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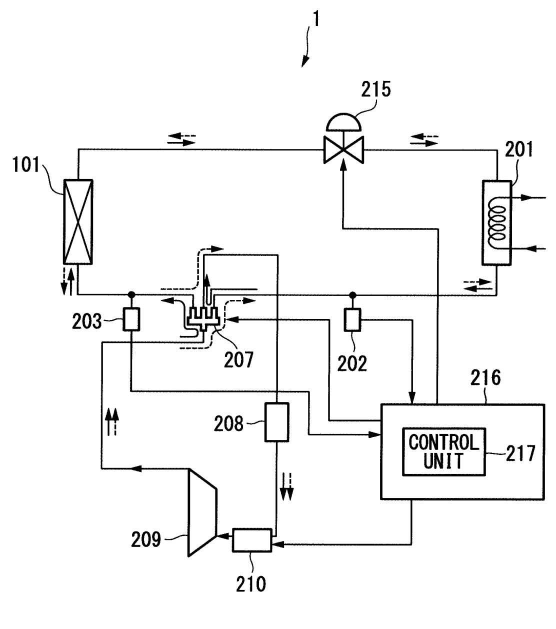
(54) CONTROL DEVICE, CONTROL METHOD, AND PROGRAM

(57) A control device (216) is provided with a control unit (217). When operating a cooling cycle for cooling water using a water heat exchanger (201), the control unit controls the differential pressure determined by subtracting the pressure of the refrigerant in a refrigerant pipe between a compressor (209) and the water heat exchanger from the pressure of a refrigerant in a refrigerant pipe between the compressor and an air heat exchanger (101), so that the differential pressure is equal to or higher than a predetermined differential pressure at which the refrigerant circulates and at which the water does not freeze. When the cooling cycle operation is performed, if the outside air temperature would lower the temperature of the water to the freezing point or below, the control unit causes a chilling unit (1) to operate a reverse cycle of the cooling cycle before causing the chilling unit to start the operation of the cooling cycle.

FIG. 1



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Description

[Technical Field]

[0001] The present invention relates to a control device, a control method, and a program.

[0002] This application claims priority based on Japanese Patent Application No. 2015-018384 filed in Japan on February 2, 2015, the entire content of which is incorporated herein by reference.

[Background Art]

[0003] There is a chilling unit which performs operation of a cooling cycle to cool water with a water heat exchanger. The chilling unit cools the water using a refrigerant.

[0004] A related technology is disclosed in Patent Document 1. A device disclosed in Patent Document 1 performs a reverse cycle operation so that a compressor does not absorb the refrigerant which has fallen into the lower temperature side of indoor and outdoor units, and prevents liquid compression or oil foaming from occurring when the compressor takes in the liquid refrigerant.

[Citation List]

[Patent Document]

[0005] [Patent Document 1] Japanese Unexamined Patent Application, First Publication No. S63-129258

[Summary of Invention]

[Technical Problem]

[0006] A chilling unit starts operation of a cooling cycle to cool water using a water heat exchanger in a period with a low outside air temperature such as winter. In this case, there is a likelihood that the temperature of a refrigerant may decrease and water to be cooled may freeze in a water heat exchanger which becomes a low-pressure side of a compressor during the operation of a cooling cycle.

[0007] An object of the present invention is to provide a control device, a control method, and a program which can solve the above problems.

[Solution to Problem]

[0008] According to a first aspect of the present invention, a control device is a control device for a chilling unit which includes an air heat exchanger configured to send out a refrigerant heat-exchanged with the outside air, a water heat exchanger configured to cool water by exchanging heat between the refrigerant sent out from the air heat exchanger and the water, a compressor configured to compress the refrigerant and to send out the compressed refrigerant, and a first refrigerant pipe configured to send out the refrigerant sent out from the compressor to the air heat exchanger. the control device includes a control unit configured to control an operation of the chilling unit, wherein the control in which the control unit performs includes: controlling a differential pressure obtained by subtracting a refrigerant pressure in a second refrigerant pipe provided between the compressor and the water heat exchanger from a refrigerant pressure in the first refrigerant pipe to be equal to or greater than a predetermined differential pressure at which the refrigerant circulates and the water does not freeze when a cooling cycle to cool the water using the water heat exchanger is operated; and causing the chilling unit to operate a reverse cycle of the cooling cycle before operation of the cooling cycle is started in the chilling unit when the outside air temperature is an outside air temperature that makes the temperature of the water equal to or lower than the freezing point of the water.

[0009] According to a second aspect of the present invention, the control device of the first aspect may include a first pressure sensor configured to detect a refrigerant pressure in the second refrigerant pipe; and a second pressure sensor configured to detect a refrigerant pressure in the first refrigerant pipe; wherein the control unit switches from operation of a reverse cycle of the cooling cycle to operation of the cooling cycle at a timing at which a differential pressure obtained by subtracting a refrigerant pressure detected by the first pressure sensor from a refrigerant pressure detected by the second pressure sensor is a predetermined range of differential pressure at which the refrigerant with the same circulation flow rate as a circulation flow rate of the refrigerant when the chilling unit reaches an equilibrium state can flow.

[0010] According to a third aspect of the present invention, in the control device of the second embodiment, when the chilling unit includes a plurality of sets of air heat exchanger, water heat exchanger, and compressor, the control unit switches from the operation of the reverse cycle of the cooling cycle to the operation of the cooling cycle at different timings for each of the plurality of sets.

[0011] According to a fourth aspect of the present invention, a control method of a control device for a chilling unit which includes an air heat exchanger configured to send out a refrigerant heat-exchanged with the outside air, a water heat exchanger configured to cool water by exchanging heat between the refrigerant sent out from the air heat exchanger and the water, a compressor configured to compress the refrigerant and to send out the compressed refrigerant, and a first refrigerant pipe configured to send out the refrigerant sent out from the compressor to the air heat exchanger. The control method of a control device includes controlling that a differential pressure obtained by subtracting a refrigerant pressure in a refrigerant pipe provided between the compressor and the water heat exchanger from a refrigerant pressure in a refrigerant pipe provided between the compressor and the air heat exchanger is equal to or greater than a predetermined differential pressure at which the refrigerant circulates and the water does not freeze when a cooling cycle to cool the water using the water heat exchanger is operated, and causing the chilling unit to operate a reverse cycle of the cooling cycle before causing the chilling unit to start operation of the cooling cycle when the outside air temperature is an outside air temperature that makes the temperature of the water equal to or lower than the freezing point of the water.

[0012] According to a fifth aspect of the present invention, a

program which causes a computer for a chilling unit including an air heat exchanger configured to send out a refrigerant heat-exchanged with the outside air, a water heat exchanger configured to cool water by exchanging heat between the refrigerant sent out from the air heat exchanger and the water, a compressor configured to compress the refrigerant and to send out the compressed refrigerant, and a first refrigerant pipe configured to send out the refrigerant sent out from the compressor to the air heat exchanger to execute following steps of: controlling that a differential pressure obtained by subtracting a refrigerant pressure in a refrigerant pipe provided between the compressor and the water heat exchanger from a refrigerant pressure in a refrigerant pipe provided between the compressor and the air heat exchanger is equal to or greater than a predetermined differential pressure at which the refrigerant circulates and the water does not freeze when a cooling cycle to cool the water using the water heat exchanger is operated, and causing the chilling unit to operate a reverse cycle of the cooling cycle before causing the chilling unit to start operation of the cooling cycle when the outside air temperature is an outside air temperature that makes the temperature of the water equal to or lower than the freezing point of the water.

[Advantageous Effects of Invention]

[0013] According to the control device, the control method, and the program described above, it is possible to prevent water to be cooled from freezing when a chilling unit starts operation of a cooling cycle.

[Brief Description of Drawings]

[0014]

Fig. 1 is a diagram which shows a configuration of a chilling unit according to an embodiment of the present invention.

Fig. 2 is a diagram which describes operation of a cooling cycle performed by the chilling unit in an embodiment of the present invention.

Fig. 3 is a diagram which describes operation of a heating cycle performed before the chilling unit according to an embodiment of the present invention starts the operation of the cooling cycle.

[Description of Embodiments]

(Embodiment)

[0015] Hereinafter, an embodiment will be described in detail with reference to drawings.

[0016] A configuration of a chilling unit including a control device according to an embodiment of the present invention will be described.

[0017] As shown in Fig. 1, a chilling unit 1 according to an embodiment of the present invention includes an air heat exchanger 101, a water heat exchanger 201, a first pressure sensor 202, a second pressure sensor 203, a four-way valve 207, an accumulator 208, a compressor 209, a compressor motor 210, an expansion valve 215, and a control device 216.

[0018] The air heat exchanger 101 functions as a condenser when the water heat exchanger 201 performs operation of a cooling cycle to cool water. The air heat exchanger 101 functions as an evaporator when operation of a heating cycle which is a reverse cycle of the cooling cycle is performed.

[0019] The water heat exchanger 201 functions as an evaporator when performing the operation of the cooling cycle. The water heat exchanger 201 functions as a condenser when the operation of the heat cycle is performed.

[0020] The first pressure sensor 202 detects a pressure of a refrigerant in the water heat exchanger 201 connected to the four-way valve 207. The first pressure sensor 202 detects a pressure of the refrigerant in the water heat exchanger 201 connected to the four-way valve 207 before the operation of the cooling cycle is started.

[0021] The second pressure sensor 203 detects a pressure of a refrigerant in the air heat exchanger 101 connected to the four-way valve 207. The second pressure sensor 203 detects a pressure of the refrigerant in the air heat exchanger 101 connected to the four-way valve 207 before the operation of the cooling cycle is started.

[0022] The four-way valve 207 has four valves. One of the four valves is connected to the water heat exchanger 201. Another one of the four valves is connected to the accumulator 208. Still another one valve of the four valves is connected to the air heat exchanger 101. The remaining one of the four valves is connected to the compressor 209.

[0023] The accumulator 208 is provided between the four-way valve 207 and the compressor motor 210. The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in a liquid form.

[0024] The compressor 209 is provided between the compressor motor 210 and the accumulator 208. The compressor 209 has the compressor motor 210 as a power source, and sends out an input gas refrigerant after turning it into a gas refrigerant with a higher temperature and a higher pressure than at a time of input.

[0025] The compressor motor 210 is provided between the accumulator 208 and the compressor 209. The compressor motor 210 operates the compressor 209.

[0026] The expansion valve 215 is provided between the air heat exchanger 101 and the water heat exchanger 201. The expansion valve 215 turns an input liquid-form refrigerant with a temperature T and a pressure P into a refrigerant with a temperature lower than the temperature T and a pressure lower than the pressure P.

[0027] The control device 216 includes a control unit 217.

[0028] The control unit 217 controls each functional unit of the chilling unit 1 to set a temperature of water cooled by the water heat exchanger 201 to a desired temperature. For example, the control unit 217 may control valve position of the expansion valve 215 to perform decompression adjustment and flow adjustment. In addition, the control unit 217 controls a differential pressure between the pressure of the refrigerant in the water heat exchanger 201 connected to the four-way valve 207 and the pressure of the refrigerant in the air heat exchanger 101 connected to the four-way valve 207 such that it is equal to or greater than a predetermined differential pressure before the chilling unit 1 starts the operation of the cooling cycle. Specifically, the control unit 217 causes the chilling unit 1 to operate the heating cycle when a differential pressure obtained by subtracting the pressure of the refrigerant detected by the first pressure sensor 202 from the pressure of the refrigerant detected by the second pressure sensor 203 is lower than a predetermined differential pressure. In addition, the control unit 217 causes the chilling unit 1 to operate the cooling cycle after the differential pressure obtained by subtracting the pressure of the refrigerant detected by the first pressure sensor 202 from the pressure of the refrigerant detected by the second pressure sensor 203 becomes equal to or greater than a predetermined differential pressure in which the refrigerant circulates and water does not freeze. For example, the control unit 217 performs control to switch from the operation of the reverse cycle of the cooling cycle to the operation of the cooling cycle in the chilling unit 1 at a timing at which the differential pressure obtained by subtracting the refrigerant pressure detected by the first pressure sensor 202 from the refrigerant pressure detected by the second pressure sensor 203 becomes within a predetermined range of differential pressure in which the refrigerant with the same circulation flow rate as a circulation flow rate of the refrigerant when the chilling unit 1 reaches an equilibrium state can flow.

[0029] In the chilling unit 1, when the control unit 217 performs control to operate the cooling cycle, the compressor 209 turns the input gas refrigerant into a gas refrigerant with a higher temperature and a higher pressure than at a time of input and sends out the gas refrigerant to the air heat exchanger 101 via the four-way valve 207 by the control of the control unit 217. The air heat exchanger 101 functioning as a condenser exchanges heat between the refrigerant and the outside air. At this time, the temperature of the refrigerant is higher than the outside air temperature. For this reason, the air heat exchanger 101 turns the input refrigerant into a refrigerant with a temperature lower than at a time of input and sends out the refrigerant to the expansion valve 215. The expansion valve 215 turns the input refrigerant into a refrigerant with a lower temperature and a lower pressure by performing decompression adjustment and flow adjustment thereon, and sends out the refrigerant to the water heat exchanger 201. The water heat exchanger 201 functioning as an evaporator exchanges heat between the refrigerant received from the expansion valve 215 and water and outside air. At this time, the temperature of the refrigerant is lower than the temperature of the water and the outside air. For this reason, the water heat exchanger 201 cools the water and increases the temperature and pressure of the refrigerant. The water heat exchanger 201 sends out the refrigerant to the accumulator 208 via the four-way valve 207. The accumulator 208 prevents refrigerant which is not gasified by the evaporator from being absorbed into the compressor 209 in the liquid state. As a result, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210.

[0030] In the chilling unit 1, when the control unit 217 performs control to operate the heating cycle, the compressor 209 turns the input gas refrigerant into a gas refrigerant with a higher temperature and a higher pressure than at a time of input and sends out the gas refrigerant to the water heat exchanger 201 via the four-way valve 207. The water heat exchanger 201 functioning as a condenser exchanges heat between the refrigerant and water and outside air. At this time, the temperature of the refrigerant is higher than the temperature of the water and the outside. For this reason, the water heat exchanger 201 turns the input refrigerant into a refrigerant with a temperature lower than at a time of input and sends out the refrigerant to the expansion valve 215. The expansion valve 215 turns the input refrigerant into a refrigerant with a lower pressure at a lower temperature by performing decompression adjustment and flow adjustment thereon and sends out the refrigerant to the air heat exchanger 101. The air heat exchanger 101 functioning as an evaporator exchanges heat between the refrigerant input from the expansion valve 215 and the outside air. At this time, the temperature of the refrigerant is lower than the temperature of the outside. Therefore, the air heat exchanger 101 increases the temperature and the pressure of the refrigerant. The air heat exchanger 101 sends out the refrigerant to the accumulator 208 via the four-way valve 207. The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in the liquid state. Accordingly, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210.

[0031] A case in which the control unit 217 performs control to immediately operate the cooling cycle without the operation of the heating cycle before the operation of the cooling cycle is started in the chilling unit 1 in a period with a low outside air temperature such as winter will be described.

[0032] In the chilling unit 1, when the control unit 217 performs control to operate the cooling cycle, the compressor 209 turns the input gas refrigerant into a refrigerant with a higher temperature and a higher pressure than at a time of input and sends out the refrigerant to the air heat exchanger 101 via the four-way valve 207 as described above. The air heat exchanger 101 functioning as a condenser exchanges heat between the refrigerant and the outside air. At this time, the temperature of the refrigerant is higher than the temperature of the outside air. For this reason, the air heat exchanger 101 turns the input refrigerant into a refrigerant with a temperature lower than at a time of input, and sends out the refrigerant to the expansion valve 215. The expansion valve 215 turns the input refrigerant into a refrigerant with a low pressure at a low temperature by performing decompression adjustment and flow adjustment thereon and sends out the refrigerant to the water heat exchanger 201. The water heat exchanger 201 functioning as an evaporator exchanges heat between the refrigerant input from the expansion valve 215 and water and outside air. At this time, the temperature of the refrigerant is lower than the temperature of the water and the outside air. For this reason, the water heat exchanger 201 cools the water and increases the temperature and the pressure of the refrigerant. The water heat exchanger 201 sends out the refrigerant to the accumulator 208 via the four-way valve 207. The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in the liquid state. Accordingly, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210. As a result, refrigerant flows in the chilling unit 1 in a direction of solid line arrows shown in Fig. 1.

[0033] Figure 2 is a diagram which shows the operation of the cooling cycle performed by the chilling unit 1 shows a relationship between a time when refrigerant is flowing in the chilling unit 1 in the direction of the solid line arrows shown in Fig. 1 and a pressure of the refrigerant. In Fig. 2, the horizontal axis represents time and the vertical axis represents the pressure of a refrigerant.

[0034] A pressure P1 is a refrigerant pressure detected by the first pressure sensor 202. In addition, a pressure P2 is a refrigerant pressure detected by the second pressure sensor 203.

[0035] A time 0 is a reference time. At the time 0, the compressor 209 does not operate. At the time 0, refrigerant in the chilling unit 1 is in an equilibrium state. In a case of Fig. 2, each of the pressure P1 and the pressure P2 at the time 0 is 0.7 MPa. A time t1 a is a time at which the compressor 209 starts to operate. A time t2a is a time at which the pressure P1 is minimized. A time t3a is a time at which the pressure P1 returns to 0.7 MPa which is the pressure at the time 0. A time t4a is a time at which the refrigerant in the chilling unit 1 is in an equilibrium state when the compressor 209 operates. In the following, an operation of the chilling unit 1 at each time will be described.

[0036] Between the time 0 and the time t1a, the compressor 209 does not operate. Between the time 0 and the time t1a, the refrigerant in the chilling unit 1 is in an equilibrium state. If the compressor 209 starts to operate at the time t1a, the compressor 209 receives the refrigerant. The compressor 209 turns the refrigerant into a refrigerant with a higher temperature and a higher pressure than the refrigerant at a time of input, and sends out the refrigerant to the air heat exchanger 101 via the four-way valve 207. At this time, the refrigerant passes through the second pressure sensor 203 provided in a refrigerant pipe between the four-way valve 207 and the air heat exchanger 101. For this reason, the pressure P2 of the refrigerant detected by the second pressure sensor 203 gradually increases from the time t1a.

[0037] The air heat exchanger 101 functioning as a condenser receives the refrigerant which has passed through the second pressure sensor 203. The air heat exchanger 101 exchanges heat between the input refrigerant and outside air and turns the refrigerant into a refrigerant with a temperature lower than at a time of input. The air heat exchanger 101 sends out the refrigerant to the expansion valve 215.

[0038] The expansion valve 215 turns the input refrigerant into a refrigerant with a lower temperature and a lower pressure by performing decompression adjustment and flow adjustment thereon, and sends out the refrigerant to the water heat exchanger 201. The temperature of the refrigerant at this time is lower than the temperature of the water and the outside air in the water heat exchanger 201.

[0039] The water heat exchanger 201 functioning as an evaporator receives refrigerant from the expansion valve 215. The air heat exchanger 101 exchanges heat between the input refrigerant and water and outside air. The temperature of the refrigerant input by the water heat exchanger 201 is lower than the temperature of the water and the outside air in the water heat exchanger 201. For this reason, the temperature and the pressure of the refrigerant increase and the water is cooled. The water heat exchanger 201 sends out the refrigerant to the accumulator 208 via the four-way valve 207. At this time, the refrigerant passes through the first pressure sensor 202 provided in the refrigerant pipe between the water heat exchanger 201 and the four-way valve 207. Immediately after the compressor 209 starts to operate at the time t1a, a differential pressure obtained by subtracting the pressure of the refrigerant detected by the first pressure sensor 202 from the pressure of the refrigerant detected by the second pressure sensor 203 in the chilling unit 1 is small. For this reason, the flow of refrigerant circulating in the chilling unit 1 per unit time is small amount. When the flow of refrigerant circulating per unit time is small amount, an amount of refrigerant compressed by the compressor 209 is also small, and a compression rate at which the compressor 209 compresses refrigerant is low. Therefore, the temperature at which the compressor 209 heats the refrigerant is made to be lower than the temperature at which the air heat exchanger 101 and the expansion valve 215 cool the refrigerant by performing decompression adjustment and flow adjustment. The refrigerant pressure P1 detected by the first pressure sensor 202 gradually decreases from the time t1a.

[0040] The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in the liquid state. Accordingly, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210.

[0041] If the operation of the cooling cycle continues, the flow of the refrigerant circulating in the chilling unit 1 per unit time increases and the temperature at which the compressor 209 compresses and heats the refrigerant increases. Therefore, the temperature of the refrigerant sent out to the air heat exchanger 101 via the four-way valve 207 by the compressor 209 increases. At a time t2a, the temperature at which the compressor 209 heats the refrigerant is higher than the temperature at which the air heat exchanger 101 and the expansion valve 215 cool the refrigerant. For this reason, the temperature of the refrigerant in the refrigerant pipe between the water heat exchanger 201 and the four-way valve 207 increases and the refrigerant pressure P1 detected by the first pressure sensor 202 increases.

[0042] Thereafter, each of the refrigerant pressure P1 detected by the first pressure sensor 202 and the refrigerant pressure P2 detected by the second pressure sensor 203 increases in a transitional manner. The refrigerant pressure P1 detected by the first pressure sensor 202 becomes 0.7 MPa which is the same as the pressure at the time 0 at a time t3a, and continues to increase.

[0043] Each of the refrigerant pressure P1 detected by the first pressure sensor 202 and the refrigerant pressure P2 detected by the second pressure sensor 203 is in a steady state designed for the operation of the cooling cycle at a time t4a.

[0044] When the water heat exchanger 201 functioning as an evaporator receives the refrigerant from the expansion valve 215 and cools water by exchanging heat between the refrigerant and the water and outside air, if the outside air temperature is low enough but slightly exceeds the freezing point of water, the water may freeze due to the heat exchange of the water heat exchanger 201. In other words, in the chilling unit 1, when the control unit 217 immediately performs control to cause the water heat exchanger 201 to operate the cooling cycle to cool water without performing control to operate the heating cycle in advance, there is a likelihood that the water to be cooled may freeze.

[0045] A case in which the control unit 217 causes the heating cycle to be operated before the operation of the cooling cycle is started, and controls a differential pressure obtained by subtracting the refrigerant pressure (P2>P1) detected by the first pressure sensor 202 from the refrigerant pressure detected by the second pressure sensor 203 such that it is equal to or greater than a predetermined differential pressure in the chilling unit 1 in a period with a low outside air temperature such as winter will be described.

[0046] In the chilling unit 1, when the control unit 217 performs control to operate the heating cycle, as described above, the compressor 209 turns an input gas refrigerant into a gas refrigerant with a higher temperature and a higher pressure than at a time of input and sends out the refrigerant to the water heat exchanger201 via the four-way valve 207. The water heat exchanger 201 functioning as a condenser exchanges heat between the refrigerant and water. At this time, the temperature of the refrigerant is higher than the water temperature. For this reason, the water heat exchanger 201 turns the input refrigerant into a refrigerant with a lower temperature than at a time of input and sends out the refrigerant to the expansion valve 215. The expansion valve 215 turns the input refrigerant into a refrigerant with a lower temperature and a lower pressure by performing decompression adjustment and flow adjustment thereon and sends out the refrigerant to the air heat exchanger 101. The air heat exchanger 101 functioning as an evaporator exchanges heat between the refrigerant input from the expansion valve 215 and the outside air. At this time, the temperature of the refrigerant is lower than the temperature of the outside air. For this reason, the air heat exchanger 101 increases the temperature of the refrigerant. Then, the air heat exchanger 101 sends out the refrigerant to the accumulator 208 via the four-way valve 207. The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in the liquid state. Accordingly, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210. As a result, the refrigerant flows in the chilling unit 1 in the direction of the dotted arrows shown in Fig. 1.

[0047] Then, the control unit 217 switches from control to operate the heating cycle to control to operate the cooling cycle. As a result, the refrigerant flows in the chilling unit 1 in the direction of the solid line arrows shown in Fig. 1.

[0048] Figure 3 is a diagram which shows the operation of the heating cycle performed before the chilling unit 1 starts the operation of the cooling cycle shows a relationship between a time at which refrigerant is flowing in the chilling unit 1 in the direction of the solid line arrows shown in Fig. 1 and a pressure of the refrigerant.

[0049] In Fig. 3, the horizontal axis represents time and the vertical axis represents the pressure of refrigerant.

[0050] The pressure P1 is a refrigerant pressure detected by the first pressure sensor 202. The pressure P2 is a refrigerant pressure detected by the second pressure sensor 203.

[0051] A time 0 is a reference time. At the time 0, the compressor 209 does not operate. At the time 0, the refrigerant in the chilling unit 1 is in an equilibrium state. In a case of Fig. 3, each of the pressure P1 and the pressure P2 at the time 0 is 0.7 MPa. A time t1b is a time at which the compressor 209 starts to operate. A time t2b is a time at which a differential pressure obtained by subtracting the refrigerant pressure P1 detected by the first pressure sensor 202 from the refrigerant pressure P2 detected by the second pressure sensor 203 is maximized. A differential pressure obtained by subtracting the refrigerant pressure P1 detected by the first pressure sensor 202 from the refrigerant pressure P2 detected by the second pressure sensor 203 at a time t3b is an example of differential pressure which shows that the differential pressure between the pressure P2 and the pressure P1 is maximized at the time t2b and then becomes a predetermined range of differential pressure (for example, 0.3 to 0.6 MPa) in which refrigerant circulates in the chilling unit 1 and water to be cooled does not freeze. In one embodiment of the present invention, the time t3b is a time at which the control unit 217 switches from control to operate the heating cycle to control to operate the cooling cycle. A time t4b is a time at which the pressure P1 matches the pressure P2. A time t5b is a time at which the refrigerant in the chilling unit 1 reaches an equilibrium state when the compressor 209 operates. In the following, the operation of the chilling unit 1 at each time will be described.

[0052] Between the time 0 and the time tlb, the compressor 209 does not operate. Between the time 0 and the time tlb, the refrigerant in the chilling unit 1 is in an equilibrium state. If the compressor 209 starts to operate at the time t1b, the compressor 209 receives refrigerant. The compressor 209 turns the input refrigerant into a refrigerant with a higher temperature and a higher pressure than the refrigerant at a time of input, and sends out the refrigerant to the water heat exchanger 201 via the four-way valve 207. At this time, the refrigerant passes through the first pressure sensor 202 provided in the refrigerant pipe between the four-way valve 207 and the water heat exchanger 201. For this reason, the refrigerant pressure P1 detected by the first pressure sensor 202 gradually increases from the time t1b.

[0053] The water heat exchanger 201 functioning as a condenser receives the refrigerant which has passed through the first pressure sensor 202. The water heat exchanger 201 exchanges heat between the input refrigerant and water and outside air to turn the input refrigerant into a refrigerant with a lower temperature than at a time of input. At this time, the temperature of the water increases. The water heat exchanger 201 sends out the refrigerant to the expansion valve 215.

[0054] The expansion valve 215 turns the input refrigerant into a refrigerant with a lower temperature and a lower pressure by performing decompression adjustment and flow adjustment thereon, and sends out the refrigerant to the air heat exchanger 101. The temperature of the refrigerant at this time is lower than the temperature of the outside air in the air heat exchanger 101.

[0055] The air heat exchanger 101 functioning as an evaporator receives the refrigerant from the expansion valve 215. The air heat exchanger 101 exchanges heat between the input refrigerant and outside air. The temperature of the refrigerant input by the air heat exchanger 101 is lower than the temperature of the outside air in the air heat exchanger 101. For this reason, the temperature and the pressure of the refrigerant increase. The air heat exchanger 101 sends out the refrigerant to the accumulator 208 via the four-way valve 207. At this time, the refrigerant passes through the second pressure sensor 203 provided in the refrigerant pipe between the air heat exchanger 101 and the four-way valve 207. Therefore, the pressure P2 of the refrigerant detected by the second pressure sensor 203 gradually decreases from the time t1b.

[0056] The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in the liquid state. Accordingly, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210.

[0057] If the operation of the cooling cycle continues, the temperature of the refrigerant sent out to the water heat exchanger 201 via the four-way valve 207 by the compressor 209 increases. The refrigerant pressure P1 detected by the first pressure sensor 202 increases, and the refrigerant pressure P2 detected by the second pressure sensor 203 decreases until the time t2b. A differential pressure obtained by subtracting the refrigerant pressure P1 detected by the first pressure sensor 202 from the refrigerant pressure P2 detected by the second pressure sensor 203 is maximized at the time t2b. At the time t2b, an increase in the temperature of the refrigerant sent out to the water heat exchanger 201 via the four-way valve 207 by the compressor 209 is larger than a decrease in the temperature of the refrigerant cooled by the water heat exchanger 201 and the expansion valve 215. The temperature of the refrigerant in the refrigerant pipe between the air heat exchanger 101 and the four-way valve 207 increases and the pressure P2 of the refrigerant detected by the second pressure sensor 203 increases.

[0058] Thereafter, each of the refrigerant pressure P1 detected by the first pressure sensor 202 and the refrigerant pressure P2 detected by the second pressure sensor 203 increases. After the differential pressure between the pressure P2 and the pressure P1 is maximized, the control unit 217 switches from control to operate the heating cycle to control to operate the cooling cycle at the time t3b at which the differential pressure becomes a predetermined range of differential pressure in which the refrigerant circulates in the chilling unit 1 and water to be cooled does not freeze. If the differential pressure obtained by subtracting the refrigerant pressure P1 detected by the first pressure sensor 202 from the refrigerant pressure P2 detected by the second pressure sensor 203 is within or greater than the predetermined range of differential pressure in which the refrigerant circulates in the chilling unit 1 and water to be cooled does not freeze, the control unit 217 may switch from the control to operate the heating cycle to the control to operate the cooling cycle.

[0059] If the control unit 217 switches from the control to operate the heating cycle to the control to operate the cooling cycle, the refrigerant pipe between the air heat exchanger 101 and the four-way valve 207 is connected to an output of the compressor 209 and the refrigerant pipe between the water heat exchanger 201 and the four-way valve 207 is connected to an input of the compressor 209 via the accumulator 208 and the compressor motor 210.

[0060] The compressor 209 receives refrigerant from the refrigerant pipe between the water heat exchanger 201 and the four-way valve 207 via the accumulator 208 and the compressor motor 210. The compressor 209 turns the input refrigerant into a refrigerant with a higher temperature and a higher pressure than the refrigerant at a time of input, and sends out the refrigerant to the air heat exchanger 101 via the four-way valve 207. At this time, the refrigerant passes through the second pressure sensor 203 provided in the refrigerant pipe between the four-way valve 207 and the air heat exchanger 101. Therefore, the refrigerant pressure P2 detected by the second pressure sensor 203 increases.

[0061] The air heat exchanger 101 functioning as a condenser receives the refrigerant which has passed through the second pressure sensor 203. The air heat exchanger 101 exchanges heat between the input refrigerant and outside air, and turns the refrigerant into a refrigerant with a lower temperature than at a time of input. The air heat exchanger 101 sends out the refrigerant to the expansion valve 215.

[0062] The expansion valve 215 turns the input refrigerant into a refrigerant with a lower temperature and a lower pressure by performing decompression adjustment and flow adjustment thereon, and sends out the refrigerant to the water heat exchanger 201. The temperature of the refrigerant at this time is lower than the temperature of the water and the outside air in the water heat exchanger 201.

[0063] The water heat exchanger 201 functioning as an evaporator receives the refrigerant from the expansion valve 215. The water heat exchanger 201 exchanges heat between the input refrigerant and water and outside air. The temperature of the refrigerant input by the water heat exchanger 201 is lower than the temperature of the water and the outside air in the water heat exchanger 201. For this reason, the temperature and the pressure of the refrigerant increase and the water is cooled. The water heat exchanger 201 sends out the refrigerant to the accumulator 208 via the four-way valve 207. At this time, the refrigerant passes through the first pressure sensor 202 provided in the refrigerant pipe between the water heat exchanger 201 and the four-way valve 207. Therefore, the refrigerant pressure P1 detected by the first pressure sensor 202 decreases from the time t3b.

[0064] The accumulator 208 prevents refrigerant which is not gasified by an evaporator from being absorbed into the compressor 209 in the liquid state. Accordingly, the accumulator 208 sends out only gas refrigerant to the compressor 209 via the compressor motor 210.

[0065] If the operation of the cooling cycle continues, the temperature of the refrigerant sent out to the air heat exchanger 101 via the four-way valve 207 by the compressor 209 increases. The refrigerant pressure P1 detected by the first pressure sensor 202 matches the refrigerant pressure P2 detected by the second pressure sensor 203 at the time t4b.

[0066] Thereafter, each of the refrigerant pressure P1 detected by the first pressure sensor 202 and the refrigerant pressure P2 detected by the second pressure sensor 203 increases.

[0067] Each of the refrigerant pressure P1 detected by the first pressure sensor 202 and the refrigerant pressure P2 detected by the second pressure sensor 203 is substantially in an equilibrium state at the time t5b.

[0068] Therefore, in the chilling unit 1 in a period with a low outside air temperature such as winter, when the control unit 217 causes the heating cycle to be operated before the operation of the cooling cycle is started, and a differential pressure obtained by subtracting the refrigerant pressure detected by the first pressure sensor 202 from the refrigerant pressure detected by the second pressure sensor 203 is controlled to be equal to or greater than a predetermined differential pressure, it is possible to prevent water to be cooled from freezing.

[0069] As described above, processing of the control device 216 according to one embodiment of the present invention has been described. According to the processing of the control device 216 of one embodiment of the present invention, the control unit 217 causes the heating cycle which is the reverse cycle of the cooling cycle to be operated before the operation of the cooling cycle to cool water using the water heat exchanger 201 is started when the operation of the cooling cycle starts to cool water, and the water temperature is an outside air temperature which is a temperature of a freezing point or below. The control unit 217, when the cooling cycle is operated, controls a differential pressure obtained by subtracting the refrigerant pressure P1 in the refrigerant pipe between the compressor 209 and the water heat exchanger 201 which is lower than the refrigerant pressure P2 from the refrigerant pressure P2 in the refrigerant pipe between the compressor 209 and the air heat exchanger 101 such that it is equal to or greater than a predetermined differential pressure at which refrigerant circulates and the water does not freeze. Specifically, the control unit 217 switches from the operation of the reverse cycle of the cooling cycle to the operation of the cooling cycle at a timing at which the differential pressure obtained by subtracting the refrigerant pressure detected by the first pressure sensor 202 from the refrigerant pressure detected by the second pressure sensor 203 becomes a predetermined range of differential pressure at which refrigerant with the same circulation flow rate as the circulation flow rate of the refrigerant when the chilling unit 1 reaches the equilibrium state can flow.

[0070] In this manner, the control device 216 can prevent water to be cooled from freezing when the operation of the cooling cycle is started without adding a special function to the chilling unit 1.

[0071] When the chilling unit 1 includes a plurality of sets of the air heat exchanger 101, the water heat exchanger 201, and the compressors 209, the control unit 217 performs control to switch from the operation of the heating cycle to the operation of the cooling cycle at different timings for each of the plurality of sets.

[0072] In this manner, the control device 216 can relax an increase in the temperature of water to be cooled when the operation of the heating cycle is performed on second set and after of the air heat exchanger 101, the water heat exchanger 201, and the compressor 209 in the chilling unit 1, and thus can suppress a final increase in the temperature of water better than in a case in which the operation of the heating cycle is simultaneously performed on a plurality of sets of the air heat exchanger 101, the water heat exchanger 201, and the compressor 209.

[0073] The control unit 217 may also perform a defrosting control when the differential pressure obtained by subtracting the refrigerant pressure detected by the first pressure sensor 202 from the refrigerant pressure detected by the second pressure sensor 203 is lower than a predetermined differential pressure.

[0074] In this manner, the control device 216 can prevent water to be cooled from freezing when the chilling unit 1 starts the operation of the cooling cycle without adding a special function.

[0075] The embodiment of the present invention has been described, but the control device 216 described above has a computer system therein. Further, a process of the processing described above is stored in a computer readable recording medium in a form of program, and a computer reads and executes this program, and thereby the processing described above is performed. Here, the computer readable recording medium refers to a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a semiconductor memory, or the like. In addition, the computer program may be delivered to a computer through a communication line and the computer which has received a delivery of the computer program may execute the program.

[0076] Moreover, the program described above may realize a portion of the functions described above. Furthermore, the program described above may be a file which realizes the functions described above by a combination with a program already recorded in the computer system, a so-called difference file (difference program).

[0077] Some embodiments of the present invention have been described, but these embodiments are examples and do not limit the scope of the invention. Various omissions, substitutions, and changes may be made in these embodiments within a range not departing from the gist of the invention.

[Industrial Applicability]

[0078] According to the control device of the embodiment of the present invention, it is possible to prevent water to be cooled from freezing when the chilling unit starts operation of a cooling cycle.

[Reference Signs List]

[0079]

1 Chilling unit
101 Air heat exchanger
201 Water heat exchanger
202 First pressure sensor
203 Second pressure sensor
207 Four-way valve
208 Accumulator
209 Compressor
210 Compressor motor
215 Expansion valve
216 Control device
217 Control unit

Claims

1. A control device for a chilling unit which includes an air heat exchanger configured to send out a refrigerant heat-exchanged with the outside air, a water heat exchanger configured to cool water by exchanging heat between the refrigerant sent out from the air heat exchanger and the water, a compressor configured to compress the refrigerant and to send out the compressed refrigerant, and a first refrigerant pipe configured to send out the refrigerant sent out from the compressor to the air heat exchanger, the control device comprising:

a control unit configured to control an operation of the chilling unit,
wherein the control in which the control unit performs includes:
controlling a differential pressure obtained by subtracting a refrigerant pressure in a second refrigerant pipe provided between the compressor and the water heat exchanger from a refrigerant pressure in the first refrigerant pipe to be equal to or greater than a predetermined differential pressure at which the refrigerant circulates and the water does not freeze when a cool-

ing cycle to cool the water using the water heat exchanger is operated; and
causing the chilling unit to operate a reverse cycle of the cooling cycle before operation of the cooling cycle is started in the chilling unit when the outside air temperature is an outside air temperature that makes the temperature of the water equal to or lower than the freezing point of the water.

2. The control device according to claim 1, the control device comprising:

a first pressure sensor configured to detect a refrigerant pressure in the second refrigerant pipe; and
a second pressure sensor configured to detect a refrigerant pressure in the first refrigerant pipe;
wherein the control unit switches from operation of a reverse cycle of the cooling cycle to operation of the cooling cycle at a timing at which a differential pressure obtained by subtracting a refrigerant pressure detected by the first pressure sensor from a refrigerant pressure detected by the second pressure sensor is a predetermined range of differential pressure at which the refrigerant with the same circulation flow rate as a circulation flow rate of the refrigerant when the chilling unit reaches an equilibrium state can flow.

3. The control device according to claim 2,
wherein, when the chilling unit includes a plurality of sets of air heat exchanger, water heat exchanger, and compressor, the control unit switches from the operation of the reverse cycle of the cooling cycle to the operation of the cooling cycle at different timings for each of the plurality of sets.

4. A control method of a control device for a chilling unit which includes an air heat exchanger configured to send out a refrigerant heat-exchanged with the outside air, a water heat exchanger configured to cool water by exchanging heat between the refrigerant sent out from the air heat exchanger and the water, a compressor configured to compress the refrigerant and to send out the compressed refrigerant, and a first refrigerant pipe configured to send out the refrigerant sent out from the compressor to the air heat exchanger, the control method comprising the steps of:

controlling a differential pressure obtained by subtracting a refrigerant pressure in a second refrigerant pipe provided between the compressor and the water heat exchanger from a refrigerant pressure in the first refrigerant pipe to be equal to or greater than a predetermined differential pressure at which the refrigerant circulates and the water does not freeze when a cooling cycle to cool the water using the water heat exchanger is operated; and
causing the chilling unit to operate a reverse cycle of the cooling cycle before operation of the cooling cycle is started in the chilling unit when the outside air temperature is an outside air temperature that makes the temperature of the water equal to or lower than the freezing point of the water.

5. A program which causes a computer for a chilling unit including an air heat exchanger configured to send out a refrigerant heat-exchanged with the outside air, a water heat exchanger configured to cool water by exchanging heat between the refrigerant sent out from the air heat exchanger and the water, a compressor configured to compress the refrigerant and to send out the compressed refrigerant, and a first refrigerant pipe configured to send out the refrigerant sent out from the compressor to the air heat exchanger to execute following steps of:

controlling that a differential pressure obtained by subtracting a refrigerant pressure in a refrigerant pipe provided between the compressor and the water heat exchanger from a refrigerant pressure in a refrigerant pipe provided between the compressor and the air heat exchanger is equal to or greater than a predetermined differential pressure at which the refrigerant circulates and the water does not freeze when a cooling cycle to cool the water using the water heat exchanger is operated, and causing the chilling unit to operate a reverse cycle of the cooling cycle before causing the chilling unit to start operation of the cooling cycle when the outside air temperature is an outside air temperature that makes the temperature of the water equal to or lower than the freezing point of the water.

FIG. 1

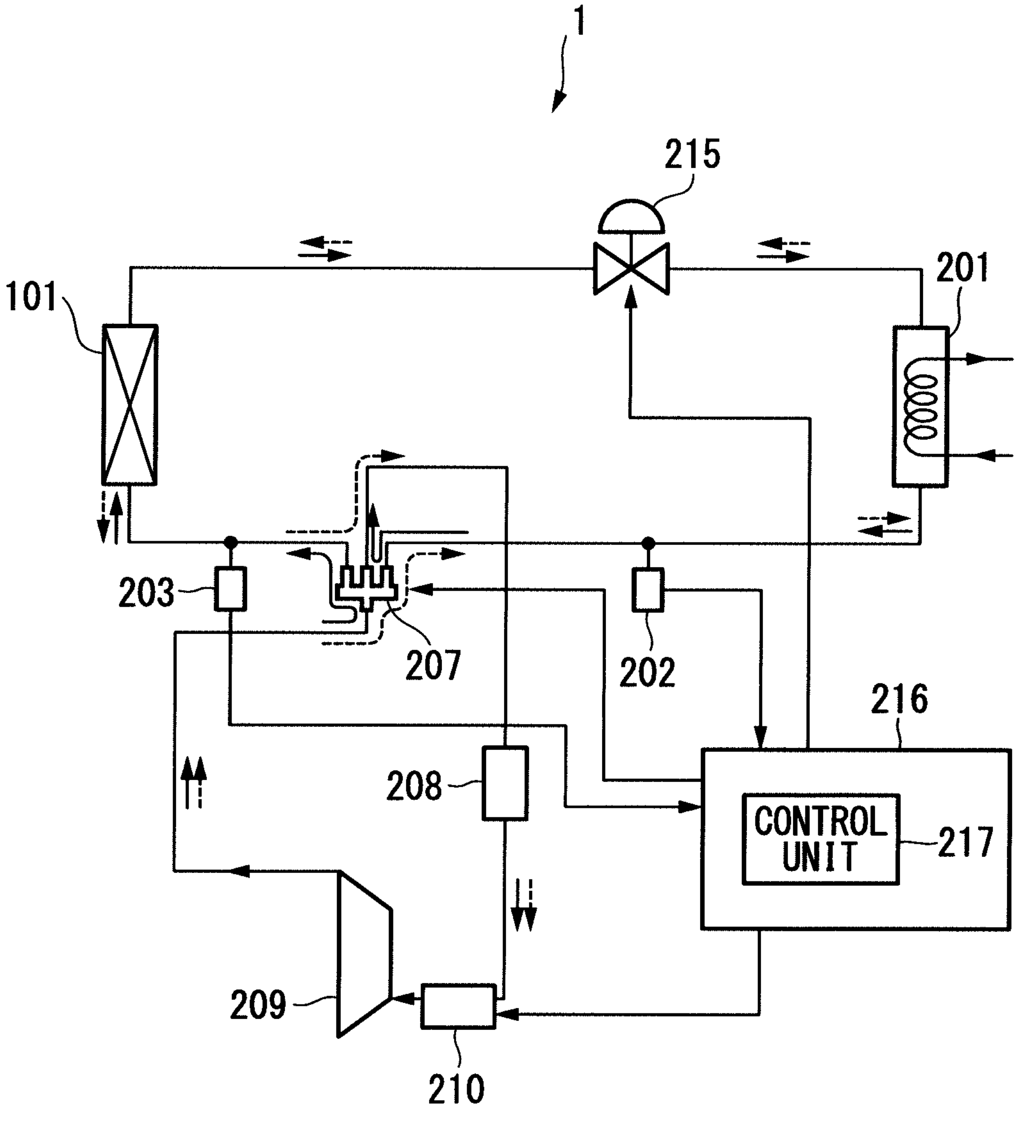


FIG. 2

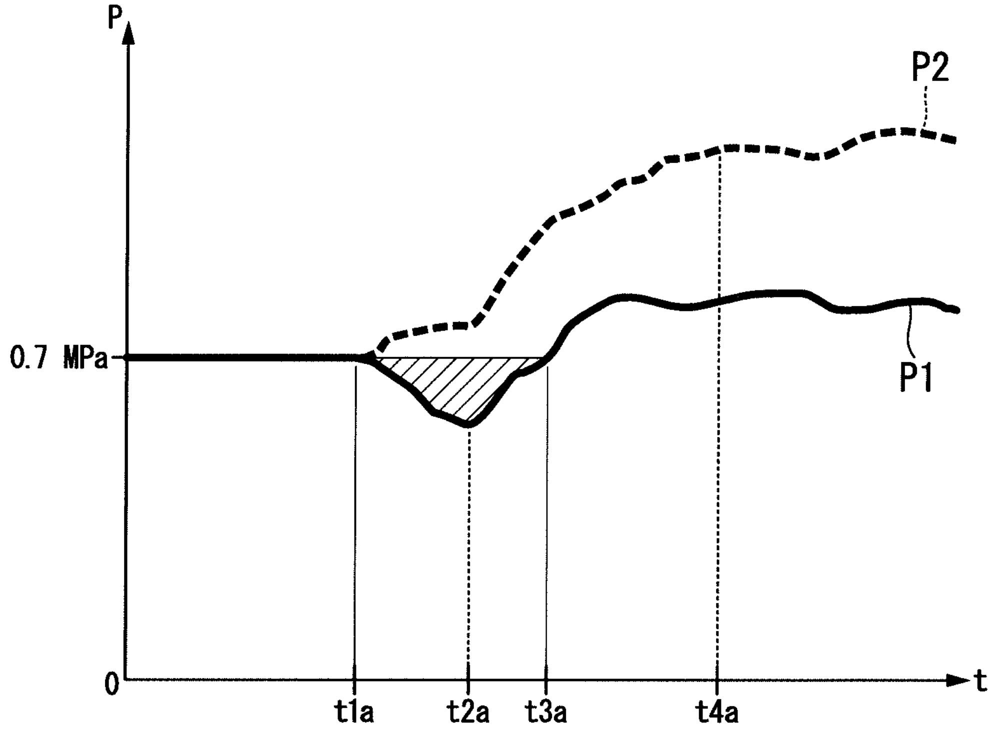
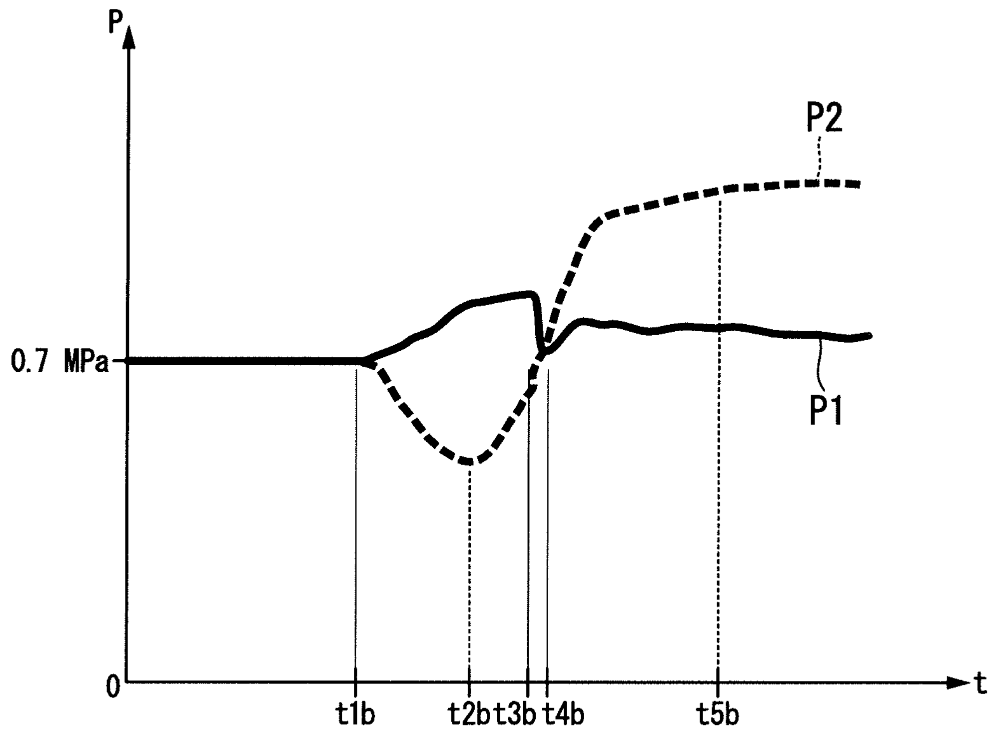

P
P2
0.7 MPa
P1
0
t
t1a
t2a
t3a
t4a

FIG. 3


P
P2
0.7 MPa
P1
0
t
t1b
t2b
t3b
t4b
t5b

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/052273

A. CLASSIFICATION OF SUBJECT MATTER
F25B13/00(2006.01)i, *F25B47/02*(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)
F25B13/00, F25B47/02, F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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 2009-174769 A (Miura Co., Ltd.), 06 August 2009 (06.08.2009), paragraphs [0040] to [0060]; fig. 1 to 3 (Family: none)	1,4-5 2-3
Y A	JP 2007-170706 A (Sanyo Electric Co., Ltd.), 05 July 2007 (05.07.2007), paragraphs [0012] to [0022]; fig. 1 & CN 1987296 A	1,4-5 2-3
Y A	JP 2005-351494 A (Daikin Industries, Ltd.), 22 December 2005 (22.12.2005), paragraphs [0042] to [0051]; fig. 1 (Family: none)	1,4-5 2-3

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

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA/	Authorized officer
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2005-300056 A (Matsushita Electric Industrial Co., Ltd.), 27 October 2005 (27.10.2005), paragraphs [0025] to [0034]; fig. 1 (Family: none)	1,4-5 2-3
Y A	JP 2011-257108 A (Mitsubishi Electric Corp.), 22 December 2011 (22.12.2011), paragraphs [0024] to [0030]; fig. 1 (Family: none)	1,4-5 2-3

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REFERENCES CITED IN THE DESCRIPTION

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