes through the electrical expansion valve 13, the bypass 24 and the four-way valve 12, and is then sucked in the compressor 11. This is achieved when the defrosting circuit is activated. That is, when the defrosting circuit is activated, it causes frost formed on the outdoor heat exchanger 14 to be removed by heat of the refrigerant having a high temperature supplied from the compressor 11.

[0015] The hot-water supply tank unit 30 comprises a hot-water supply tank 31. To lower part and upper part of the hot-water supply tank 31, an incurrent pipe 41 and an excurrent pipe 42 are connected respectively. The incurrent pipe 41 guides water of a water supply source to the lower part of the hot-water supply tank 31. The excurrent pipe 42 guides hot water in the upper part of the hot-water supply tank 31 to a load.

[0016] An incurrent pipe 32 is provided to extend from the lower part of the hot-water supply tank 31 to one end of a water way of the water heat exchanger 22. Also, an excurrent pipe 33 is provided to extend from the other end of the water way of the water heat exchanger 22 to the upper part of the hot-water supply tank 31. At the incurrent pipe 32, a circulating pump 27 for water supply is provided. When the circulating pump 27 is operated, it causes hot water in the hot-water supply tank 31 to pass through the water heat exchanger 22, and to be circulated.

[0017] Furthermore, in the outdoor unit 10, at a pipe for discharge, which extends between the discharge port of the compressor 11 and the four-way valve 12, a refrigerant-temperature sensor 15 is provided to detect a temperature Td of the refrigerant discharged from the compressor 11. At a pipe for intake, which extends between the four-way valve 12 and the compressor 11, a refrigerant temperature sensor 16 is provided to detect a temperature Ts of the refrigerant sucked in the compressor 11. In addition, an outside-air temperature sensor 17 is provided close to the outdoor heat exchanger 14 to detect an outside air temperature To. At the outdoor heat exchanger 14, a heat-exchange temperature sensor 18 is provided to detect a temperature T2 of the outdoor heat exchanger 14.

[0018] In the water heat exchanging unit 20, a heat-exchange sensor 25 is attached to the water heat exchanger 22 to a temperature Tc of the water heat exchanger 22. At a pipe for liquid which extends between the water heat exchanger 22 and the pulse motor valve 23, a refrigerant temperature sensor 26 is provided to detect a temperature Tx of the refrigerant. At the incurrent pipe 32, a water temperature sensor 28 is provided to detect a temperature Twi of water which will flow into the water heat exchanger 22. At the excurrent pipe 33, a water temperature sensor 29 is provided to detect a temperature Two of water which has flowed out from the water heat exchanger 22.

[0019] At the hot-water supply tank unit 30, an electric heater 34 for heating hot water is provided in the hot-water supply tank 31. Also, a water temperature sensor 35 configured to detect a temperature Tt of water in the electric heater 34 is attached to lower part of the hot-water supply tank 31.

[0020] The control section 50 comprises a microcomputer and a peripheral circuit thereof. To be more specific, the control section 50 comprises a random-access memory (RAM) which is a volatile memory, as storage section, and also an electrolytic capacitor 53 as a power supply for operating the RAM 52.

[0021] Furthermore, the control section 50 comprises, as main means thereof, the following sections (1)-(7):

(1) a heating operation section configured to activate a heating circuit in which the refrigerant discharged from the compressor 11 passes through the four-way valve 12, the two-way valve 21, the water heat exchanger 22, the pulse motor valve 23, the electrical expansion valve 13, the outdoor heat exchanger 14 and the four-way valve 12 and returns to the compressor 11, and also to operate the circulating pump 27, in order to heat water in the hot-water supply tank 31;
(2) a defrosting operation section configured to activate a defrosting circuit in which the refrigerant discharged from the compressor 11 passes through the four-way valve 12, the outdoor heat exchanger 14, the electrical expansion valve 13, the bypass 24 and the four-way valve 12 and returns to the compressor 11, in order to remove frost formed on the outdoor heat exchanger 14, the defrosting operation section being further configured to close the pulse motor valve 23 and the two-way valve 21 at the time of performing the above defrosting operation;
(3) a first control section configured to cause the heating operation of the heating operation section and the defrosting operation of the defrosting operation section to be selectively performed;
(4) a second control section configured to operate the circulating pump 27 if the temperature Tx detected by the refrigerant temperature sensor 26 lowers to be equal to or less than a set value during the defrosting operation;
(5) a third control section configured to control the number of revolutions of the circulating pump 27 which is operated during the defrosting operation, in accordance with the temperature Tx detected by the refrigerant temperature sensor 26;
(6) a fourth control section configured to correct the number of revolutions of the circulating pump 27 which is controlled by the third control section, in accordance with the temperature Twi detected by the water temperature sensor 28; and
(7) a first control section configured to stop, if the temperature tx detected by the refrigerant temperature sensor 26 lowers to be lower than a predetermined value lower than the above set value, the operation of the compressor 11; once totally operate the pulse motor valve 23 and then totally close it (initializing operation); and thereafter restart the operation of the compressor 11.

[0022] Next, the operation will be explained with reference to the flowchart of FIG. 2.

[0023] When a hot-water supply tap on a load side is opened, hot water in the upper part of the hot-water supply tank 31 flows to the load through the excurrent pipe 42. Thus, water is resupplied from the water supply source into the lower part of the hot-water supply tank 31 through the incurrent pipe 41.

[0024] The temperature Tt of water in the hot-water supply tank 31 is detected by the water sensor 35. When the temperature Tt detected by the water sensor 35 becomes lower than a temperature set by the operation of the operation and display section 51, the compressor 11 is operated to provide the heating circuit, and the circulating pump 27 is also operated. Due to the heating operation by the heating circuit and the circulating pump 27, water in the hot-water supply tank 31 is heated. When this heating operation continues, and the temperature Tt detected by the water sensor 35 rises to be higher than the set value, the compressor 11 is stopped to deactivate the heating circuit, and the circulating pump 27 is also stopped.

[0025] During the heating operation, in the case where the temperature of outside air is low, frost gradually forms on a surface of the outdoor heat exchanger 14, which functions as an evaporator. In accordance with formation of the frost, the temperature Te of the outdoor heat exchanger 14 lowers.

[0026] The temperature Te of the outdoor heat exchanger 14 is detected by the heat-exchange temperature sensor 18. In the case where a defrosting condition is satisfied in which the temperature Te detected by the heat-exchange temperature sensor 18 lowers to be equal to or lower than a set value (e.g., 0°C), and this state continues for a predetermined time period (Yes in step 101), the defrosting circuit is activated, and the defrosting operation for the outdoor heat exchanger 14 is started (step 102).

[0027] At the time of performing the defrosting operation, the circulating pump 27 is stopped to also stop circulation of water to the water heat exchanger 22, and the two-way valve 21 is closed to totally close the pulse motor valve 23. That is, the pulse motor valve 23 is totally closed in order to prevent the refrigerant whose temperature lowers due to the defrosting operation for the outdoor heat exchanger 14 from flowing into the water heat exchanger 22. Furthermore, in the defrosting circuit, since the refrigerant flows toward the four-way valve 12 through the bypass 24, if the two-way valve 21 is kept opened, there is a possibility that a negative pressure will be applied to the pulse motor valve 23 through the water heat exchanger 22, and the refrigerant will leak from the pulse motor valve 23 due to the applied negative pressure. In order to prevent such a problem, the two-way valve 21 is closed.

[0028] However, there is a case where for example, dust is caught in the pulse motor valve 23 or the number of drive voltage pulses applied in a control of the degree of the opening of the pulse motor valve 23 varies from a set number of pulses, as a result of which the pulse motor valve 23, which should be totally closed, is opened to permit the refrigerant to leak therefrom. In this case, there is a case where the leaking refrigerant will flow into the water heat exchanger 22, and ice the water heat exchanger 22.

[0029] In order to avoid such a problem, during the defrosting operation, the circulating pump 27 is controlled based on the temperature Tx detected by the refrigerant temperature sensor 26 at the pipe for liquid between the pulse motor valve 23 and the water heat exchanger 22 (step 200).

[0030] In the above circulation-pump control, temperature zone conditions as shown in FIG. 3 and number-of-revolutions conditions as shown in FIG. 4 are applied. To be more specific, as the temperature zone conditions, a relationship between the temperature Tx detected by the refrigerant temperature sensor 26 and a plurality of zones a, b, c, d and e set for the detected temperature Tx is established as shown in FIG. 3, and as the number-of-revolutions conditions, the number of revolutions of the circulating pump 27 is determined with respect to each of the above zones as shown in FIG. 4.

[0031] Under the temperature zone conditions shown in FIG. 3, a temperature difference of 1K (hysteresis) is ensured between each of boundaries between the zones which are set with respect to the case where the detected temperature Tx rises and a respective one of boundaries between the zones which are set with respect to the case where the detected temperature Tx lowers, as shown in FIG. 3.

[0032] For example, in the case where the detected temperature Tx rises, -25°C is determined as a boundary from the zone e to the zone d, -5°C is determined as a boundary from the zone d to the zone c, 0°C is determined as a boundary from the zone c to the zone b, and 10°C is determined as a boundary from the zone b to the zone a. In the case where the detected temperature Tx lowers, 9°C is determined as a boundary from the zone a to the zone b, -1°C is determined as a boundary from the zone b to the zone c, -6°C is set as a boundary from the zone c to the zone b, and -26°C is set as a boundary from the zone d to the zone e.

[0033] If the detected temperature Tx falls within the zone a (Yes in step 201), it is determined that refrigerant does not leak from the pulse motor valve 23, and the number of revolutions of the circulating pump 27 is set to zero (step 202).

[0034] If the detected temperature Tx falls within the zone b lower than the zone a (Yes in step 203), it is determined that a small amount of refrigerant leaks from the pulse motor valve 23, and the circulating pump 27 is operated at 1300 rpm (step 204). This causes water in the hot-water supply tank 31 to flow into the water heat exchanger 22, and restricts lowering of the temperature of the water heat exchanger 22 due to leakage of the above small amount of refrigerant from the pulse motor valve 23.

[0035] If the detected temperature Tx falls within the zone c lower than the zone b (Yes in step 205), it is determined that the amount of refrigerant leaking from the pulse motor valve 23 is larger than the above small amount of refrigerant, and the circulating pump 27 is operated at 2600 rpm (step 206). In such a manner, when the number of revolutions of the circulating pump 27 is increased, the amount of water flowing into the water heat exchanger 22 is also increased to be larger than that in the case where the detected temperature Tx falls within the zone b. Thereby, even if the amount of refrigerant leaking from the pulse motor valve 23 is larger than the above small amount of refrigerant, lowering of the temperature of the water heat exchanger 22 is restricted.

[0036] If the detected temperature Tx falls within the zone d lower than the zone c (Yes in step 207), it is determined that the amount of refrigerant leaking from the pulse motor valve 23 is much larger than the above small amount of refrigerant, and the circulating pump 27 is operated at 3420 rpm (step 208). In such a manner, when the number of revolutions is increased, the amount of water flowing into the water heat exchanger 22 is also increased to be larger than that in the case where the detected temperature Tx falls within the zone c. Therefore, even if the amount of refrigerant leaking from the pulse motor valve 23 is much larger than the above small amount of refrigerant, lowering of the temperature of the water heat exchanger 22 is restricted.

[0037] In such a manner, lowering of the temperature of the water heat exchanger 22 can be restricted, and thus the water heat exchanger 22 is prevented from being iced. As a result, water in the hot-water supply tank 31 can be reliably heated, and the reliability of the hot-water supply apparatus is improved.

[0038] If the detected temperature Tx falls within the zone e lower than the zone d (No in step 207), it is determined that a considerably large amount of refrigerant leaks from the pulse motor valve 23, and the operation of the compressor 11 is stopped. In this state, initialization processing is executed in which the pulse motor valve 23 is totally opened once, and then totally closed; and thereafter the operation of the compressor 11 is restarted (step 209).

[0039] In the case where dust is caught in the pulse motor valve 23 to cause refrigerant to leak from the pulse motor valve 23, the dust is swept away from the pulse motor valve 23 when the pulse motor valve 23 is totally opened by the above initialization processing. As a result, the pulse motor valve 23 is reliably totally opened to prevent leakage of the refrigerant.

[0040] Also, in the case where the number of drive voltage pulses applied to the pulse motor valve 23 varies from a set number of pulses to cause refrigerant to leak from the pulse motor valve 23, the pulse motor valve 23 is totally opened once and then totally closed by the initialization processing, as a result of which the number of drive voltage pulses applied to the pulse motor valve 23 coincides with the set number of pulses. Thereby, the pulse motor valve 23 is reliably totally closed, thus preventing leakage of the refrigerant.

[0041] Since the refrigerant is prevented from leaking from the pulse motor valve 23, the water heat exchanger 22 is also prevented from being iced. In addition, water in the hot-water supply tank 31 can be reliably heated.

[0042] On the other hand, in the operation of the circulating pump 27 and the control of the number of revolutions thereof, the temperature Twi of water which will flow from the hot-water supply tank 31 into the water heat exchanger 22 is detected by the water temperature sensor 28. Based on the temperature Twi detected by the water temperature sensor 28, a control value for the number of revolutions by the circulating-pump control in step 200 is corrected.

[0043] In this correction, temperature zone conditions as shown in FIG. 6 and number-of-revolutions conditions as shown in FIG. 7 are applied. To be more specific, as the temperature zone conditions, a relationship between the temperature Twi detected by the water temperature sensor 28 and a plurality of zones A and B set for the detected temperature Twi is established as shown in FIG. 6, and as the number-of-revolutions conditions, a correction value of the number of revolutions is determined with respect to each of the zones as shown in FIG. 7.

[0044] Under the temperature zone conditions as shown in FIG. 6, a temperature difference of 1K (hysteresis) is ensured between each of boundaries between the zones which are set with respect to the case where the detected temperature Twi rises and a respective one of boundaries between the zones which are set with respect to the case where the detected temperature Twi lowers, as shown in FIG. 6.

[0045] For example, in the case where the detected temperature Twi rises, 5°C is determined as a boundary from an unavailable zone to the zone A, and 10°C is determined as a boundary from the zone A to the zone B. In the case where the detected temperature Twi lowers, 9°C is determined as a boundary from the zone B to the zone A, and 5°C is determined as a boundary from the zone A to the unavailable zone.

[0046] More specifically, if the detected temperature Twi falls within the zone A lower than 10°C (Yes in step 201), a correction value for the number of revolutions is one times the control value for the number of revolutions, i.e., it is equal to the control value, and is not corrected. If the detected temperature Twi exceeds 10°C to fall within the zone B (No in step 201), the correction value for the number of revolutions is 0.6 times the control value therefore. In this case, for example, if the control value is 1300 rpm, the actual number of revolutions of the circulating pump 27 is set to 780 rpm which is 0.6 times the control value. If the control value is 2600 rpm, the actual number of revolutions of the circulating pump 27 is set to 1560 rpm which is 0.6 times the control value. If the control value is 3420 rpm, the actual number of revolutions of the circulating pump 27 is set to 2052 rpm which is 0.6 times the control value.

[0047] In the case where the detected temperature Twi is higher than 10°C, it is determined that even if the amount of water to flow into the water heat exchanger 22 is decreased, lowering of the temperature of the water heat exchanger 22 can be restricted. Based on this determination, the number of revolutions of the circulating pump 27 is corrected to be decreased. This correction enables the power required to operate the circulating pump 27 to be reduced as much as possible, thus achieving energy saving.

[0048] If the defrosting operation for the outdoor heat exchanger 14 advances, and the temperature Te detected by the heat-exchange temperature sensor 18 exceeds the set value, e.g., 8°C (Yes in step 212), the defrosting circuit is deactivated to end the defrosting operation (step 103). As a result, the heating operation is restarted as appropriate in accordance with the temperature Tt detected by the water sensor 35.

[2] Second embodiment

[0049] A second embodiment will be explained.

[0050] In addition to the sections (1)-(7) provided with respect to the first embodiment, the control section 50 further comprises the following sections (8)-(11):

(8) a sixth section configured to make a check to determine whether the refrigerant temperature sensor 26 has abnormality or not based on the temperature detected by the refrigerant temperature sensor 26, while operating the circulating pump 27 at a predetermined number of revolutions, e.g., 342 rpm, with the pulse motor valve 23 opened at an predetermined degree of opening, e.g., a degree of opening corresponding to 100 pulses, at at least an initial stage of shifting from the heating operation to the defrosting operation;

(9) a seventh control section configured to cause the defrosting operation to continue, and also an RAM 52 to hold a check completion flag on to indicate that the check is completed, when the sixth control section determines that the refrigerant temperature sensor 26 does not have abnormality; and stop all operations including the defrosting operation (stop due to abnormality) when the sixth control section determines that the refrigerant temperature sensor 26 has abnormality;

(10) an eighth control section configured to make, when during the heating operation, the check completion flag of the RAM 52 is held on to indicate that the above check is completed, a simply check to determine whether the refrigerant temperature sensor 26 has abnormality or not based on a variation of the temperature Tx detected by the refrigerant temperature sensor 26; and

(11) a ninth control section configured to hold the check completion flag of the RAM 52 on when the eighth control section determines that the refrigerant temperature sensor 26 does not have abnormality; and clear the check completion flag held on in the RAM 52 when the eighth control sections determines that the refrigerant temperature sensor 26 has abnormality.

[0051] The RAM 52 in the control section 50 functions as a storage section configured to hold the check completion flag on to indicate that the check on whether the sensor has abnormality or not is completed. Furthermore, the RAM 52 can hold the contents of stored information for approximately 12 hours due to charge remaining in the electrolytic capacitor 53 even if supply of power is stopped by turning off a power supply switch or a commercial alternating-current power supply is instantly interrupted.

[0052] The other structural features of the second embodiment are the same as those of the first embodiment, and their explanations will thus be omitted.

[0053] With respect to the operation, as shown in the flowchart of FIG. 7, a step 300 is added as a sensor-abnormality checking control between the step 102 in which the defrosting operation is started and the step 200 in which the circulating-pump control is performed. In the step 300, a check is made to determine whether the refrigerant temperature sensor 26 has abnormality or not.

[0054] To be more specific, during the heating operation, if the temperature Te of the outdoor heat exchanger 14 which is detected by the heat-exchange temperature sensor 18 lowers to be lower than a set value (e.g., 0°C), and this state continues for the predetermined time period; that is, the defrosting condition is satisfied (Yes in step 101), the defrosting circuit is activated to start the defrosting operation on the outdoor heat exchanger 14 (step 102). When the defrosting operation starts, the above sensor-abnormality checking control is performed to determine whether the refrigerant temperature sensor 26 has abnormality or not (step 300).

[0055] In the sensor-abnormality checking control, first, it is monitored whether the check completion flag of the RAM 52 is on or not (step 301). If it takes long time until the heating operation is started just after the power supply switch is turned on or just after the commercial AC power supply is recovered from instant interruption thereof, the charge remaining in the electrolytic capacitor 53 is lost, and the information in the RAM 52 is erased. In this case, the check completion flag of the RAM 52 is off.

[0056] If the check completion flag of the RAM 52 is off (No in step 301), it is determined that it indicates an initial stage of shifting from the heating operation to the defrosting operation, the pulse motor valve 23 is opened to a predetermined degree of opening, e.g., a degree of opening corresponding to 100 pulses (step 302), the circulating pump 27 is started, and the number of revolutions thereof is set to a predetermined number of revolutions, e.g., 3420 rpm (step 303).

[0057] The degree of opening corresponding to 100 pulses is a degree of opening at which the pulse motor valve 23 is opened to permit a small amount of low-temperature refrigerant flowing from the outdoor heat exchanger 14 to pass through the pulse motor valve 23, by applying 100 drive voltage pulses to the pulse motor valve 23. At this time, in order to restrict lowering of the temperature of the water heat exchanger 22 due to the low-temperature refrigerant flowing into the water heat exchanger 22, the circulating pump 27 is started and operated at 3420 rpm. Thereby, water in the hot-water supply tank 31 passes through the water heat exchanger 22 and circulates.

[0058] When the pulse motor valve 23 is opened in accordance with application of 100 drive voltage pulses in the above manner, it is determined whether the temperature Tx detected by the refrigerant temperature sensor 26 lowers to be lower than, e.g., -5°C which is a set value for checking abnormality (step 304). In the case where the detected temperature Tx lowers to be lower than -5°C (Yes in step 304), it is determined that the refrigerant temperature sensor 26 is normal, and also determined that the check on the refrigerant temperature sensor 26 is completed. As a result, the check completion flag of the RAM 52 is made on (step 306).

[0059] Even in the case where the detected temperature Tx does not lower to be lower than -5°C (No in step 304), if it is lower than the temperature Txo detected by the refrigerant temperature sensor 26 before the above defrosting operation, and the difference between the detected temperatures Tx and Txo exceeds 25K (Yes in step 305), it is determined that the refrigerant temperature sensor 26 is normal, and also determined that the check on the refrigerant temperature sensor 26 is completed. As a result, the check completion flag of the RAM 52 is made on (step 306).

[0060] When the check completion flag is made on, the circulating-pump control accompanying the defrosting operation is performed (step 200). The circulating-pump control is the same as that of the first embodiment, and its explanation will thus be omitted.

[0061] When the defrosting operation for the outdoor heat exchanger 14 advances, and the temperature Te detected by the heat-exchange temperature sensor 18 exceeds the set value, e.g., 8°C, the defrosting circuit is deactivated to end the defrosting operation (step 103). As a result, the heating operation is restarted as appropriate in accordance with the temperature Tt detected by the water sensor 35.

[0062] After the restart of the heating operation, when the defrosting condition is satisfied (Yes in step 101), a second defrosting operation is started (step 102). At this time, since the check completion flag of the RAM 52 is on (Yes in step 301), the circulating-pump control is performed (step 200) without performing the check from the step 302.

[0063] On the other hand, at the time of performing the first defrosting operation, if the detected temperature Tx does not lower less than -5°C (No in step 304) or the difference between the detected temperature Tx and the temperature Tx0 detected by the refrigerant temperature sensor 26 before the first defrosting operation does not exceed -25K (Yes in step 305), and then if three minutes elapse from the time the first defrosting operation starts (Yes in step 307), it is determined that the refrigerant temperature sensor 26 is abnormal. Based on this determination, the compressor 11 is stopped, all operations including the first defrosting operation are stopped (due to abnormality), and this stop is indicated by the operation and display section 51 (step 308). For example, the refrigerant temperature sensor 26 can have the following abnormalities: the detection function of the refrigerant temperature sensor 26 itself fails; the refrigerant temperature sensor 26 is detached from the pipe due to vibration or the like; and a signal line for transmitting a detection signal from the refrigerant temperature sensor 26 is cut.

[0064] A user who uses the hot-water supply apparatus knows from the display of the operation and display section 51 why all the operations are stopped, and can thus ask a maker or a distributor for the hot-water supply apparatus to, e.g., inspect or repair the hot-water supply apparatus in order to maintain it. Until this maintenance is performed, all the operations are kept stopped.

[0065] Therefore, the defrosting operation is not performed, with abnormality occurring in the refrigerant temperature sensor 26. Thus, the water heat exchanger 22 can be reliably prevented from being iced. Accordingly, water in the hot-water supply tank 31 can be heated reliably.

[0066] It should be noted that there is a case where the first defrosting operation for the outdoor heat exchanger 14 advances in a state in which the detected temperature Tx does not lower less than -5°C (No in step 304) or the difference between the detected temperature Tx and the temperature Tx0 detected by the refrigerant temperature sensor 26 before the first defrosting operation does not exceed -25K (Yes in step 305), and three minutes do not elapse from the time the first defrosting operation is started (No in step 307); and as a result the temperature Te detected by the heat-exchange temperature sensor 18 exceeds the set value, e.g., 8°C (Yes in step 309). In this case, it is determined that the check on the refrigerant temperature sensor 26 is not completed, and the check completion flag of the RAM 52 is kept off (step 310). Then, the defrosting circuit is deactivated to end the defrosting operation (step 103). As a result, the heating operation is restarted as appropriate in accordance with the temperature Tt detected by the water sensor 35.

[0067] In the case where the defrosting operation is restarted after the restart of the heating operation; i.e., the second defrosting operation is started, the check completion flag of the RAM 52 is kept off (No in step 301). Thus, the check from the step 302 is repeated.

[0068] Also, it should be noted that the check completion flag of the RAM 52 is kept on for approximately 12 hours due to the charge remaining in the electrolytic capacitor 53, even if the power supply switch is turned off or the commercial AC power supply is instantly interrupted. Thus, after the heating operation is started (the compressor 11 is operated) upon turning on of the power supply switch or recovery of the commercial AC power supply from instant interruption, if the check completion flag of the RAM 52 is kept on, the check is not made even if the defrosting operation is started. Thus, there is a possibility that unexpected abnormality of the refrigerant temperature sensor 26 will be overlooked.

[0069] In view of the above, in the checking control of checking whether the sensor has abnormality or not, at the time of performing the heating operation (Yes in step 311), in the case where the check completion flag of the RAM 52 is kept on to indicate that the check is completed (Yes in step 312), the simply check on the refrigerant temperature sensor 26 is made.

[0070] To be more specific, where Txa is a temperature detected by the refrigerant temperature sensor 26 just after the heating operation is started (just after the compressor 11 is operated) (the detected temperature being the temperature of refrigerant flowing from the water heat exchanger 22 toward the pulse motor valve 23) and Txb is a temperature detected by the refrigerant temperature sensor 26 during the heating operation (the detected temperature being also the temperature of the refrigerant flowing from the water heat exchanger 22 toward the pulse motor valve 23), the difference between the above detected temperatures (Txb - Txa) exceeds 3K (Yes in step 313), it is determined that the refrigerant temperature sensor 26 properly detects the temperature of the refrigerant, i.e., it does not have abnormality, and thus the check completion flag of the RAM 52 is kept on (step 314).

[0071] However, in the case where the difference between the above detected temperatures (Txb - Txa) does not exceed 3K (Yes in step 313), and a predetermined time period, e.g., 5 minutes, elapses from the time when the heating operation is started (Yes in step 315), it is determined that the refrigerant temperature sensor 26 has abnormality due to which it cannot properly detect the temperature of the refrigerant, and the check completion flag of the RAM 52 which is on is cleared (step 316). That is, the check completion flag of the RAM 52 is made off.

[0072] When the check completion flag is made off to shift the operation from the heating operation to the defrosting operation, the check from the step 302 is made, and it is checked whether the refrigerant temperature sensor 26 has abnormality or not.

[0073] Therefore, even if unexpected abnormality occurs in the refrigerant temperature sensor 26 during the heating operation, it is not overlooked, i.e., it is reliably detected. Thus, the circulating-pump control is improved as a control for preventing icing of the water heat exchanger 22.

[3] Modifications

[0074] With respect to each of the first and second embodiments, in the circulating-pump control, the number of revolutions of the circulating pump 27 can be varied in three stages: 1300 rpm; 2600 rpm; and 3420 rpm. However, the value to which the number of revolutions can be varied is not limited to the above values, and the number of stages in which it can be varied is not limited to three. They may be determined as appropriate in accordance with the capacity of the circulating pump 27, the diameter of each of the incurrent pipe 32 and the excurrent pipe 33, or the capacity of the water heat exchanger 22.

[0075] While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

Claims

1. A hot-water supply apparatus **characterized by** comprising:

   a hot-water supply tank (31);
   a heat-pump type refrigeration cycle which comprises a compressor (11) configured to compress and discharge refrigerant, and in which the compressor (11), a four-way valve (12), a water heat exchanger (22), an open/close valve (23), a pressure reducing unit (13) and an outdoor heat exchanger (14) are connected in this order;
   a bypass (24) connected between the open/close valve (23) and the pressure reducing unit (13) and between the four-way valve (12) and the water heat exchanger (22);
   a circulating pump (27) configured to circulate water in the supply-water tank (31) after making the water pass through the water heat exchanger (22);
   a refrigerant temperature sensor (26) configured to detect a temperature of the refrigerant when the refrigerant flows between the water heat exchanger (22) and the open/close valve (23); and
   a control section (50) configured to perform a defrosting operation of defrosting the outdoor heat exchanger (14) by activating a defrosting circuit in which the refrigerant discharged from the compressor (11) flows through the four-way valve (12), the outdoor heat exchanger (14), the pressure reducing unit (13), the bypass (24) and the four-way valve (12) and returns to the compressor (11), and also configured to operate the circulating pump (27) in a case where the temperature detected by the refrigerant temperature sensor (26) lowers to be less than a set value during the defrosting operation.

2. The apparatus of claim 1, **characterized in that** the control section (50) performs a heating operation of heating the water in the hot-water supply tank (31) by activating a heating circuit in which the refrigerant discharged from the compressor (11) passes through the four-way valve (12), the water heat exchanger (22), the open/close valve (23), the pressure reducing unit (13), the outdoor heat exchanger (14) and the four-way valve (12) and returns to the compressor, and also by operating the circulating pump (27).

3. The apparatus of claim 1, **characterized in that** the bypass (24) includes a check valve (24a).

4. The apparatus of claim 1, **characterized in that** the control section (50) closes the open/close valve (23) at time of performing the defrosting operation.

5. The apparatus of claim 1, **characterized in that** the heat-pump type refrigeration cycle includes an open/close valve (21) between the four-way valve (12) and the water heat exchanger (22).

6. The apparatus of claim 1, **characterized in that** the control section (50) closes the open/close valve (23) and the close/open valve (21) at time of performing the defrosting operation.

7. The apparatus of claim 5, **characterized in that** the open/close valve (21) is a two-way valve, and the open/close valve (23) is a pulse motor valve which is continuously variable in degree of opening.

8. The apparatus of claim 1, **characterized in that** the control section (50) controls a number of revolutions of the circulating pump (27) in accordance with the temperature detected by the refrigerant temperature sensor (26) when the circulating pump (27) is operated at time of performing the defrosting operation.

9. The apparatus of claim 1, which further comprises a water temperature sensor configured to detect a temperature of the water before the water flows into the water heat exchanger (22), and **characterized in that** the control section (50) controls a number of revolutions of the circulating pump (27) in accordance with the temperature detected by the refrigerant temperature sensor (26) when the circulating pump (27) is operated at time of performing the defrosting operation, and also corrects the controlled number of revolutions in accordance with the temperature detected by the water temperature sensor (25).

10. The apparatus of claim 1, **characterized in that** the open/close valve (23) is a pulse motor valve which

is continuously variable in degree of opening.

11. The apparatus of claim 10, **characterized in that** at time of performing the defrosting operation, if the temperature detected by the refrigerant temperature sensor (26) lowers to be less than a predetermined value lower than the set value, the control section (50) stops an operation of the compressor (11) and totally closes the pulse motor valve (23) after totally opening the pulse motor valve (23); and therafter, restarts the operation of the compressor (11).

12. The apparatus of claim 10, **characterized in that** at at least an initial stage of shifting from the heating operation to the defrosting operation, while operating the circulating pump (27) at a predetermined number of revolutions, with the pulse motor valve (23) opened at a predetermined degree of opening, the control section (50) makes a check on the refrigerant temperature sensor (26) based on the temperature detected by the refrigerant temperature sensor (26) to determine whether the refrigerant temperature sensor (26) has abnormality or not; and if determining that the refrigerant temperature sensor (26) does not have abnormality, the control section (50) causes the defrosting operation to continue, and holds in a storage section (52), information indicating that the check is completed, and if determining that the refrigerant temperature sensor (26) has abnormality, the control section (50) stops all operations including the defrosting operation.

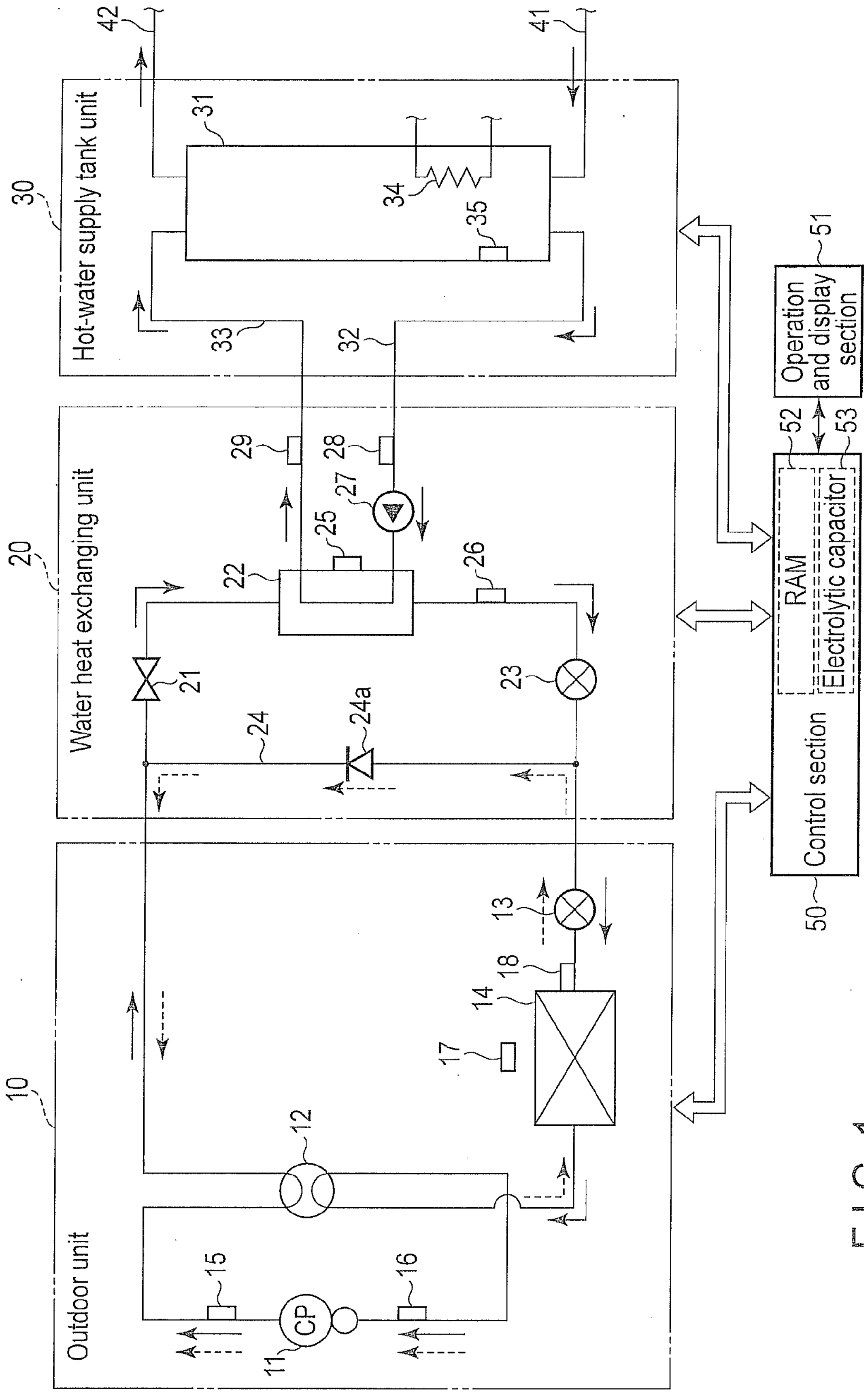
13. The apparatus of claim 12, **characterized in that** at time of performing the heating operation, if the information held in the storage section (52) indicates that the check is completed, the control section (50) makes a simple check on the refrigerant temperature sensor (26) based on the temperature detected by the refrigerant temperature sensor (26) to determine whether the refrigerant temperature sensor (26) has abnormality or not; and if determining that the refrigerant temperature sensor (26) does not have abnormality, the control section (50) maintains the information in the storage section (52), and if determining that the refrigerant temperature sensor (26) has abnormality, the control section (52) clears the information in the storage section (52).

14. A control method of a hot-water supply apparatus which comprises:

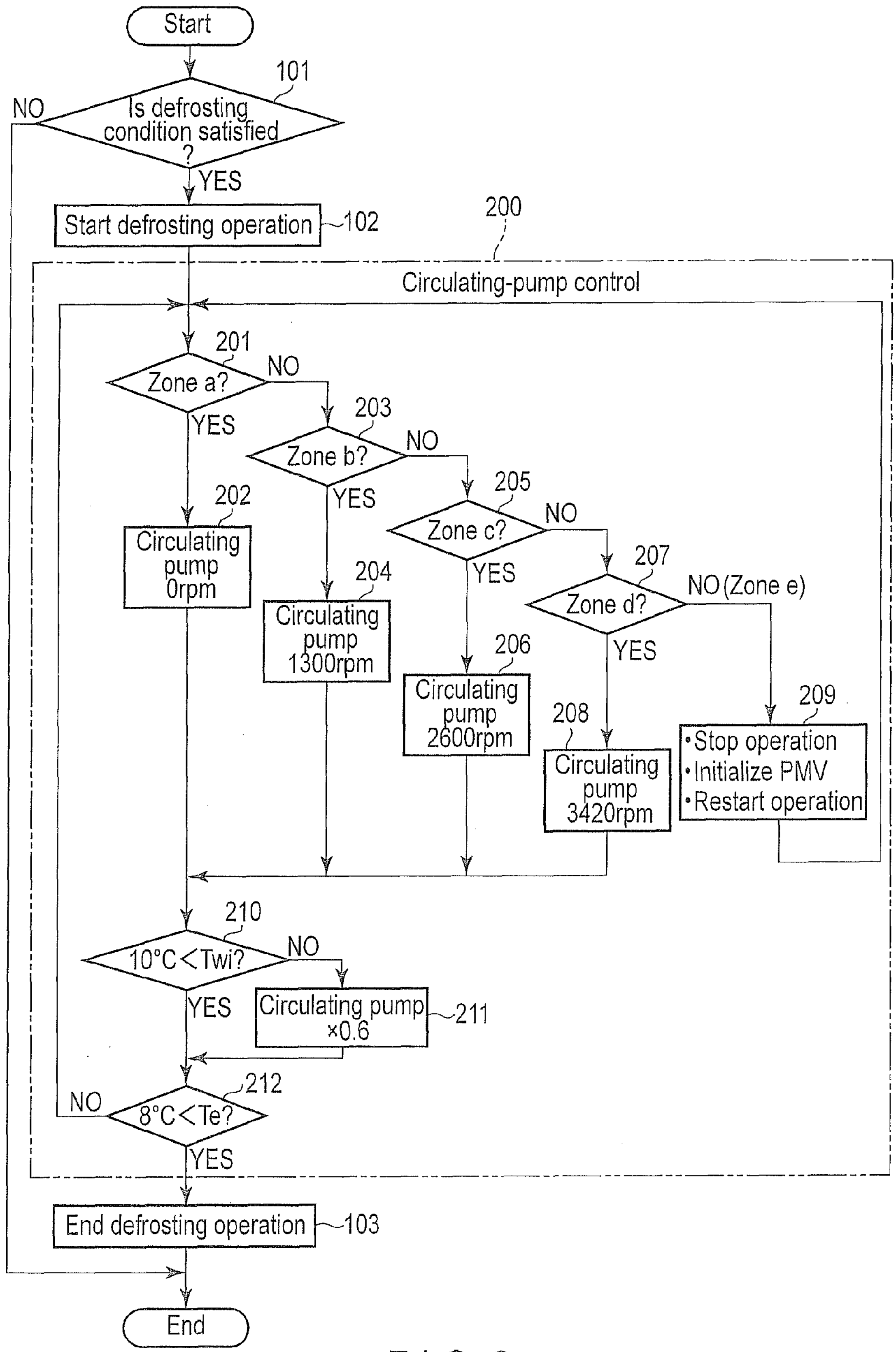
a hot-water supply tank (31);
a heat-pump type refrigeration cycle which comprises a compressor (11) configured to compress and discharge refrigerant, and in which the compressor (11), a four-way valve (12), a water heat exchanger (22), an open/close valve (23), a pressure reducing unit (13) and an outdoor heat exchanger (14) are connected in this order;
a bypass (24) connected between the open/close valve (23) and the pressure reducing unit (13) and between the four-way valve (12) and the water heat exchanger (22);
a circulating pump (27) configured to circulate water in the supply-water tank (31) after making the water pass through the water heat exchanger (22); and
a refrigerant temperature sensor (26) configured to detect a temperature of the refrigerant when the refrigerant flows between the water heat exchanger (22) and the open/close valve (23),
the control method **characterized by** comprising:

defrosting the outdoor heat exchanger (14) by activating a defrosting circuit in which the refrigerant discharged from the compressor (11) flows through the four-way valve (12), the outdoor heat exchanger (14), the pressure reducing unit (13), the bypass (24) and the four-way valve (12) and returns to the compressor (11); and
operating the circulating pump (27) if at time of defrosting the outdoor heat exchanger (14), the temperature detected by the refrigerant temperature sensor (26) lowers to be less than a set value.

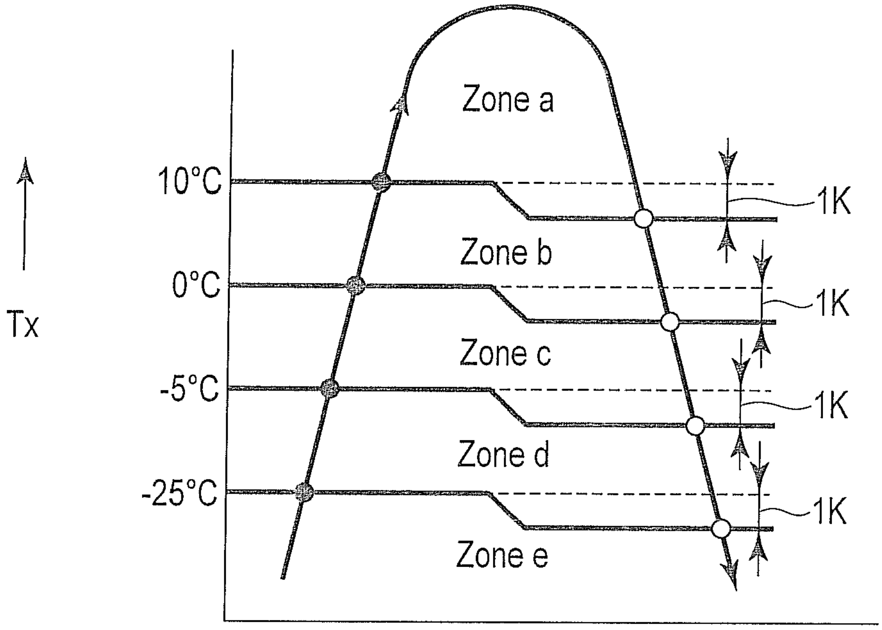
15. The method of claim 14, **characterized by** further comprising heating the hot-water supply tank (31) by activating a heating circuit in which the refrigerant discharged from the compressor (11) passes through the four-way valve (12), the water heat exchanger (22), the open/close valve (23), the pressure reducing unit (13), the outdoor heat exchanger (14) and the four-way valve (12) and returns to the compressor, and also by operating the circulating pump (27).


Hot-water supply tank unit
Water heat exchanging unit
Outdoor unit
Control section
RAM
Electrolytic capacitor
Operation and display section
CP
10
11
12
13
14
15
16
17
18
20
21
22
23
24
24a
25
26
27
28
29
30
31
32
33
34
35
41
42
50
51
52
53

F I G. 1


Start
101
Is defrosting condition satisfied ?
NO
YES
Start defrosting operation
102
200
Circulating-pump control
201
Zone a?
NO
YES
202
Circulating pump 0rpm
203
Zone b?
NO
YES
204
Circulating pump 1300rpm
205
Zone c?
NO
YES
206
Circulating pump 2600rpm
207
Zone d?
NO (Zone e)
YES
208
Circulating pump 3420rpm
209
•Stop operation
•Initialize PMV
•Restart operation
210
10°C<Twi?
NO
YES
Circulating pump ×0.6
211
212
8°C<Te?
NO
YES
End defrosting operation
103
End

F I G. 2



F I G. 3

Detected temperature Tx	Zone	Number of revolutions of pump rpm
10°C<Tx	a	0
0°C<Tx≦10°C	b	1300
-5°C<Tx≦0°C	c	2600
-25°C≦Tx≦-5°C	d	3420
Tx<-25°C	e	3420

F I G. 4

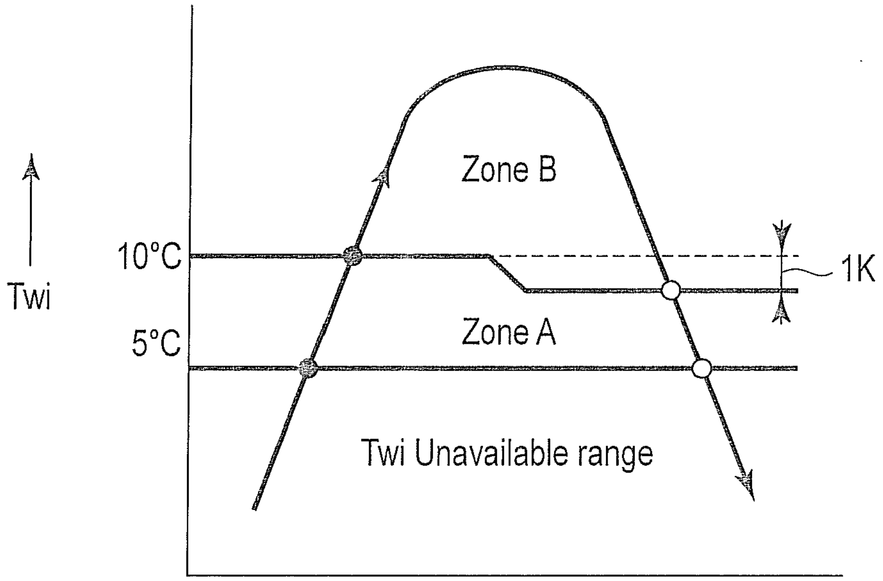
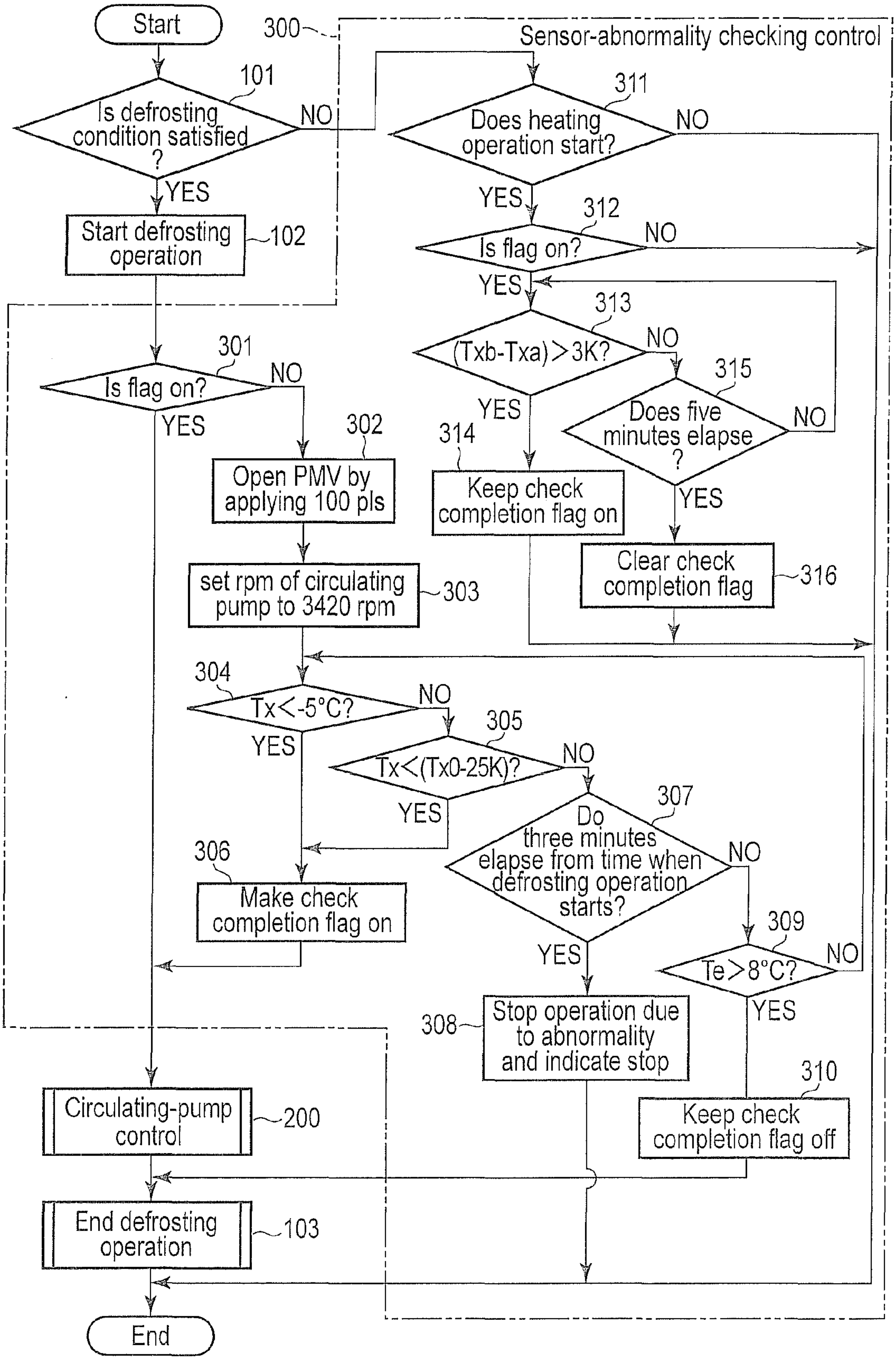


FIG. 5

Detected temperature Twi	Zone	Correction value for number of revolutions of pump
5°C≦Twi<10°C	A	×1
10°C≦Twi	B	×0.6

FIG. 6



Start
300
Sensor-abnormality checking control
101
Is defrosting condition satisfied ?
NO
YES
Start defrosting operation
102
311
Does heating operation start?
NO
YES
312
Is flag on?
NO
YES
313
(Txb-Txa)>3K?
NO
315
Does five minutes elapse ?
NO
YES
314
Keep check completion flag on
YES
Clear check completion flag
316
301
Is flag on?
NO
YES
302
Open PMV by applying 100 pls
set rpm of circulating pump to 3420 rpm
303
304
Tx<-5°C?
NO
YES
305
Tx<(Tx0-25K)?
NO
YES
306
Make check completion flag on
307
Do three minutes elapse from time when defrosting operation starts?
NO
YES
309
Te>8°C?
NO
YES
308
Stop operation due to abnormality and indicate stop
310
Keep check completion flag off
Circulating-pump control
200
End defrosting operation
103
End

F I G. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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