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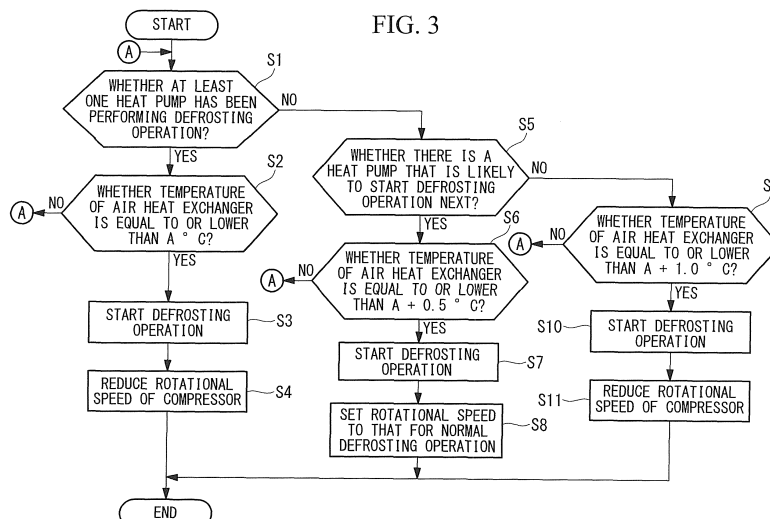
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(54) **DEFROSTING OPERATION METHOD FOR HEAT PUMP SYSTEM, AND HEAT PUMP SYSTEM**

(57) A heat-pump-system defrosting operation method includes: a step (S2) of determining, if at least one of heat pumps has already performed a defrosting operation, whether to make a target heat pump that is a determination target start the defrosting operation based on the temperature of an air heat exchanger of the target heat pump and a first threshold temperature; and a step (S6) of determining, if none of the plurality of heat pumps

has performed the defrosting operation, and if there is a heat pump that is likely to start the defrosting operation next to the target heat pump, whether to make the target heat pump start the defrosting operation, based on the temperature of the air heat exchanger of the target heat pump and a second threshold temperature that is higher than the first threshold temperature.

FIG. 3



Description

{Technical Field}

[0001] The present invention relates to a defrosting operation method for a heat pump system having a plurality of heat pumps and also relates to a heat pump system.

{Background Art}

[0002] In a heat pump system that uses a plurality of heat pumps (for example, air-cooled heat pump chillers), the plurality of heat pumps are connected to a water pipe, and water heat exchangers of the heat pumps perform heat exchange with water flowing in the water pipe. Thus, water in the water pipe is heated or cooled.

[0003] PTL 1 discloses a technology that has a configuration in which a plurality of chilling units are connected to a liquid line and that efficiently controls the number of chilling units to be operated while easily performing data transmission between the chilling units and a control unit. Furthermore, PTL 2 discloses a technology that has a configuration in which a plurality of heat-pump chiller units are connected to a water pipe and that is developed to equalize the operating hours of the chiller units while suppressing reductions in the heating capability of the chiller units during defrosting.

{Citation List}

{Patent Literature}

[0004]

{PTL 1} Publication of Japanese Patent No. 3731095
{PTL 2} Japanese Unexamined Patent Application, Publication No. H06-74531

{Summary of Invention}

{Technical Problem}

[0005] When a heat pump performs a heating operation, frosting occurs on the surface of an air heat exchanger. Thus, it is necessary to make the air heat exchanger act as a condenser to perform a defrosting operation for melting frost. However, during the defrosting operation, a water heat exchanger acts as an evaporator to cool water in the water pipe, thus reducing the water temperature.

[0006] In a heat pump system in which a plurality of heat pumps are connected to a water pipe, even though one of the heat pumps performs the defrosting operation, the other heat pumps can make up for the heating capability of the entire heat pump system, in some cases. However, when two or more heat pumps perform the defrosting operation at the same time, it is difficult to prevent a reduction in the heating capability of the entire

heat pump system.

[0007] The present invention has been made in view of such a circumstance, and an object thereof is to provide a heat-pump-system defrosting operation method and a heat pump system capable of avoiding, as much as possible, a situation in which two or more heat pumps perform the defrosting operation at the same time, thus preventing a reduction in the temperature of water in the water pipe.

{Solution to Problem}

[0008] According to a first aspect, the present invention provides a defrosting operation method for a heat pump system in which a plurality of heat pumps are connected to a water pipe, and water heat exchangers of the heat pumps perform heat exchange with water flowing in the water pipe, the method comprising: a step of determining whether at least one of the heat pumps has already been performing defrosting operation; a step of determining whether to make a target heat pump that is a determination target start defrosting operation based on a temperature of an air heat exchanger of the target heat pump and a first threshold temperature in a case in which at least one of the heat pumps has already been performing the defrosting operation.; a step of determining whether there is a heat pump that is likely to start defrosting operation next to the target heat pump in a case in which none of the plurality of heat pumps has been performing the defrosting operation; and a step of determining whether to make the target heat pump start the defrosting operation based on the temperature of the air heat exchanger of the target heat pump and a second threshold temperature that is higher than the first threshold temperature in a case in which there is a heat pump that is likely to start the defrosting operation next to the target heat pump.

[0009] According to this configuration, water flows in the water pipe which passes through the water heat exchangers of the plurality of heat pumps, thereby performing heat exchange to cause a temperature change. Then, regarding the timing at which the defrosting operation of the target heat pump will be started, in a case where another heat pump has already been performing the defrosting operation, whether to start the defrosting operation of the target heat pump is determined by comparing the temperature of the air heat exchanger of the target heat pump and the first threshold temperature. Furthermore, if none of the plurality of heat pumps has been performing the defrosting operation, and if there is a heat pump that is likely to start the defrosting operation next to the target heat pump, whether to start the defrosting operation of the target heat pump is determined by comparing the temperature of the air heat exchanger of the target heat pump and the second threshold temperature, which is higher than the first threshold temperature.

[0010] As a result, if another heat pump has already been performing the defrosting operation, it is possible

to delay the timing at which the defrosting operation of the target heat pump will be started, compared with a case in which none of the plurality of heat pumps has been performing the defrosting operation. Furthermore, if none of the plurality of heat pumps has been performing the defrosting operation, and if there is a heat pump that is likely to start the defrosting operation next to the target heat pump, it is possible to bring forward the timing at which the defrosting operation of the target heat pump will be started, compared with a case in which another heat pump has already been performing the defrosting operation.

[0011] In the first aspect of the present invention, the method may further includes a step of determining whether to make the target heat pump start the defrosting operation based on the temperature of the air heat exchanger of the target heat pump and a third threshold temperature that is higher than the second threshold temperature in a case in which none of the plurality of heat pumps has been performing the defrosting operation and when there is no heat pump that is likely to start the defrosting operation next to the target heat pump.

[0012] According to this configuration, if none of the plurality of heat pumps has been performing the defrosting operation, and if there is no heat pump that is likely to start the defrosting operation next to the target heat pump, whether to start the defrosting operation of the target heat pump is determined by comparing the temperature of the air heat exchanger of the target heat pump and the third threshold temperature, which is higher than the second threshold temperature.

[0013] As a result, if none of the plurality of heat pumps has been performing the defrosting operation, and if there is no heat pump that is likely to start the defrosting operation next to the target heat pump, it is possible to bring forward the timing at which the defrosting operation of the target heat pump will be started, compared with a case in which another heat pump has already been performing the defrosting operation or a case in which there is a heat pump that is likely to start the defrosting operation next to the target heat pump. By bringing forward the timing at which the defrosting operation of the target heat pump will be started, it is possible to increase the time period which takes for the defrosting operation, for example.

[0014] In the first aspect of the present invention, the method may further includes a step of making the target heat pump perform the defrosting operation while reducing a rotational speed of a compressor of the target heat pump compared with that for a normal defrosting operation in a case in which at least one of the heat pumps has already been performing the defrosting operation and when the target heat pump is made to perform the defrosting operation.

[0015] According to this configuration, because there is the heat pump that has already been performing the defrosting operation, the temperature of fluid flowing in a fluid pipe may be reduced. However, by reducing the

rotational speed of the compressor of the target heat pump compared with a case in which the normal defrosting operation is performed, it is possible to reduce the speed of refrigerant flowing in the water heat exchanger of the target heat pump, thereby suppressing a further reduction in the temperature of the fluid.

[0016] In the first aspect of the present invention, the method may further includes a step of suspending the defrosting operation of the target heat pump until at least one of the heat pumps that has already been performing the defrosting operation completes the defrosting operation in a case in which the at least one of the heat pumps has already been performing the defrosting operation and when the target heat pump is made to perform the defrosting operation.

[0017] According to this configuration, because there is the heat pump that has already been performing the defrosting operation, the temperature of fluid flowing in a fluid pipe may be reduced. However, because the defrosting operation of the target heat pump is suspended until the heat pump that has already been performing the defrosting operation completes the defrosting operation, it is possible to suppress a further reduction in the temperature of the fluid.

[0018] In the first aspect of the present invention, the method may further includes a step of making the target heat pump perform the defrosting operation while setting a rotational speed of a compressor of the target heat pump at the same rotational speed as that for a normal defrosting operation in a case in which none of the plurality of heat pumps has been performing the defrosting operation and when there is a heat pump that is likely to start the defrosting operation next to the target heat pump.

[0019] According to this configuration, the target heat pump performs the normal defrosting operation, thereby making it possible to reduce the time which it takes for the defrosting operation as much as possible and to complete the defrosting operation of the target heat pump before the heat pump that is supposed to start the defrosting operation starts the defrosting operation or to complete the defrosting operation of the target heat pump so as to reduce the time period when defrosting operations are performed simultaneously.

[0020] In the first aspect of the present invention, the method may further includes a step of making the target heat pump perform the defrosting operation while reducing a rotational speed of a compressor of the target heat pump compared with that for a normal defrosting operation in a case in which none of the plurality of heat pumps has been performing the defrosting operation and when there is no heat pump that is likely to start the defrosting operation next to the target heat pump.

[0021] According to this configuration, because there is no heat pump that is likely to start the defrosting operation next to the target heat pump, it is possible to increase the time which it takes for the defrosting operation and to reduce the refrigerant flow flowing in the water

heat exchanger of the target heat pump by reducing the rotational speed of the compressor of the target heat pump compared with the case in which the normal defrosting operation is performed, thereby suppressing a further reduction in fluid temperature.

[0022] The method may further includes a step of making the heat pumps that are performing their operations regularly, other than the target heat pump, perform their normal operations while increasing rotational speeds of compressors of the heat pumps other than the target heat pump compared with those in a normal mode.

[0023] According to this configuration, because the rotational speeds of the compressors of the heat pumps performing not the defrosting operation but the normal operation, other than the target heat pump, are increased, the refrigerant flow flowing in the water heat exchanger is increased, thereby making it possible to suppress a reduction in fluid temperature even though the target heat pump performs the defrosting operation. Note that it is desirable that the rotational speeds of the compressors be increased within a range in which frosting does not progress.

[0024] In the first aspect of the present invention, the method may further includes: a step of obtaining a load of the target heat pump or a compressor rotational speed thereof before the defrosting operation of the target heat pump is started, and calculating a performance reduction to be caused by starting the defrosting operation before the target heat pump starts the defrosting operation; and a step of determining an upper rotational speed of the compressor of the target heat pump for the defrosting operation such that the other heat pumps can make up for the performance reduction.

[0025] According to this configuration, because the upper rotational speed of the compressor of the target heat pump for the defrosting operation is determined such that the other heat pumps can make up for a performance reduction to be caused by starting the defrosting operation, even though the target heat pump performs the defrosting operation, a reduction in fluid temperature can be suppressed.

[0026] Furthermore, according to a second aspect, the present invention provides a heat pump system in which a plurality of heat pumps are connected to a water pipe, and water heat exchangers of the heat pumps perform heat exchange with water flowing in the water pipe, comprising: an operating-state determining part that determines whether at least one of the heat pumps has already been performing defrosting operation; and a defrosting-operation start determining part that determines whether to make a target heat pump that is a determination target start defrosting operation based on a temperature of an air heat exchanger of the target heat pump and a first threshold temperature in a case in which at least one of the heat pumps has already been performing the defrosting operation, wherein the operating-state determining part determines whether there is a heat pump that is likely to start defrosting operation next to the target heat pump

in a case in which none of the plurality of heat pumps has been performing the defrosting operation; and the defrosting-operation start determining part determines whether to make the target heat pump start the defrosting operation based on the temperature of the air heat exchanger of the target heat pump and a second threshold temperature that is higher than the first threshold temperature in a case in which there is a heat pump that is likely to start the defrosting operation next to the target heat pump.

{Advantageous Effects of Invention}

[0027] According to the present invention, it is possible to avoid, as much as possible, a situation in which two or more heat pumps perform the defrosting operation at the same time, thus preventing a reduction in the temperature of water in the water pipe.

{Brief Description of Drawings}

[0028]

{Fig. 1} Fig. 1 shows a configuration of a heat pump system according to an embodiment of the present invention.

{Fig. 2} Fig. 2 shows a block diagram representing the heat pump system according to the embodiment of the present invention.

{Fig. 3} Fig. 3 shows a flowchart showing an operation of defrosting operation of the heat pump system according to the embodiment of the present invention.

{Description of Embodiment}

[0029] A heat pump system 1 according to an embodiment of the present invention will be described below with reference to the drawings.

[0030] First, the configuration of the heat pump system 1 will be described with reference to Fig. 1.

[0031] The heat pump system 1 of this embodiment is formed of a plurality of heat pumps 2, a water pipe 11 connected to the heat pumps 2, and etc. The heat pumps 2 are, for example, air-cooled heat pump chillers and can generate cold water or hot water by performing heat exchange with water flowing in the water pipe 11.

[0032] Each of the heat pumps 2 has a compressor 5, a four-way valve 6, a water heat exchanger 7, an expansion valve 8, an air heat exchanger 9, an accumulator 10, and etc. The compressor 5, the four-way valve 6, the water heat exchanger 7, the expansion valve 8, the air heat exchanger 9, and the accumulator 10 are connected by a refrigerant pipe 3, thus forming a refrigerant circuit.

[0033] A motor of the compressor 5 is driven by an inverter. In the compressor 5, the rotational speed of the motor, that is, the refrigerant discharge rate, is adjusted by the output frequency of the inverter.

[0034] The air heat exchanger 9 performs heat exchange between outside air and refrigerant, and the water heat exchanger 7 performs heat exchange between water and the refrigerant. The accumulator 10 prevents refrigerant that has not been completely gasified in an evaporator (the water heat exchanger 7 or the air heat exchanger 9) from being suctioned into the compressor 5 in the form of a liquid.

[0035] In the heat pump 2, a heating operation and a cooling (or defrosting) operation are changed over when the flow direction of the refrigerant is changed by switching the four-way valve 6. During the heating operation, the refrigerant discharged from the compressor 5 flows through the water heat exchanger 7, the expansion valve 8, the air heat exchanger 9, and the accumulator 10 in this order. The water heat exchanger 7 acts as a condenser, and the air heat exchanger 9 acts as an evaporator. Then, hot water heated in the water heat exchanger 7 is supplied to the next heat pump 2 or the outside via the water pipe 11.

[0036] During the cooling (defrosting) operation, the refrigerant discharged from the compressor 5 flows through the air heat exchanger 9, the expansion valve 8, the water heat exchanger 7, and the accumulator 10 in this order. The air heat exchanger 9 acts as a condenser, and the water heat exchanger 7 acts as an evaporator. Then, cold water cooled in the water heat exchanger 7 is supplied to the next heat pump 2 or the outside via the water pipe 11.

[0037] While the entire heat pump system 1 performs a heating operation, when the heat pump 2 performs the heating operation, frosting occurs on the surface of the air heat exchanger 9. Therefore, the system makes the air heat exchanger 9 act as the condenser to perform the defrosting operation for melting frost. However, because hot water flowing in the water pipe 11 is cooled by the water heat exchanger 7 of the heat pump 2 performing the defrosting operation, the temperature of the water flowing in the water pipe 11 may be reduced.

[0038] In this embodiment, the operating states of the plurality of heat pumps 2 are monitored, and the timing at which the heat pumps 2 will start the defrosting operation and the refrigerant flow rate during the defrosting operation are adjusted according to the operating states.

[0039] The heat pump system 1 of this embodiment has a control section 12 that monitors the operating states of the plurality of heat pumps 2 and that changes over the operations of the heat pumps 2. As shown in Fig. 2, the control section 12 and the heat pumps 2 are connected by a control cable 13, for example, and control signals are sent and received therebetween.

[0040] The control section 12 includes, for example, an operating-state determining part 14, a defrosting-operation start determining part 15, a defrosting-operation control part 16, a normal-operation control part 17, and an operation-capability calculating part 18. The control section 12 may be provided separately from the heat pumps 2 or may be provided in one of the heat pumps 2.

[0041] The operating-state determining part 14 determines whether at least one of the plurality of heat pumps 2 has already been performing the defrosting operation. Furthermore, if none of the plurality of heat pumps 2 has been performing the defrosting operation, the operating-state determining part 14 determines whether there is a heat pump 2 that is likely to start the defrosting operation next to a target heat pump 2A. Here, the target heat pump 2A is a candidate heat pump 2 that will start the defrosting operation. In the heat pumps 2, when the heating operation is continued, frosting occurs on the air heat exchangers 9, thus reducing the temperatures of the air heat exchangers 9. Therefore, whether the heat pump 2 are just about to start its operation and a defrosting-operation start order are determined based on the temperatures of the air heat exchangers 9 of the heat pumps 2.

[0042] If at least one heat pump 2 has already been performing the defrosting operation, the defrosting-operation start determining part 15 determines whether to make the target heat pump 2A start the defrosting operation, based on the temperature of the air heat exchanger 9 of the target heat pump 2A and a first threshold temperature (for example, A °C). If the temperature of the air heat exchanger 9 decreases to the first threshold temperature (for example, A °C) or lower, the frosting load of the air heat exchanger 9 is increased to an unacceptable level, and therefore decreasing the temperature of the air heat exchanger 9 to a temperature equal to or lower than the first threshold temperature is not desirable.

[0043] Furthermore, if none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is a heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, the defrosting-operation start determining part 15 determines whether to make the target heat pump 2A start the defrosting operation, based on the temperature of the air heat exchanger 9 of the target heat pump 2A and a second threshold temperature (for example, A + 0.5 °C). The second threshold temperature is higher than the first threshold temperature. Note that the second threshold temperature of A + 0.5 °C is merely an example and can be set to another value. Furthermore, the second threshold temperature is not limited to the fixed value, and the second threshold temperature may be changed according to the rate of decline of the temperature of the air heat exchanger 9, or etc.

[0044] Furthermore, if none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is no heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, the defrosting-operation start determining part 15 determines whether to make the target heat pump 2A start the defrosting operation, based on the temperature of the air heat exchanger 9 of the target heat pump 2A and a third threshold temperature (for example, A + 1.0 °C). The third threshold temperature is higher than the second threshold temperature. Note that the third threshold temperature of A + 1.0 °C is merely an example and can be

set to another value. Furthermore, the third threshold temperature is not limited to the fixed value, and the third threshold temperature may be changed according to the rate of decline of the temperature of the air heat exchanger 9.

[0045] If at least one heat pump 2 has already been performing the defrosting operation, and if the target heat pump 2A starts the defrosting operation, the defrosting-operation control part 16 makes the target heat pump 2A perform the defrosting operation while reducing the rotational speed of the compressor 5 of the target heat pump 2A compared with that for a normal defrosting operation. Note that, instead of reducing the rotational speed of the compressor 5, the defrosting-operation control part 16 may suspend the defrosting operation of the target heat pump 2A until the heat pump 2 that has already been performing the defrosting operation completes the defrosting operation.

[0046] If none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is a heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, the defrosting-operation control part 16 makes the target heat pump 2A perform the defrosting operation while setting the rotational speed of the compressor of the target heat pump 2A at the same rotational speed as that for the normal defrosting operation.

[0047] If none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is no heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, the defrosting-operation control part 16 makes the target heat pump 2A perform the defrosting operation while reducing the rotational speed of the compressor 5 of the target heat pump 2A compared with that for the normal defrosting operation.

[0048] If none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is no heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, the normal-operation control part 17 makes the heat pumps 2 other than the target heat pump 2A perform a normal operation while increasing the rotational speeds of the compressors 5 of the heat pumps 2 other than the target heat pump 2A that are performing the normal operation, compared with that in the normal mode.

[0049] Before the target heat pump 2A starts the defrosting operation, the operation-capability calculating part 18 obtains the load of the target heat pump 2A or the rotational speed of the compressor 5 thereof immediately before the start of the defrosting operation and calculates a performance reduction to be caused by starting the defrosting operation. At this time, the defrosting-operation control part 16 determines an upper rotational speed of the compressor 5 of the target heat pump 2A for the defrosting such that the other heat pumps 2 can make up for the performance reduction calculated by the operation-capability calculating part 18. Because the upper rotational speed of the compressor 5 of the target

heat pump 2A for the defrosting is determined such that the other heat pumps 2 can make up for the performance reduction to be caused by starting the defrosting operation, even though the target heat pump 2A performs the defrosting operation, it is possible to suppress a reduction in the temperature of water flowing in the water pipe 11.

[0050] Next, the operation of the defrosting operation of the heat pump system 1 according to this embodiment will be described with reference to Fig. 3. First, a description will be given as to the timing at which the defrosting operation of the heat pump 2 will be started.

[0051] First, it is determined whether at least one of the plurality of heat pumps 2 has already been performing the defrosting operation (Step S1). If at least one of the heat pumps 2 has already been performing the defrosting operation, it is determined whether the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the first threshold temperature (for example, A °C), thereby determining whether to make the target heat pump 2A start the defrosting operation (Step S2).

[0052] Then, if the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the first threshold temperature (for example, A °C), the target heat pump 2A is made to start the defrosting operation (Step S3).

[0053] On the other hand, if none of the plurality of heat pumps 2 has been performing the defrosting operation, it is determined whether there is a heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A (Step S5). If there is a heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, it is determined whether the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the second threshold temperature (for example, $A + 0.5$ °C), thereby determining whether to make the target heat pump 2A start the defrosting operation (Step S6).

[0054] Then, if the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the second threshold temperature (for example, $A + 0.5$ °C), the target heat pump 2A is made to start the defrosting operation (Step S7).

[0055] Specifically, if another heat pump 2 has already been performing the defrosting operation, it is possible to delay the timing at which the target heat pump 2A will be made to start the defrosting operation, compared with a case in which none of the plurality of heat pumps 2 has been performing the defrosting operation. As a result, it is possible to avoid a situation in which a plurality of heat pumps 2 perform the defrosting operation simultaneously.

[0056] Furthermore, if none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is a heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, it is possible to bring forward the timing at which the target heat pump 2A will be made to start the defrosting operation.

ation, compared with a case in which another heat pump 2 has already been performing the defrosting operation. As a result, it is possible to increase the time period from the start of the defrosting operation of the target heat pump 2A until the start of the defrosting operation of the heat pump 2 that is likely to start the defrosting operation next, thus avoiding a situation in which a plurality of heat pumps 2 perform the defrosting operation simultaneously.

[0057] If none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is no heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, it is determined whether the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the third threshold temperature (for example, $A + 1.0\text{ }^{\circ}\text{C}$), thereby determining whether to make the target heat pump 2A start the defrosting operation (Step S9).

[0058] Then, if the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the third threshold temperature (for example, $A + 1.0\text{ }^{\circ}\text{C}$), the target heat pump 2A is made to start the defrosting operation (Step S10).

[0059] As a result, if none of the plurality of heat pumps 2 has been performing the defrosting operation, and if there is no heat pump that is likely to start the defrosting operation next to the target heat pump 2A, it is possible to bring forward the timing at which the target heat pump 2A will be made to start the defrosting operation, compared with a case in which another heat pump 2 has already been performing the defrosting operation and a case in which there is a heat pump that is likely to start the defrosting operation next to the target heat pump 2A. Specifically, by bringing forward the timing at which the target heat pump 2A will be made to start the defrosting operation, it is possible to increase the time period which the target heat pump 2A takes for the defrosting operation, for example.

[0060] According to the above-described operation of this embodiment, a situation in which a plurality of heat pumps 2 perform the defrosting operation at the same time in an overlapped manner can be avoided as much as possible.

[0061] Next, a description will be given as to an operation for controlling the defrosting operation in order to prevent the water temperature in the water pipe 11 from being reduced during the defrosting operation.

[0062] As shown in the above-described Step S3, in the case in which at least one heat pump 2 has already been performing the defrosting operation, and when the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the first threshold temperature (for example, $A\text{ }^{\circ}\text{C}$), the target heat pump 2A is made to start the defrosting operation.

[0063] In this case, the target heat pump 2A is made to perform the defrosting operation while the rotational speed of the compressor 5 of the target heat pump 2A is reduced compared with a case in which the normal

defrosting operation is performed (Step S4). Specifically, because there is the heat pump 2 that has already been performing the defrosting operation, if the target heat pump 2A starts the defrosting operation, the temperature of the water flowing in the water pipe 11 may be reduced. However, as described in this embodiment, by reducing the rotational speed of the compressor 5 of the target heat pump 2A compared with a case in which the normal defrosting operation is performed, it is possible to reduce the refrigerant flow flowing in the water heat exchanger 7 of the target heat pump 2A, thereby suppressing a further reduction in water temperature.

[0064] Furthermore, by doing so, it is not necessary for the other heat pumps 2 performing the normal operation to increase the rotational speeds of the compressors 5 thereof in order to make up for performance reductions of the two heat pumps 2 performing the defrosting operation.

[0065] Note that, in Step S4, instead of reducing the rotational speed of the compressor 5, it is possible to suspend the defrosting operation of the target heat pump 2A until the heat pump 2 that has already been performing the defrosting operation completes the defrosting operation. By doing so, because the defrosting operation of the target heat pump 2A is suspended, a further reduction in water temperature can be suppressed.

[0066] As in the above-described Step S7, in the case where there is a heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, when the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the second threshold temperature (for example, $A + 0.5\text{ }^{\circ}\text{C}$), the target heat pump 2A is made to start the defrosting operation.

[0067] In this case, the target heat pump 2A is made to perform the defrosting operation while the rotational speed of the compressor of the target heat pump 2A is set to the rotational speed for the normal defrosting operation (Step S8). Thus, the time period it takes for the defrosting operation can be reduced as much as possible, and the defrosting operation of the target heat pump 2A can be completed before the heat pump 2 that is supposed to start the defrosting operation starts the defrosting operation or can be completed so as to reduce the time period for which the defrosting operations are overlapped.

[0068] As shown in the above-described Step S10, in the case where there is no heat pump 2 that is likely to start the defrosting operation next to the target heat pump 2A, when the temperature of the air heat exchanger 9 of the target heat pump 2A is equal to or lower than the third threshold temperature (for example, $A + 1.0\text{ }^{\circ}\text{C}$), the target heat pump 2A is made to start the defrosting operation.

[0069] In this case, the target heat pump 2A is made to perform the defrosting operation while the rotational speed of the compressor 5 of the target heat pump 2A is reduced compared with the case in which the normal

defrosting operation is performed (Step S11). Specifically, because there is no heat pump that is likely to start the defrosting operation next to the target heat pump 2A, it is possible to elongate the time period for the defrosting operation and to reduce the refrigerant flow flowing in the water heat exchanger 7 of the target heat pump 2A by reducing the rotational speed of the compressor of the target heat pump 2A compared with the case in which the normal defrosting operation is performed, thereby suppressing a further reduction in water temperature.

[0070] Furthermore, in Step S11, the heat pumps 2 other than the target heat pump 2A are made to perform the normal operation while the rotational speeds of the compressors 5 of the heat pumps 2 are increased compared with the rotational speed in the normal mode.

[0071] By doing so, because the rotational speeds of the compressors 5 of the heat pumps 2 performing not the defrosting operation but the normal operation, other than the target heat pump 2A, are increased, the refrigerant flow flowing in the water heat exchanger is increased, thereby making it possible to suppress a reduction in water temperature even though the target heat pump 2A performs the defrosting operation. Note that it is desirable that the rotational speeds of the compressors 5 be increased within a range in which frosting does not progress.

[0072] In the above-described operation, before the target heat pump 2A starts the defrosting operation, the load of the target heat pump 2A or the rotational speed of the compressor 5 thereof immediately before the start of the defrosting operation should be obtained, and a performance reduction to be caused by starting the defrosting operation should be calculated.

[0073] At this time, the defrosting-operation control part 16 determines the upper rotational speed of the compressor 5 of the target heat pump 2A for the defrosting such that the other heat pumps 2 can make up for the performance reduction calculated by the operation-capability calculating part 18. By doing so, because the upper rotational speed of the compressor 5 of the target heat pump 2A for the defrosting is determined such that the other heat pumps 2 can make up for the performance reduction to be caused by starting the defrosting operation, even though the target heat pump 2A performs the defrosting operation, a reduction in the temperature of water flowing in the water pipe 11 can be suppressed.

{Reference Signs List}

[0074]

- 1 heat pump system
- 2 heat pump
- 3 refrigerant pipe
- 5 compressor
- 6 four-way valve
- 7 water heat exchanger
- 8 expansion valve

- 9 air heat exchanger
- 10 accumulator
- 11 water pipe

Claims

1. A defrosting operation method for a heat pump system in which a plurality of heat pumps are connected to a water pipe, and water heat exchangers of the heat pumps perform heat exchange with water flowing in the water pipe, the method comprising:

a step of determining whether at least one of the heat pumps has already been performing defrosting operation;

a step of determining whether to make a target heat pump that is a determination target start defrosting operation based on a temperature of an air heat exchanger of the target heat pump and a first threshold temperature in a case in which at least one of the heat pumps has already been performing the defrosting operation;

a step of determining whether there is a heat pump that is likely to start defrosting operation next to the target heat pump in a case in which none of the plurality of heat pumps has been performing the defrosting operation; and

a step of determining whether to make the target heat pump start the defrosting operation based on the temperature of the air heat exchanger of the target heat pump and a second threshold temperature that is higher than the first threshold temperature in a case in which there is a heat pump that is likely to start the defrosting operation next to the target heat pump.

2. The defrosting operation method for a heat pump system according to claim 1, further comprising a step of determining whether to make the target heat pump start the defrosting operation based on the temperature of the air heat exchanger of the target heat pump and a third threshold temperature that is higher than the second threshold temperature in a case in which none of the plurality of heat pumps has been performing the defrosting operation and when there is no heat pump that is likely to start the defrosting operation next to the target heat pump.

3. The defrosting operation method for a heat pump system according to claim 1 or 2, further comprising a step of making the target heat pump perform the defrosting operation while reducing a rotational speed of a compressor of the target heat pump compared with that for a normal defrosting operation in a case in which at least one of the heat pumps has already been performing the defrosting operation and when the target heat pump is made to perform

the defrosting operation.

4. The defrosting operation method for a heat pump system according to claim 1 or 2, further comprising a step of suspending the defrosting operation of the target heat pump until at least one of the heat pumps that has already been performing the defrosting operation completes the defrosting operation in a case in which the at least one of the heat pumps has already been performing the defrosting operation and when the target heat pump is made to perform the defrosting operation. 5
5. The defrosting operation method for a heat pump system according to claim 1 or 2, further comprising a step of making the target heat pump perform the defrosting operation while setting a rotational speed of a compressor of the target heat pump at the same rotational speed as that for a normal defrosting operation in a case in which none of the plurality of heat pumps has been performing the defrosting operation and when there is a heat pump that is likely to start the defrosting operation next to the target heat pump. 10
6. The defrosting operation method for a heat pump system according to claim 1 or 2, further comprising a step of making the target heat pump perform the defrosting operation while reducing a rotational speed of a compressor of the target heat pump compared with that for a normal defrosting operation in a case in which none of the plurality of heat pumps has been performing the defrosting operation and when there is no heat pump that is likely to start the defrosting operation next to the target heat pump. 15
7. The defrosting operation method for a heat pump system according to claim 6, further comprising a step of making the heat pumps that are performing their operations regularly, other than the target heat pump, perform their normal operations while increasing rotational speeds of compressors of the heat pumps other than the target heat pump compared with those in a normal mode. 20
8. The defrosting operation method for a heat pump system according to any one of claims 1 to 6, further comprising: 25

a step of obtaining a load of the target heat pump or a compressor rotational speed thereof before the defrosting operation of the target heat pump is started, and calculating a performance reduction to be caused by starting the defrosting operation before the target heat pump starts the defrosting operation; and 30

a step of determining an upper rotational speed of the compressor of the target heat pump for the defrosting operation such that the other heat 35

pumps can make up for the performance reduction.

9. A heat pump system in which a plurality of heat pumps are connected to a water pipe, and water heat exchangers of the heat pumps perform heat exchange with water flowing in the water pipe, comprising: 40

an operating-state determining part that determines whether at least one of the heat pumps has already been performing defrosting operation; and

a defrosting-operation start determining part that determines whether to make a target heat pump that is a determination target start defrosting operation based on a temperature of an air heat exchanger of the target heat pump and a first threshold temperature in a case in which at least one of the heat pumps has already been performing the defrosting operation, 45

wherein the operating-state determining part determines whether there is a heat pump that is likely to start defrosting operation next to the target heat pump in a case in which none of the plurality of heat pumps has been performing the defrosting operation; and

the defrosting-operation start determining part determines whether to make the target heat pump start the defrosting operation based on the temperature of the air heat exchanger of the target heat pump and a second threshold temperature that is higher than the first threshold temperature in a case in which there is a heat pump that is likely to start the defrosting operation next to the target heat pump. 50

FIG. 1

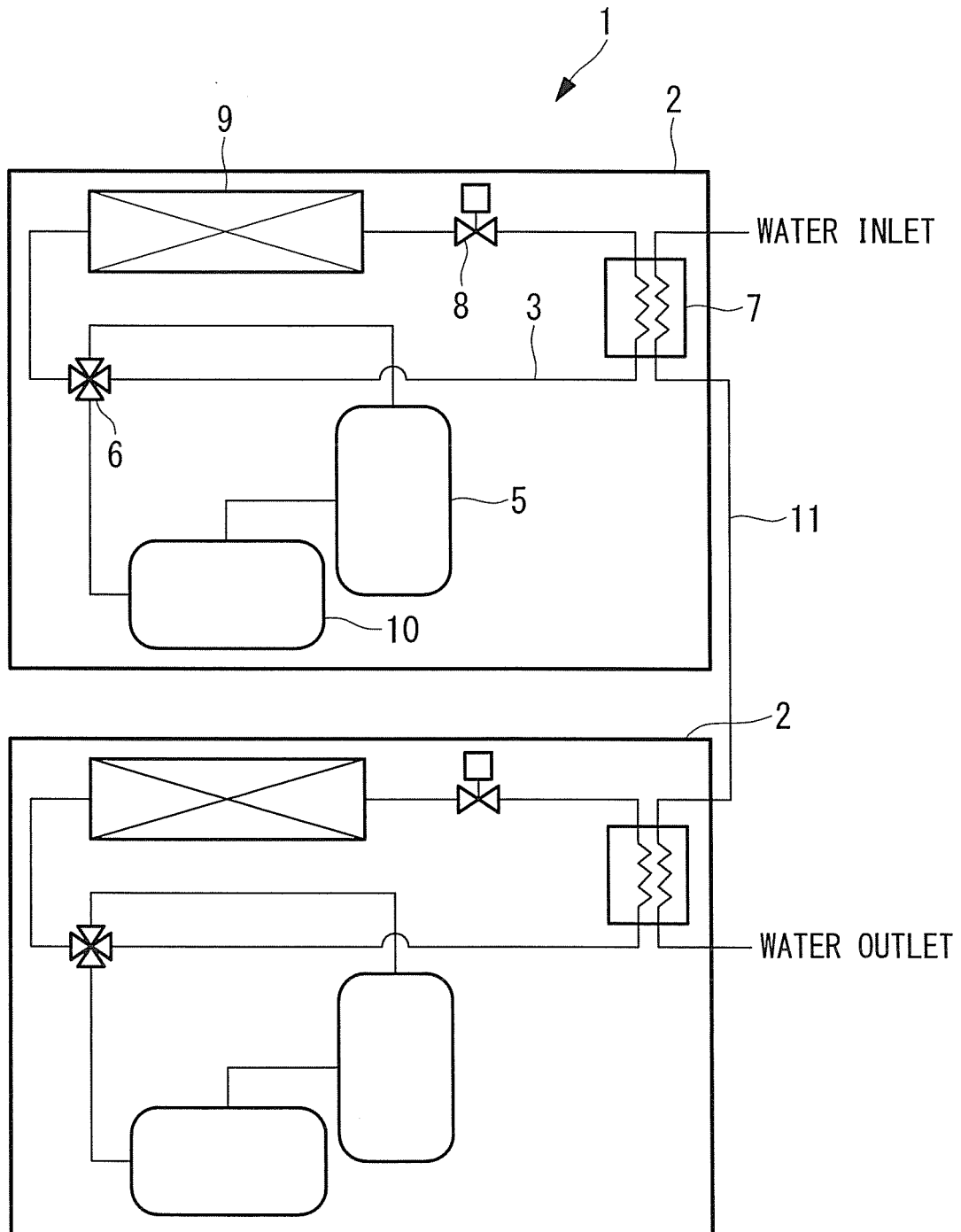


FIG. 2

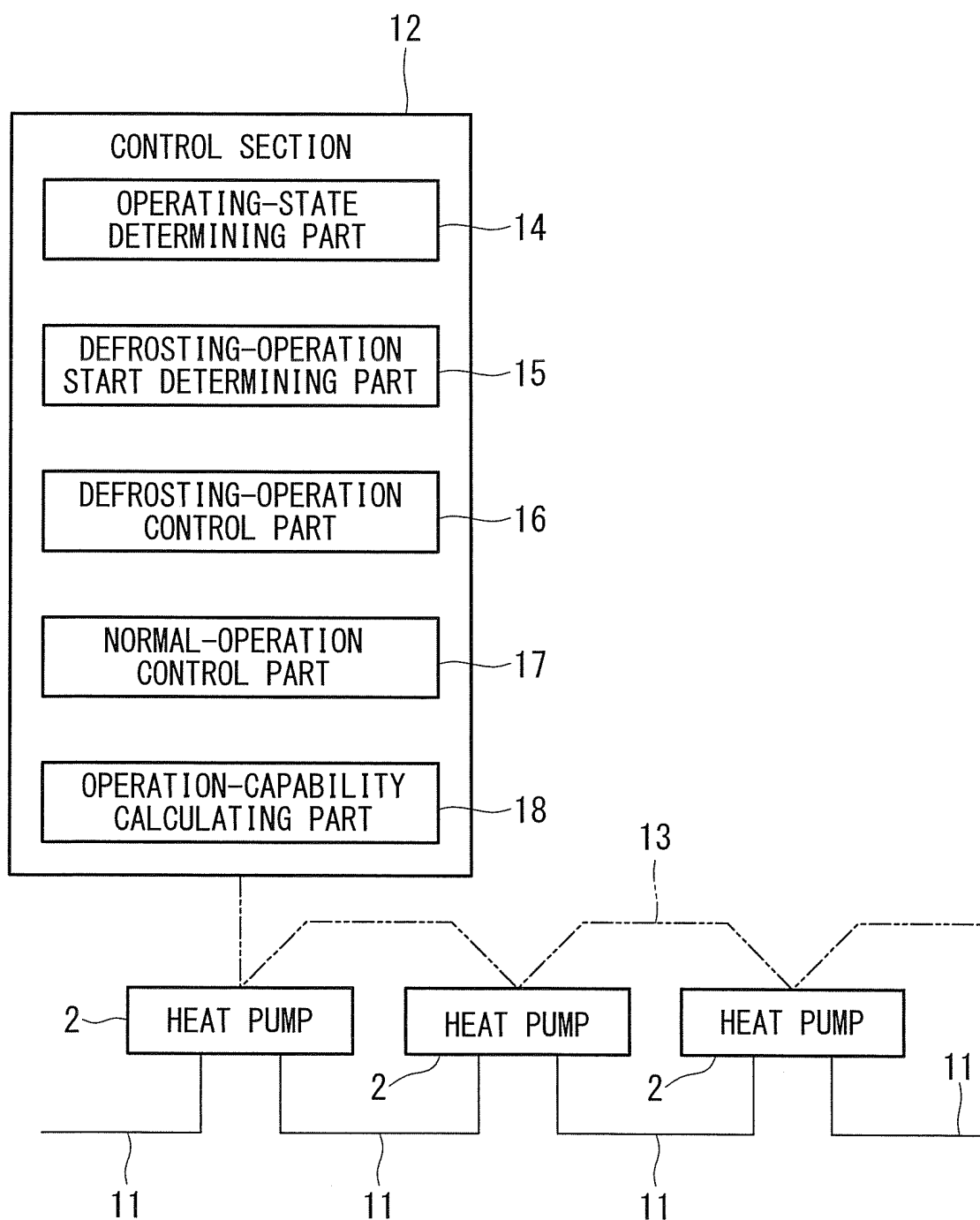
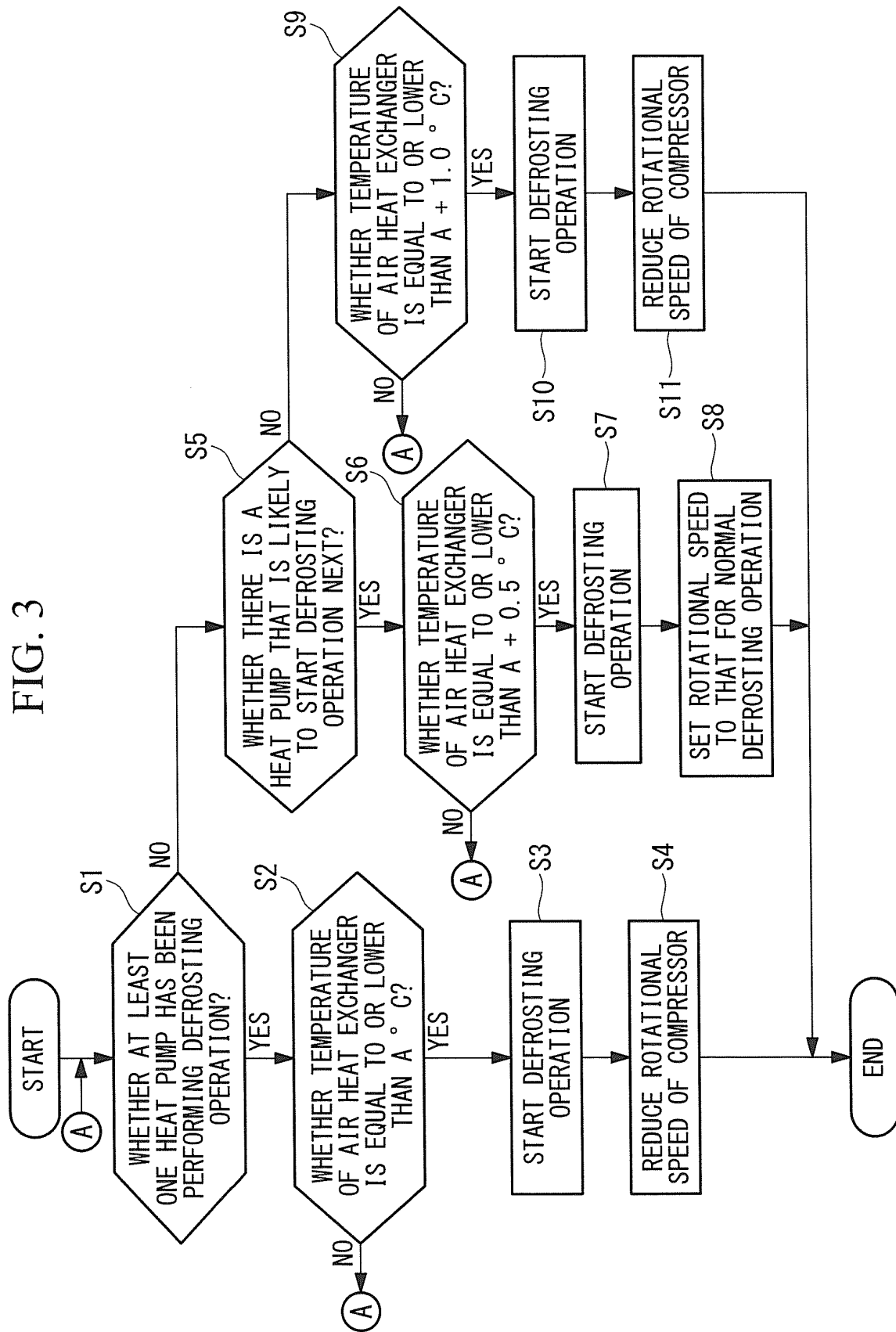


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/078430

A. CLASSIFICATION OF SUBJECT MATTER

F25B47/02(2006.01) i, F25B1/00(2006.01) i, F25D21/06(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, F25B1/00, F25D21/06

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.
Y A	JP 2005-90784 A (Matsushita Electric Industrial Co., Ltd.), 07 April 2005 (07.04.2005), paragraphs [0057] to [0076], [0223] to [0232]; fig. 1 to 3, 18 (Family: none)	1-5, 8, 9 6, 7
Y A	JP 2010-121798 A (Mitsubishi Electric Corp.), 03 June 2010 (03.06.2010), paragraphs [0034] to [0050]; fig. 4 & US 2010/0125370 A1 & EP 2336660 A1 & CN 101737867 A	1-5, 8, 9 6, 7
Y A	JP 7-167519 A (Daikin Industries, Ltd.), 04 July 1995 (04.07.1995), paragraphs [0070] to [0079]; fig. 11 to 12 (Family: none)	1-5, 8, 9 6, 7

☒ Further documents are listed in the continuation of Box C.
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Date of the actual completion of the international search
23 January, 2013 (23.01.13)Date of mailing of the international search report
05 February, 2013 (05.02.13)Name and mailing address of the ISA/
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/078430

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2011-153792 A (Corona Corp.), 11 August 2011 (11.08.2011), paragraph [0008] (Family: none)	1-5, 8, 9

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP H0674531 B [0004]