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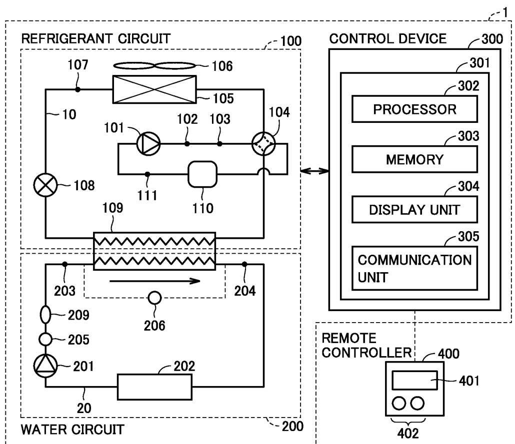
(54) REFRIGERATION CYCLE DEVICE

(57) A refrigeration cycle apparatus (1) comprises a refrigerant circuit (100), a water circuit (200), and a control device (300). The refrigerant circuit (100) includes a compressor (101), a four-way valve (104), a heat exchanger (105), a fan (106), a diaphragm mechanism (108), a water heat exchanger (109), and an accumulator (110). Based on a value of a low-pressure sensor (111) or a high-pressure sensor (103) and a water temperature on an outlet side of the water heat exchanger (109), the refrigeration cycle apparatus (1) determines whether or not there is an abnormality due to dirtiness adhered to a plate inside the water heat exchanger (109).

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a refrigeration cycle apparatus.

BACKGROUND ART

[0002] Conventionally, there has been known a refrigeration cycle apparatus comprising: a first refrigerant circuit that constitutes a heat source device; and a second refrigerant circuit connected to a load apparatus that uses heat of the heat source device. This type of refrigeration cycle apparatus may be provided with a plate type heat exchanger between the first refrigerant circuit and the second refrigerant circuit.

[0003] PTL 1 describes that calcium ions or the like contained in water inside a heat medium circuit are solidified inside the plate type heat exchanger to cause clogging in the plate type heat exchanger. A cooling device described in PTL 1 determines whether or not a temperature difference between upstream-side temperature and downstream-side temperature of the plate type heat exchanger becomes more than a threshold value, thereby detecting whether or not there is clogging in the plate type heat exchanger.

CITATION LIST

[0004] PTL 1: Japanese Patent Laying-Open No. 2003-50067

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] The clogging in the plate type heat exchanger occurs due to dirtiness such as calcium ions being gradually accumulated on the plate. Therefore, if an abnormality of the plate type heat exchanger can be found at a stage prior to occurrence of clogging, the occurrence of clogging can be prevented by a subsequent appropriate procedure.

[0006] It is an object of the present disclosure to provide a refrigeration cycle apparatus to detect occurrence of an abnormality in a plate type heat exchanger at an early stage.

SOLUTION TO PROBLEM

[0007] A refrigeration cycle apparatus of the present disclosure comprises: a heat-source-side first refrigerant circuit configured to circulate a first refrigerant, the heat-source-side first refrigerant circuit having a first compressor, a first heat exchanger configured to exchange heat between outside air and the first refrigerant, and a first diaphragm mechanism; a load-side refrigerant circuit configured to circulate a second refrigerant, the load-side refrigerant circuit having a pump, and a load apparatus configured to use heat; a first plate type heat exchanger configured to exchange heat between the first refrigerant and the second refrigerant; and a temperature sensor configured to detect a temperature of the second refrigerant on an outlet side of the first plate type heat exchanger, wherein the heat-source-side first refrigerant circuit circulates the first refrigerant at least among the first compressor, the first heat exchanger, the first diaphragm mechanism, and the first plate type heat exchanger, and the load-side refrigerant circuit circulates the second refrigerant in one direction at least among the pump, the load apparatus, and the first plate type heat exchanger, the refrigeration cycle apparatus further comprising a control device configured to diagnose a flow path for the second refrigerant in the first plate type heat exchanger using the temperature detected by the temperature sensor and a saturation temperature of the first refrigerant.

ADVANTAGEOUS EFFECTS OF INVENTION

[0008] According to the present disclosure, a refrigeration cycle apparatus can be provided to more precisely diagnose an abnormality of a plate type heat exchanger.

BRIEF DESCRIPTION OF DRAWINGS

[0009]

Fig. 1 is a diagram showing a configuration of a refrigeration cycle apparatus according to a first embodiment.
Fig. 2 is a flowchart showing a dirtiness diagnosis process during a cooling operation.
Fig. 3 is a p-h diagram showing a state difference between a case where there is refrigerant leakage and a case where there is no refrigerant leakage.
Fig. 4 is a flowchart showing a dirtiness diagnosis process during a heating operation.
Fig. 5 is a flowchart for determining whether clogging has occurred in a water heat exchanger or a strainer.
Fig. 6 is a graph showing a state of progress of dirtiness.
Fig. 7 is a flowchart for recording the progress of the dirtiness inside the water heat exchanger.
Fig. 8 is a diagram showing a configuration of a refrigeration cycle apparatus according to a second embodiment.
Fig. 9 is a flowchart showing contents of control of the refrigeration cycle apparatus according to the second embodiment.
Fig. 10 is a diagram showing a configuration of a refrigeration cycle apparatus according to a third embodiment.
Fig. 11 is a diagram showing a water heat exchanger portion of a refrigeration cycle apparatus according to a fourth embodiment.

DESCRIPTION OF EMBODIMENTS

[0010] Hereinafter, the present embodiment will be described in detail with reference to figures. In the description below, a plurality of embodiments will be described; however, it is initially expected at the time of filing of the present application to appropriately combine configurations described in the embodiments. It should be noted that in the figures, the same or corresponding portions are denoted by the same reference characters, and will not be described repeatedly.

First Embodiment.

[0011] Fig. 1 is a diagram showing a configuration of a refrigeration cycle apparatus 1 according to a first embodiment. Circuit configuration and operation of refrigeration cycle apparatus 1 will be described with reference to Fig. 1. Refrigeration cycle apparatus 1 includes a refrigerant circuit 100, a water circuit 200, and a control device 300. Control device 300 performs wireless communication with a remote control device 400 (hereinafter, referred to as "remote controller") operated by a user.

<Configuration of Refrigerant Circuit 100>

[0012] Refrigerant circuit 100 constitutes, for example, a heat source device installed outdoors. Refrigerant circuit 100 includes a compressor 101, a four-way valve 104, a heat exchanger 105, a fan 106, a diaphragm mechanism 108, a water heat exchanger 109, an accumulator 110, and a refrigerant pipe 10 that connects them. In refrigerant circuit 100, a refrigerant such as chlorofluorocarbon circulates. Refrigerant pipe 10 is provided with a discharge temperature sensor 102, a high-pressure sensor 103, a refrigerant temperature sensor 107, and a low-pressure sensor 111.

[0013] Compressor 101 circulates the refrigerant in refrigerant circuit 100 by increasing pressure of the refrigerant. Compressor 101 controls a motor (not shown) inside compressor 101 using an inverter, thereby changing an operating capacity in accordance with a situation. Compressor 101 controls a frequency of compressor 101 to attain a target outlet water temperature set through a control board 301 of control device 300 or remote controller 400 during a cooling operation and during a heating operation. It should be noted that two or more compressors 101 may be connected to refrigerant pipe 10 in parallel or in series.

[0014] Four-way valve 104 switches a direction in which the refrigerant flows. During the cooling operation, four-way valve 104 switches a flow path for the refrigerant as indicated by a solid line in Fig. 1. During the heating operation, four-way valve 104 switches the flow path for the refrigerant as indicated by a broken line in Fig. 1. During the heating operation, refrigerant circuit 100 functions as a heat source. On the other hand, during the cooling operation, refrigerant circuit 100 functions as a cold source.

[0015] Heat exchanger 105 is, for example, a fin-tube type heat exchanger constituted of a large number of fins and heat transfer tubes. Heat exchanger 105 exchanges heat between the refrigerant circulating in refrigerant pipe 10 and outdoor air. Heat exchanger 105 functions as a condenser during the cooling operation. On the other hand, heat exchanger 105 functions as an evaporator during the heating operation.

[0016] Fan 106 is, for example, a propeller fan driven by a motor. Fan 106 has a function of suctioning the outdoor air for the heat exchange by heat exchanger 105 and discharging, to the outdoors, the air having been through the heat exchange by heat exchanger 105.

[0017] Diaphragm mechanism 108 adjusts a flow rate of the refrigerant flowing through refrigerant pipe 10. Diaphragm mechanism 108 is, for example, an electronic expansion valve or a capillary. The electronic expansion valve has a function of efficiently controlling the flow rate of the refrigerant by adjusting a degree of opening of diaphragm.

[0018] Water heat exchanger 109 is a plate type heat exchanger. In the plate type heat exchanger, a plurality of undulating plates are stacked together. These plates are brazed to form a sealed structure. In water heat exchanger 109, the refrigerant in refrigerant circuit 100 and a refrigerant (water) in water circuit 200 flow through alternate spaces between the stacked plates. That is, a first flow path through which the refrigerant in refrigerant circuit 100 flows and a second flow path through which the refrigerant in water circuit 200 flows are formed inside water heat exchanger 109. In the first flow path and the second flow path, the heat of the refrigerant in refrigerant circuit 100 and the heat of the refrigerant in water circuit 200 are exchanged. Water heat exchanger 109 functions as an evaporator during the cooling operation, and functions as a condenser during the heating operation.

[0019] Accumulator 110 separates liquid refrigerant and gas refrigerant from each other and stores an excess of the liquid refrigerant. Accumulator 110 is provided to prevent compressor 101 from being failed due to suction of the refrigerant liquid into compressor 101 (liquid back).

[0020] Discharge temperature sensor 102 is provided on the discharge side of compressor 101. Discharge temperature sensor 102 detects the temperature of the high-temperature refrigerant discharged from compressor 101. High-pressure sensor 103 is provided on the discharge side of compressor 101. A high-pressure saturation temperature CT can be calculated from the detection value of high-pressure sensor 103.

[0021] Refrigerant temperature sensor 107 is provided between heat exchanger 105 and diaphragm mechanism 108. Refrigerant temperature sensor 107 detects a temperature of the refrigerant on the outlet side of heat exchanger 105, which has exchanged heat between the air and the refrigerant during the cooling operation. As required, refrigerant circuit 100 may be provided with: a temperature sensor configured to detect a temperature on the inlet side of water heat exchanger 109; and a temperature sensor configured to detect a temperature of the refrigerant on the outlet side of water heat exchanger 109.

[0022] Low-pressure sensor 111 is provided on the suction portion side of compressor 101. A low-pressure saturation temperature ET can be calculated from the detection value of low-pressure sensor 111.

[0023] Refrigerant circuit 100 circulates the refrigerant through a circulation path including compressor 101, heat exchanger 105, diaphragm mechanism 108, and water heat exchanger 109. A circulation direction of the refrigerant during the cooling and a circulation direction of the refrigerant during the heating are different from each other. Refrigerant circuit 100 includes a microcomputer configured to be operated in response to a command of control device 300.

<Configuration of Water Circuit 200>

[0024] Water circuit 200 constitutes, for example, an air conditioner installed indoors. Water circuit 200 includes a pump 201, a load apparatus 202, a strainer 209, and a water pipe 20 that connects them. Water serving as a refrigerant flows through water pipe 20. The water may be mixed with an additive to lower the freezing point. Refrigerant pipe 10 is provided with a temperature sensor 203, a temperature sensor 204, a flowmeter 205, and a differential manometer 206. Water heat exchanger 109 described as the configuration on the refrigerant circuit 100 side may be a configuration on the water circuit 200 side, rather than the configuration on the refrigerant circuit 100 side.

[0025] Water circuit 200 drives pump 201 through inverter control so as to attain a previously set target value of flowmeter 205 or differential manometer 206. A type of control on pump 201 is set in accordance with a type of air conditioning apparatus and an installation state of the air conditioning apparatus.

[0026] Load apparatus 202 is an air conditioner such as an air handling unit or a fan coil unit. Load apparatus 202 has a heat exchanger configured to exchange heat between indoor air and the water that circulates in water pipe 20. Fig. 1 shows a configuration in which one load apparatus 202 is provided in water circuit 200. This configuration is just exemplary, and a plurality of load apparatuses 202 may be provided in water circuit 200.

[0027] Temperature sensor 203 is provided on the inlet side of water heat exchanger 109. Temperature sensor 203 detects a temperature Twin of the water flowing into water heat exchanger 109. Temperature sensor 204 is provided on the outlet side of water heat exchanger 109. Temperature sensor 204 detects a temperature Twout of the water having been through the heat exchange with the refrigerant in refrigerant circuit 100 inside water heat exchanger 109. That is, Twout represents a temperature on the outlet side of the second flow path through which the water flows in water heat exchanger 109. Flowmeter 205 is provided on the discharge side of pump 201. Flowmeter 205 detects a flow rate Gw of the water that circulates in water circuit 200. Differential manometer 206 measures a water pressure difference ΔPw between the inlet and outlet of water heat exchanger 109. Strainer 209 removes a foreign matter introduced into the water that circulates in water pipe 20. A flow path in strainer 209 may be clogged by the foreign matter.

[0028] Water circuit 200 circulates the refrigerant in one direction, i.e., in the direction from the left to the right in Fig. 1 through a circulation path including pump 201, load apparatus 202, and water heat exchanger 109. Water circuit 200 includes a microcomputer configured to be operated in response to a command of control device 300.

<Configuration of Control Device 300>

[0029] Control device 300 includes control board 301. A processor 302, a memory 303, a display unit 304, and a communication unit 305 are provided on control board 301. Processor 302 executes an operating system and an application program stored in memory 303. When executing the application program, reference is made to various types of data stored in memory 303. Processor 302 receives a command transmitted from remote controller 400 and controls refrigerant circuit 100 and water circuit 200. Processor 302 collects detection values of various types of sensors provided in refrigerant circuit 100 and water circuit 200, and operation data of the load apparatus (air conditioning apparatus) 202.

[0030] Memory 303 includes, for example, a ROM (Read Only Memory), a RAM (Random Access Memory), and a flash memory. The flash memory stores the operating system and the application program. Further, the flash memory stores the detection values of the various types of sensors provided in refrigerant circuit 100 and water circuit 200, and the operation data of load apparatus 202 measured by devices.

[0031] Communication unit 305 communicates with remote controller 400 and also communicates with refrigerant circuit 100 and water circuit 200. Communication unit 305 receives command information transmitted from remote controller 400. Communication unit 305 receives, from refrigerant circuit 100 and water circuit 200, the detection values of the various types of sensors and the operation data of load apparatus 202 measured by the devices. Information indicating occurrence of an abnormality is displayed on display unit 304.

[0032] Remote controller 400 controls control device 300 remotely by communicating with control device 300. Remote controller 400 includes a display unit 401 and an operation unit 402. The user can operate operation unit 402 to switch on/off an indoor unit and adjust a setting temperature. Remote controller 400 transmits, to the control device, various types of commands that correspond to respective operations on operation unit 402. For example, an operation command (command for cooling or heating) is transmitted from remote controller 400 to control device 300. Alternatively, the outlet water temperature of water heat exchanger 109 is transmitted from remote controller 400 to control device 300. In addition to the various types of setting information, information notifying occurrence of an abnormality is displayed on display unit 401.

<Operation of Refrigerant Circuit 100>

[0033] First, the operation of refrigerant circuit 100 during the cooling operation will be described. During the cooling operation, four-way valve 104 switches the flow path for the refrigerant as indicated by the solid line in Fig. 1. The high-temperature and high-pressure gas refrigerant discharged from compressor 101 flows to heat exchanger 105. On this occasion, heat exchanger 105 functions as a condenser. Since the refrigerant in refrigerant pipe 10 exchanges heat with the air by fan 106, the refrigerant is changed from gas refrigerant to liquid refrigerant.

[0034] The liquid refrigerant flowing from heat exchanger 105 to diaphragm mechanism 108 is decreased in pressure by diaphragm mechanism 108. As a result, the liquid refrigerant is changed to a low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant is moved from diaphragm mechanism 108 to water heat exchanger 109. On this occasion, water heat exchanger 109 functions as an evaporator. The refrigerant flowing into water heat exchanger 109 is changed into a gas refrigerant by exchanging heat with water inside water heat exchanger 109. The gas refrigerant passes through accumulator 110 and is suctioned into compressor 101.

[0035] Next, the operation of refrigerant circuit 100 during the heating operation will be described. During the heating operation, four-way valve 104 switches the flow path for the refrigerant as indicated by the broken line in Fig. 1. The high-temperature and high-pressure gas refrigerant discharged from compressor 101 flows to water heat exchanger 109. On this occasion, water heat exchanger 109 functions as a condenser. Since the refrigerant in refrigerant pipe 10 exchanges heat with the water in water pipe 20, the refrigerant is changed from gas refrigerant to liquid refrigerant.

[0036] The liquid refrigerant flowing from water heat exchanger 109 to diaphragm mechanism 108 is decreased in pressure by diaphragm mechanism 108. As a result, the liquid refrigerant is changed to a low-pressure two-phase refrigerant. The low-pressure two-phase refrigerant is moved from diaphragm mechanism 108 to heat exchanger 105. On this occasion, heat exchanger 105 functions as an evaporator. The refrigerant flowing into heat exchanger 105 exchanges heat with air by fan 106. Thereafter, the refrigerant flowing into accumulator 110 is separated into a liquid refrigerant and a gas refrigerant, and the gas refrigerant is suctioned into compressor 101.

[0037] Since four-way valve 104 is included, refrigerant circuit 100 can perform the cooling operation and the heating operation. However, as the present embodiment, a refrigeration cycle apparatus may be constructed using a refrigerant circuit that does not include four-way valve 104. In other words, as the present embodiment, a refrigeration cycle apparatus only for cooling or a refrigeration cycle apparatus only for heating may be employed.

<Cause of Freezing of Refrigerant in Water Heat Exchanger 109>

[0038] When the water flowing through water heat exchanger 109 becomes frozen, the plates of water heat exchanger 109 are adversely affected. When freezing and unfreezing occur repeatedly, a plate may be fractured (so-called "freezing puncture"), thus resulting in damage on water heat exchanger 109. On that occasion, when water enters refrigerant circuit 100, a degree of trouble is increased, with the result that a large amount of time is required for maintenance and inspection operations.

[0039] Therefore, it is important to identify a cause of freezing and take a measure in advance to prevent freezing.

[0040] The cause of freezing of water is dirtiness in water pipe 20. The dirtiness in water pipe 20 is gradually adhered to a surface of a plate of water heat exchanger 109. The dirtiness adhered to the surface of the plate is referred to as "scale" or "sludge". When the adhesion of dirtiness to the surface of the plate is repeated, flow path resistance of the water flow path formed by the space between the plates becomes large. A portion at which water is locally stagnated is formed in water heat exchanger 109 to cause deteriorated flow of water, which will result in the water flow path being completely blocked. So-called clogging will occur in water heat exchanger 109. When the dirtiness is adhered to the surface of the plate, heat transfer performance of water heat exchanger 109 is deteriorated. In order to compensate for the deterioration of the heat transfer performance, it is necessary to further decrease the temperature of the refrigerant in refrigerant circuit 100 during the cooling operation. When the temperature of the refrigerant becomes equal to or less than the freezing point of water, freezing is likely to occur in water heat exchanger 109 at the portion at which the water is locally stagnated.

[0041] Therefore, in order to prevent freezing, it is important to prevent clogging in water heat exchanger 109 in advance. To achieve this, it is necessary to know whether or not dirtiness is adhered to the inside of water heat exchanger 109 to such an extent that an adverse effect is caused. Therefore, in the refrigeration cycle apparatus according to the present embodiment, dirtiness diagnosis in water heat exchanger 109 can be performed. The following individually describes a dirtiness diagnosis for the cooling operation and a dirtiness diagnosis for the heating operation according to the present embodiment.

<Dirtiness Diagnosis Method during Cooling Operation>

[0042] During the cooling operation, four-way valve 104 switches the flow path for the refrigerant as indicated by the solid line in Fig. 1. On this occasion, water heat exchanger 109 functions as an evaporator. The refrigerant in refrigerant pipe 10 flows from the left to the right in Fig. 1. Control device 300 calculates low-pressure saturation temperature ET from a pressure value Ps detected by low-pressure sensor 111. Control device 300 calculates "Twout-ET" from low-pressure saturation temperature ET and water temperature Twout detected by temperature sensor 204.

[0043] When dirtiness is adhered to a surface of a plate of water heat exchanger 109, a heat transfer failure occurs, thus resulting in decreased low-pressure saturation temperature ET. Therefore, the differential temperature "Twout-ET" between water temperature Twout and low-pressure saturation temperature ET is increased. Therefore, when "Twout-ET > threshold value" is satisfied, it can be diagnosed that dirtiness affecting the water flow inside water heat exchanger 109 is adhered to the plate. In this case, an appropriate value for the dirtiness diagnosis is set as the threshold value. By setting the threshold value to the appropriate value, an abnormality in water heat exchanger 109 can be found at an early stage before clogging occurs in water heat exchanger 109.

[0044] At the time of an operation such as regular inspection, an operator may change the setting water temperature of water heat exchanger 109 in accordance with a situation in the inspection. However, the differential temperature "Twout-ET" is hardly affected by the setting value of the outlet water temperature of water heat exchanger 109. Therefore, even when the operator changes the setting of the target outlet water temperature of water heat exchanger 109 through remote controller 400 or control board 301 of control device 300, the dirtiness diagnosis in water heat exchanger 109 can be performed.

[0045] When the dirtiness on the surface of the plate of water heat exchanger 109 is progressed, the water flow path inside water heat exchanger 109 may be blocked to cause clogging. By comparing the detection value of flowmeter 205 or differential manometer 206 with a reference value, control device 300 may perform, together with the dirtiness diagnosis, determination as to whether or not there is clogging in water heat exchanger 109.

[0046] Control device 300 may estimate a water flow rate during the cooling operation based on a predetermined calculation formula, and may determine whether or not there is clogging in water heat exchanger 109 based on the estimation result. Exemplary formulas regarding the estimation of the water flow rate during the cooling operation are shown below. Control device 300 may estimate the water flow rate using the following formulas (1) and (2):

[Formula 1]

$$Qr = Gr \times (h2 - h1) \cdots (1)$$

[Formula 2]

$$Gw = \frac{Qr}{\rho w \times Cpw \times (Tin - Tout)} \times 3600 \cdots (2)$$

[0047] Here, Qr represents a refrigerant-side heat amount [kW], Gr represents a refrigerant circulation amount [kg/s], h2 represents a water heat exchanger outlet specific enthalpy [kJ/kg], h1 represents a water heat exchanger inlet specific enthalpy [kJ/kg], Gw represents a water flow rate [m3/h], ρw represents a water density [kg/m3], Cp represents a water specific heat [kJ/kg·K], Twin represents a water heat exchanger inlet water temperature [°C], and Twout represents a water heat exchanger outlet water temperature [°C].

<Dirtiness Diagnosis Method during Heating Operation>

[0048] During the heating operation, four-way valve 104 switches the flow path for the refrigerant in the direction indicated by the broken line in Fig. 1. On this occasion, water heat exchanger 109 functions as a condenser. The refrigerant in refrigerant pipe 10 flows from the right to the left in Fig. 1. Control device 300 calculates high-pressure saturation temperature CT from a pressure value Pd detected by high-pressure sensor 103. Control device 300 calculates "CT-Twout" from high-pressure saturation temperature CT and water temperature Twout detected by temperature sensor 204.

[0049] When dirtiness is adhered to a surface of a plate of water heat exchanger 109, a heat transfer failure occurs, thus resulting in increased high-pressure saturation temperature CT. Therefore, the differential temperature "CT-Twout" between water temperature Twout and high-pressure saturation temperature CT is increased. Therefore, when "CT-Twout > threshold value" is satisfied, it can be diagnosed that dirtiness affecting the water flow inside water heat exchanger 109 is adhered to the plate. In this case, an appropriate value for the dirtiness diagnosis is set as the threshold value. By setting the threshold value to the appropriate value, an abnormality in water heat exchanger 109 can be found at an early stage before clogging occurs in water heat exchanger 109.

[0050] As with the cooling operation, the differential temperature "CT-Twout" indicates a similar value regardless of the setting value of the outlet water temperature of water heat exchanger 109. Therefore, even when the operator changes the setting of the target outlet water temperature of water heat exchanger 109 through remote controller 400 or control board 301 of control device 300, the dirtiness diagnosis in water heat exchanger 109 can be performed. By comparing the detection value of flowmeter 205 or differential manometer 206 with a reference value, control device 300 may perform, together with the dirtiness diagnosis, determination as to whether or not there is clogging in water heat exchanger 109.

< Flow of Dirtiness Diagnosis during Cooling Operation>

[0051] Fig. 2 is a flowchart showing a dirtiness diagnosis process during the cooling operation. This flowchart shows a process performed by control device 300. A control program necessary for this process is stored in memory 303 of control device 300.

[0052] Among the steps in the flowchart of Fig. 2, steps S2 to S6 are processes regarding determination as to refrigerant leakage. That is, in the dirtiness diagnosis process for water heat exchanger 109, control device 300 also determines whether or not there is refrigerant leakage in refrigerant circuit 100. Here, prior to describing each step of the flowchart, the following describes a reason why control device 300 performs, together with the dirtiness diagnosis in water heat exchanger 109, the determination as to whether or not there is refrigerant leakage. For the description, reference will be made to Fig. 3.

[0053] Fig. 3 is a p-h diagram showing a state difference between a case where there is refrigerant leakage and a case where there is no refrigerant leakage. Referring to Fig. 3, SC represents a degree of supercooling, TdSH represents a degree of discharge superheating, ET represents the low-pressure saturation temperature, and CT represents the high-pressure saturation temperature. The p-h diagram when there is no refrigerant leakage is "1—>2—>3—>4—>1", whereas the p-h diagram when there is refrigerant leakage is "1'→2'→3'→4'→1'". Therefore, when there is refrigerant leakage, low-pressure saturation temperature ET and high-pressure saturation temperature CT are decreased, whereas TdSH is increased.

[0054] As described above, low-pressure saturation temperature ET is a value used when performing the dirtiness diagnosis in water heat exchanger 109 during the cooling operation. High-pressure saturation temperature CT is a value used when performing the dirtiness diagnosis in water heat exchanger 109 during the heating operation. Therefore, the refrigerant leakage affects the dirtiness diagnosis in water heat exchanger 109. Therefore, in the present embodiment, whether or not there is refrigerant leakage is also determined when performing the dirtiness diagnosis in water heat exchanger 109. In other words, in the present embodiment, the dirtiness diagnosis in water heat exchanger 109 is performed in combination with the determination as to whether or not there is refrigerant leakage. Accordingly, an error can be prevented from being introduced in the dirtiness diagnosis in water heat exchanger 109 due to the influence of the refrigerant leakage.

[0055] Returning to Fig. 2, the dirtiness diagnosis process during the cooling operation will be described. First, control device 300 collects operation data from refrigerant circuit 100 and water circuit 200 (step S1). Next, control device 300 calculates SC and TdsH in order to make determination as to refrigerant leakage based on the operation data collected in step S1 (step S2). A calculation procedure is as follows. First, control device 300 extracts pressure Pd obtained from high-pressure sensor 103, Trout obtained from refrigerant temperature sensor 107, and discharge temperature Td obtained from discharge temperature sensor 102. Pressure Pd is converted into a saturation temperature to find high-pressure saturation temperature CT. Further, degree of supercooling SC on the outlet side of heat exchanger 105 and degree of discharge superheating TdSH of refrigerant circuit 100 are calculated using the following formulas 3 and 4.

[Formula 3]

$$SC = CT - Trout \cdots (3)$$

[Formula 4]

$$TdSH = Td - CT \cdots (4)$$

[0056] Next, control device 300 determines whether or not SC < A (step S3). A represents a threshold value set to detect refrigerant leakage. Next, control device 300 determines whether or not TdsH > B (step S4). B also represents a threshold value set to detect refrigerant leakage. As each of threshold values A and B, an optimal value is appropriately employed in accordance with a type of air conditioning apparatus. When degree of supercooling SC is smaller than threshold value A and degree of discharge superheating TdSH is larger than threshold value B, control device 300 determines that there is refrigerant leakage (step S5). In this case, control device 300 notifies the refrigerant leakage (step S6).

[0057] Specifically, control device 300 outputs, from communication unit 305 to remote controller 400, a signal for notifying the refrigerant leakage. Thus, a message indicating the occurrence of refrigerant leakage is displayed on the display unit of remote controller 400. Further, control device 300 outputs a signal indicating the occurrence of refrigerant leakage to display unit 304 of control board 301. A message indicating the occurrence of refrigerant leakage is displayed on display unit 304.

[0058] After step S6, control device 300 ends the process of this flowchart. That is, when there is refrigerant leakage in refrigerant circuit 100, control device 300 does not perform dirtiness diagnosis in water heat exchanger 109. In this way, control device 300 makes determination as to refrigerant leakage before performing dirtiness diagnosis in water heat exchanger 109, with the result that the dirtiness diagnosis, which may lead to an inaccurate diagnosis result, can be prevented from being performed in addition to the determination as to the refrigerant leakage.

[0059] When it is determined NO in step S3 or step S4, control device 300 converts the detection value of low-pressure sensor 111 into low-pressure saturation temperature ET (step S7). Next, control device 300 determines whether or not Twout-ET > C (step S8). Here, Twout represents a temperature of the water having been through the heat exchange with the refrigerant in refrigerant circuit 100 inside water heat exchanger 109. In other words, Twout represents the temperature on the outlet side of the second flow path through which the water flows in water heat exchanger 109.

[0060] Further, C represents a threshold value set to diagnose the dirtiness in water heat exchanger 109. By adjusting this value, a diagnosis corresponding to a degree of dirtiness can be performed. Threshold value C is made to differ depending on the specification of the water heat exchanger. Further, threshold values may be provided in a stepwise manner so as to diagnose an abnormality level. When Twout-ET > C, control device 300 diagnoses that there is an abnormality due to dirtiness (step S9). In other words, when Twout-ET > C, control device 300 diagnoses that a heat transfer failure has occurred in water heat exchanger 109. This heat transfer failure occurs because dirtiness is adhered to the flow path in water heat exchanger 109 to increase the flow path resistance. Therefore, it can be said that the diagnosis in step S9 is a diagnosis on a heat transfer failure or a diagnosis on a flow path resistance (difficulty in flow of water).

[0061] Before notifying the abnormality of water heat exchanger 109, control device 300 determines whether or not ET < D (step S10). Here, D represents a threshold value to know, from low pressure saturation temperature ET, a possibility of freezing of water in the second flow path of water heat exchanger 109. For example, threshold value D represents a freezing determination temperature of water. The freezing determination temperature is a temperature at which water becomes frozen. The freezing determination temperature may be higher, by about 1 degree or 2 degrees, than the temperature at which water becomes frozen. When ET < D, water may become frozen in water heat exchanger 109. Therefore, when it is determined that ET < D, control device 300 increases the setting temperature (target outlet water temperature) on the outlet side of water heat exchanger 109 (step S11). Thus, freezing of water in water heat exchanger 109 is prevented. As a result, water heat exchanger 109 is prevented from being damaged due to freezing of water.

[0062] When it is determined NO in step S10, control device 300 prohibits the setting temperature from being decreased (step S12). In step S12, for example, when the user operates remote controller 400 to provide a command to decrease the setting temperature, control device 300 does not accept the command. Thus, the current setting temperature is maintained. As a result, the water is prevented in advance from being frozen due to the water temperature being decreased to be less than the current temperature.

[0063] In this way, when Twout-ET > C, control device 300 does not proceed to the step of notifying the dirtiness abnormality in water heat exchanger 109, but determines the possibility of freezing of water and performs the process of preventing the freezing of water. Therefore, the freezing of water can be prevented in advance as compared with the case where only the dirtiness abnormality in water heat exchanger 109 is notified. It should be noted that control device 300 may notify the possibility of freezing of water.

[0064] After step S11 or S12, control device 300 notifies the dirtiness abnormality (step S13). Specifically, control device 300 outputs a signal from communication unit 305 to remote controller 400 to indicate that there is dirtiness in water heat exchanger 109. Thus, a message indicating the occurrence of the dirtiness abnormality is displayed on the display unit of remote controller 400. Further, control device 300 outputs a signal to display unit 304 of control board 301 to indicate that there is dirtiness in water heat exchanger 109. A message indicating the occurrence of the dirtiness abnormality is displayed on display unit 304. After step S13, control device 300 ends the process of this flowchart.

[0065] It should be noted that in the flowchart of Fig. 2, whether or not there is refrigerant leakage may be determined after the dirtiness diagnosis in water heat exchanger 109. Further, in the flowchart of Fig. 2, after the notification of the dirtiness abnormality in step S13, the processes in steps S10 to S12 may be performed. Furthermore, when it is determined in step S8 that there is dirtiness in water heat exchanger 109, control device 300 controls compressor 101 in accordance with the setting value of remote controller 400.

< Flow of Dirtiness Diagnosis during Heating Operation>

[0066] Fig. 4 is a flowchart of the dirtiness diagnosis during the heating operation. This flowchart shows a process performed by control device 300. A control program necessary for this process is stored in memory 303 of control device 300. An exemplary diagnosis flow during the heating operation will be described with reference to Fig. 4.

[0067] Control device 300 collects operation data from refrigerant circuit 100 and water circuit 200 (step S 100). Before performing the dirtiness diagnosis in water heat exchanger 109, control device 300 determines whether or not there is refrigerant leakage in refrigerant circuit 100. This is due to the reason described above. That is, when there is refrigerant leakage in refrigerant circuit 100, high-pressure saturation temperature CT is decreased. Since high-pressure saturation temperature CT is a parameter used for the dirtiness diagnosis in water heat exchanger 109 during the heating operation, an error is introduced into the dirtiness diagnosis in water heat exchanger 109 when there is refrigerant leakage.

[0068] Therefore, control device 300 first determines whether or not there is refrigerant leakage. First, control device 300 calculates degree of discharge superheating TdSH (step S101). Degree of discharge superheating

TdSH is calculated using the formula (4) described above. That is, degree of discharge superheating TdSH is calculated by subtracting high-pressure saturation temperature CT from discharge temperature Td. Here, discharge temperature Td is obtained from the detection value of discharge temperature sensor 102. Further, high-pressure saturation temperature CT is found by converting pressure Pd obtained from high-pressure sensor 103 into a saturation temperature.

[0069] In particular, during the heating operation, an excess of the refrigerant is likely to remain in accumulator 110. Therefore, control device 300 determines whether or not there is refrigerant leakage by using degree of discharge superheating TdSH, which apparently differs between the case where there is no refrigerant leakage and the case where there is refrigerant leakage.

[0070] Next, control device 300 determines whether or not TdsH > E (step S102). E represents a threshold value set to detect refrigerant leakage. Threshold value E is made to differ depending on a type of air conditioning apparatus. When degree of discharge superheating TdSH is more than threshold value E, control device 300 determines that there is refrigerant leakage (step S103). In this case, control device 300 notifies the refrigerant leakage (step S104). The process in step S104 is the same as that in step S6 described above. As a result, a message indicating the occurrence of refrigerant leakage is displayed on the display unit of remote controller 400 and display unit 304 of control board 301.

[0071] After step S104, control device 300 ends the process of this flowchart. That is, when there is refrigerant leakage in refrigerant circuit 100, control device 300 does not perform the dirtiness diagnosis in water heat exchanger 109. In this way, the control unit makes determination as to the refrigerant leakage before performing the dirtiness diagnosis in water heat exchanger 109, with the result that the dirtiness diagnosis, which may lead to an inaccurate diagnosis result, can be prevented from being performed in addition to the determination as to the refrigerant leakage.

[0072] When it is determined NO in step S102, control device 300 converts the detection value of high-pressure sensor 103 into high-pressure saturation temperature CT (step S105). Next, control device 300 determines whether or not CT-Twout > F (step S106). Here, Twout represents the temperature of the water having been through the heat exchange with the refrigerant in refrigerant circuit 100 inside water heat exchanger 109. In other words, Twout represents the temperature on the outlet side of the second flow path through which water flows in water heat exchanger 109.

[0073] Further, F represents a threshold value set to diagnose the dirtiness in water heat exchanger 109. By adjusting this value, a diagnosis corresponding to a degree of dirtiness can be performed. Threshold value F is made to differ depending on the specification of the water heat exchanger. Further, threshold values may be provided in a stepwise manner so as to diagnose an abnormality level. When CT-Twout > F, control device 300 diagnoses that there is an abnormality due to dirtiness (step S107). In other words, when CT-Twout > F, control device 300 diagnoses that a heat transfer failure has occurred in water heat exchanger 109. This heat transfer failure occurs because dirtiness is adhered to the flow path in water heat exchanger 109 to increase the flow path resistance. Therefore, it can be said that the diagnosis in step S107 is a diagnosis on a heat transfer failure or a diagnosis on a flow path resistance (difficulty in flow of water).

[0074] After step S106, control device 300 notifies the dirtiness abnormality (step S108). The process in step S108 is the same as that in step S13 described above. As a result, a message indicating the occurrence of the dirtiness abnormality is displayed on the display unit of remote controller 400 and display unit 304 of control board 301. After step S108, control device 300 ends the process of this flowchart.

[0075] It should be noted that in the flowchart of Fig. 4, whether or not there is refrigerant leakage may be determined after the dirtiness diagnosis in water heat exchanger 109. Further, when it is determined in step S107 that there is dirtiness in water heat exchanger 109, control device 300 controls compressor 101 in accordance with the setting value of remote controller 400.

<Specifying Location of Clogging>

[0076] Fig. 5 is a flowchart for determining whether clogging has occurred in water heat exchanger 109 or strainer 209. This flowchart shows a process performed by control device 300. A control program necessary for this process is stored in memory 303 of control device 300.

[0077] Referring to Fig. 5, control device 300 determines whether or not Gw < G (step S200). Here, Gw represents a flow rate of the water circulating in water circuit 200. Gw is specified from a measurement value of flowmeter 205. Further, G represents a threshold value set to determine a degree of the flow rate of the water. By determining whether or not water Gw < G, it can be determined whether or not the water flow of water circuit 200 is decreased to be less than a reference value. By adjusting threshold value G, it can be determined whether or not clogging has occurred in water circuit 200.

[0078] As shown in the flowchart of step S200, control device 300 may determine whether or not ΔPw > H instead of determining whether or not Gw < G. Here, ΔPw represents a differential pressure between the inlet and outlet of water heat exchanger 109 on the water circuit 200 side. The differential pressure is specified from a detection value of differential manometer 206. Further, H represents a threshold value set to determine a degree of differential pressure.

[0079] When it is determined NO in step S200, control device 300 ends the process. When it is determined YES in step S200, control device 300 determines whether or not it has been diagnosed that there is a dirtiness abnormality in water heat exchanger 109 (step S201). Control device 300 performs the determination of step S201 by making reference to the determination result of step S9 in Fig. 2 during the cooling operation and by making reference to the determination result of step S107 in Fig. 4 during the heating operation.

[0080] When control device 300 determines in step S201 that there is a dirtiness abnormality in water heat exchanger 109, control device 300 determines that the cause of decreased water amount in step S200 resides in water heat exchanger 109. That is, control device 300 determines that there is clogging in water heat exchanger 109 (step S202). When it is determined in step S201 that there is no dirtiness abnormality in water heat exchanger 109, control device 300 determines that the cause of decreased water amount in step S200 resides in strainer 209. That is, control device 300 determines that there is clogging in strainer 209 (step S204).

[0081] When it is determined in step S202 that clogging has occurred in water heat exchanger 109, control device 300 notifies that clogging has occurred in water heat exchanger 109 (step S203). When it is determined in step S204 that clogging has occurred in strainer 209, control device 300 notifies that clogging has occurred in strainer 209 (step S205). Specifically, control device 300 outputs a signal from communication unit 305 to remote controller 400 so as to notify the clogging in water heat exchanger 109 or the clogging in strainer 209. Thus, a message indicating the clogging in water heat exchanger 109 or strainer 209 is displayed on the display unit of remote controller 400 and display unit 304 of control device 300. After step S203 and step S205, control device 300 ends the process of this flowchart.

[0082] In this way, control device 300 has a function of not only diagnosing the dirtiness on water heat exchanger 109 but also specifying the location of the clogging and notifying the location. In other words, control device 300 can specify the clogging of the water path in a wide range including water heat exchanger 109 and strainer 209, and can further specify whether the clogging has occurred in water heat exchanger 109 or strainer 209.

<Graph Representation of State of Progress of Dirtiness>

[0083] Fig. 6 is a graph showing a state of progress of dirtiness. Fig. 6 is a graph during the cooling operation. Control device 300 calculates a state of dirtiness in water heat exchanger 109 at a timing set in advance, and stores the calculation result into memory 303. Control device 300 displays the graph shown in Fig. 6 in response to an operation on remote controller 400 or a direct operation on control board 301. This graph is displayed on display unit 304 of control board 301. Further, this graph is displayed on display unit 401 of remote controller 400.

[0084] Referring to Fig. 6, in the graph, the vertical axis represents "Twout-ET" and the horizontal axis represents time. In the graph, the limit of "Twout-ET" determined as a dirtiness abnormality is represented by the indication "ABNORMALITY". 30A, 30B, 30C, 30D, and 30D represent respective values of "Twout-ET" calculated at different timings. In view of this graph, it is readily understandable that as time elapses, "Twout-ET" becomes closer to the threshold value and the degree of dirtiness is increased. Further, in view of this graph, it is understandable that at the stage of 30D, water heat exchanger 109 is brought into a state in which the dirtiness abnormality is diagnosed and the degree of dirtiness is still progressed thereafter. Therefore, by displaying such a graph by control device 300, convenience is improved for the user or the operator on regular inspection.

[0085] The graph of Fig. 6 is a graph during the cooling operation. Control device 300 may display a graph corresponding to the heating operation as well. In this case, "CT-Twout" is displayed on the vertical axis.

[0086] Fig. 7 is a flowchart for recording the progress of dirtiness inside the water heat exchanger. This flowchart shows a process performed by control device 300. A control program necessary for this process is stored in memory 303 of control device 300. By this process, for example, the graph shown in Fig. 6 is presented to the user.

[0087] First, control device 300 determines whether or not a set calculation timing is reached (step S300). The calculation timing can be appropriately set. For example, the calculation timing may be freely set using remote controller 400 or control board 301. Next, control board 301 collects operation data from refrigerant circuit 100 and water circuit 200 (step S301). Next, control device 300 calculates Twout-ET from the collected operation data (step S302). The procedure of calculating Twout-ET has been already described, and is therefore not described repeatedly here.

[0088] Next, control device 300 stores, into memory 303, the calculation result together with the date and time of calculation (step S303). Next, control device 300 determines whether or not a command to display the graph has been made (step S304). In the present embodiment, the command to display the graph can be input through an operation on remote controller 400 or an operation on control board 301. Control device 300 determines whether or not the command has been made through such an operation. When control device 300 determines that the command to display the graph has been made, control device 300 reads out accumulated data from memory 303 and displays the data in the form of the graph (step S305). Then, control device 300 ends the process of this flowchart.

[0089] For regular inspection or the like, control device 300 may regularly calculate the differential temperature "Twout-ET". Thus, for example, the operator on regular inspection can know the progress of dirtiness in water heat exchanger 109. For example, in view of calculation result 30C in Fig. 6, the operator understands that water heat exchanger 109 is becoming closer to the abnormal state. This allows the operator to perform planned maintenance inspection by inspecting water pipe 20 and washing the inside of water heat exchanger 109 in the next regular inspection. As a result, occurrence of a trouble in the refrigeration cycle apparatus can be prevented. It should be noted that a plurality of threshold values for determining the abnormality of water heat exchanger 109 may be set in a stepwise manner.

[0090] For example, a first threshold value and a second threshold value larger than the first threshold value are set. Control device 300 determines, in a stepwise manner, whether or not the dirtiness in water heat exchanger 109 becomes more than the first threshold value and whether or not the dirtiness in water heat exchanger 109 becomes more than the second threshold value.

Second Embodiment.

[0091] Fig. 8 is a diagram showing a configuration of a refrigeration cycle apparatus 2 according to a second embodiment. Refrigeration cycle apparatus 2 according to the second embodiment differs from refrigeration cycle apparatus 1 according to the second embodiment in terms of the number of refrigerant circuits connected to one water circuit 200. In refrigeration cycle apparatus 1 according to the first embodiment, one refrigerant circuit 100 is connected to one water circuit 200. On the other hand, in refrigeration cycle apparatus 2 according to the second embodiment, a plurality of refrigerant circuits A 100a and B 100b are connected to one water circuit 200.

[0092] Refrigerant circuit A 100a includes a compressor 101a, a four-way valve 104a, a heat exchanger 105a, a fan 106a, a diaphragm mechanism 108a, a water heat exchanger 109a, an accumulator 110a, and a refrigerant pipe 10a that connects them. Refrigerant circuit B 100b includes a compressor 100b, a four-way valve 104b, a heat exchanger 105b, a fan 106b, a diaphragm mechanism 108b, a water heat exchanger 109b, an accumulator 110b, and a refrigerant pipe 10b that connects them. These components have the same functions as the corresponding components described in the first embodiment.

[0093] Water circuit 200 according to the second embodiment is connected to two water heat exchangers A 109a and B 109b in series. A differential manometer 206 is provided in water circuit 200 so as to detect a differential pressure between a pressure on the inlet side of water heat exchanger A 109a and a pressure on the outlet side of water heat exchanger B 109b. Refrigerant circuit A 100a and refrigerant circuit B 100b control the frequencies of compressors 101a, 101b to cause the water temperature at the outlet of water heat exchanger B 109b to attain a target set value. Refrigeration cycle apparatus 2 according to the second embodiment can perform each of the processes described in the first embodiment. As a result, control device 300 can diagnose a dirtiness abnormality in each of water heat exchanger A 109a and water heat exchanger B 109b.

[0094] Fig. 9 is a flowchart showing contents of control of refrigeration cycle apparatus 2 according to the second embodiment. This flowchart shows a process performed by control device 300 of Fig. 8. A control program necessary for this processing is stored in memory 303 of control device 300 shown in Fig. 8.

[0095] Control device 300 diagnoses whether or not there is a dirtiness abnormality in water heat exchanger A 109a (step S400). When there is no dirtiness abnormality in water heat exchanger A 109a, control device 300 diagnoses whether or not there is a dirtiness abnormality in water heat exchanger B 109b (step S401). When there is no dirtiness abnormality in water heat exchanger B 109b, control device 300 ends the process of this flowchart. When there is a dirtiness abnormality in water heat exchanger B109b, control device 300 stops refrigerant circuit B 100b (step S403). Thus, the dirtiness abnormality of water heat exchanger B 109b can be prevented from adversely affecting refrigeration cycle apparatus 2. Further, control device 300 notifies the dirtiness abnormality of water heat exchanger B 109b (step S404).

[0096] After step S404, control device 300 adjusts compressor 101a of refrigerant circuit A 100a (step S405). In this adjustment, with only refrigerant circuit A 100a, the temperature on the outlet side of water heat exchanger B 109b (detected by temperature sensor 204) is adjusted to attain the target outlet temperature. Next, control device 300 determines whether or not the temperature on the outlet side of water heat exchanger B 109b has reached the target outlet temperature (step S406). Control device 300 continues to adjust compressor 101a in step S405 until it is determined YES in step S406. When it is determined YES in step S406, control device 300 ends the process of this flowchart.

[0097] When it is diagnosed in step S400 that there is a dirtiness abnormality in water heat exchanger A 109a, control device 300 diagnoses whether or not there is a dirtiness abnormality in water heat exchanger B 109b (step S402). When there is no dirtiness abnormality in water heat exchanger B 109b, control device 300 stops refrigerant circuit A 100a (step S407). Thus, the dirtiness abnormality of water heat exchanger A 109a can be prevented from adversely affecting refrigeration cycle apparatus 2. Further, control device 300 notifies the dirtiness abnormality of water heat exchanger A 109a (step S408).

[0098] After step S408, control device 300 adjusts compressor 101b of refrigerant circuit B 100b (step S409). In this adjustment, with only refrigerant circuit B 100b, the temperature on the outlet side of water heat exchanger B 109b (detected by temperature sensor 204) is adjusted to attain the target outlet temperature. Next, control device 300 determines whether or not the temperature on the outlet side of water heat exchanger B109b has reached the target outlet temperature (step S410). Control device 300 continues to adjust compressor 100b in step S409 until it is determined YES in step S410. When it is determined YES in step S410, control device 300 ends the process of this flowchart.

[0099] When it is determined YES in step S402, i.e., when it is diagnosed that there is a dirtiness abnormality in each of water heat exchanger A 109a and water heat exchanger B 109b, control device 300 stops refrigerant circuit A 100a and refrigerant circuit B 100b (step S411). Further, control device 300 notifies the dirtiness abnormality of each of water heat exchanger A 109a and water heat exchanger B 109b (step S412), and ends the process of this flowchart.

[0100] It should be noted that the diagnosis method in steps S400 to S402 and the notification method in steps S404, S408, and S412 are the same as those of the first embodiment described with reference to Figs. 2 and 4. In this flowchart, when it is diagnosed that there is a dirtiness abnormality in each of water heat exchanger A 109a and water heat exchanger B 109b, refrigerant circuit A 100a and refrigerant circuit B 100b are stopped. However, instead of such a process, various processes may be applied to avoid immediate stop of refrigeration cycle apparatus 2. For example, it is considered to continue the operation of a refrigerant circuit having a lower degree of dirtiness abnormality.

[0101] In the second embodiment, it has been illustratively described in Fig. 8 that two refrigerant circuits A 100a and B 100b are provided for one water circuit 200. However, a larger number of refrigerant circuits may be provided for one water circuit 200. The refrigerant flowing through refrigerant circuit A 100a and the refrigerant flowing through refrigerant circuit B 100b may be the same type of refrigerant or different types of refrigerants.

Third Embodiment.

[0102] Fig. 10 is a diagram showing a configuration of a refrigeration cycle apparatus 3 according to a third embodiment. In refrigeration cycle apparatus 2 according to the third embodiment, a group of refrigerant circuits is connected to one water circuit 200 in parallel. As shown in Fig. 10, in refrigeration cycle apparatus 2 according to the third embodiment, a refrigerant circuit 100a and a refrigerant circuit 100b are connected in series, and these two refrigerant circuits constitute a first group of refrigerant circuits. On the other hand, a refrigerant circuit 100c and a refrigerant circuit 100d are connected in series, and these two refrigerant circuits constitute a second group of refrigerant circuits. The first group of refrigerant circuits and the second group of refrigerant circuits are connected to water circuit 200 in parallel. Each of refrigerant circuits 100a to 100d includes a water heat exchanger (plate type heat exchanger).

[0103] Refrigeration cycle apparatus 3 according to the third embodiment performs the processes according to the first and second embodiments in a similar manner. For example, the dirtiness diagnosis in water heat exchanger is performed for each water heat exchanger, and the determination as to refrigerant leakage in the refrigerant circuit is performed for each refrigerant circuit.

Fourth Embodiment.

[0104] Fig. 11 is a diagram showing a water heat exchanger portion of a refrigeration cycle apparatus according to a fourth embodiment. The fourth embodiment represents an example in which the saturation temperature is directly detected by a temperature sensor. As shown in Fig. 11, in the fourth embodiment, a saturation temperature sensor 210 for detecting the saturation temperature is provided inside water heat exchanger 109. In the first embodiment, high-pressure saturation temperature CT and low-pressure saturation temperature ET are calculated from the pressures from the pressure sensors (high-pressure sensor 103 and low-pressure sensor 111) provided in refrigerant circuit 100. However, saturation temperature sensor 210 for detecting the saturation temperature may be provided in water heat exchanger 109 at an appropriate position, and control device 300 may specify the saturation temperature based on the detection value of saturation temperature sensor 210. This leads to simplified control of control device 300. A method of specifying the saturation temperature using saturation temperature sensor 210 may be applied to any of the first to third embodiments.

[0105] As described above, according to the refrigeration cycle apparatus of each of the embodiments, dirtiness inside plate type water heat exchanger 109 can be diagnosed. In other words, this dirtiness diagnosis is a diagnosis on a heat transfer failure of water heat exchanger 109 or a diagnosis on a state of a flow path in water heat exchanger 109. By such a diagnosis, a trouble in water heat exchanger 109 can be found. In particular, since clogging between the plates is caused by accumulation of dirtiness, according to the refrigeration cycle apparatus of each of the embodiments, a trouble of water heat exchanger 109 can be detected at an early stage before clogging in water heat exchanger 109.

[0106] According to the refrigeration cycle apparatus of each of the embodiments, regardless of the set water temperature on the outlet side, the dirtiness state inside the plate type heat exchanger can be diagnosed. Therefore, a trouble (for example, freezing) in water heat exchanger 109 can be avoided at an early stage.

[0107] The refrigeration cycle apparatus according to each of the first to fourth embodiments can also be applied to a hot water supply apparatus. In each of the first to fourth embodiments, water is illustratively described as a heat medium to exchange heat with the refrigerant circuit serving as a heat source. However, the heat medium may be any medium other than water as long as the medium transfers heat. For example, brine or the like may be used instead of water.

[0108] Control device 300 may control an air conditioning system including refrigerant circuit 100 and water circuit 200 via a network such as the Internet. Control device 300 may control one air conditioning system including refrigerant circuit 100 and water circuit 200, or may control a plurality of such air conditioning systems.

[0109] The embodiments disclosed herein are illustrative and non-restrictive in any respect. The scope of the present invention is defined by the terms of the claims, rather than the embodiments described above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0110] 1, 2, 3: refrigeration cycle apparatus; 100, 100a to 100d: refrigerant circuit; 101: compressor; 102: discharge temperature sensor; 103: high-pressure sensor; 104: four-way valve; 105: heat exchanger; 106: fan; 107: refrigerant temperature sensor; 108: diaphragm mechanism; 109: water heat exchanger; 110: accumulator; 111: low-pressure sensor; 200: water circuit; 201: pump; 202: load apparatus; 203, 204: temperature sensor; 205: flowmeter; 206: differential manometer; 209: strainer; 210: saturation temperature sensor; 300: control device; 400: remote controller.

Claims

1. A refrigeration cycle apparatus comprising:

    a heat-source-side first refrigerant circuit configured to circulate a first refrigerant, the heat-source-side first refrigerant circuit having

        a first compressor,
        a first heat exchanger configured to exchange heat between outside air and the first refrigerant, and
        a first diaphragm mechanism;

    a load-side refrigerant circuit configured to circulate a second refrigerant, the load-side refrigerant circuit having

        a pump, and
        a load apparatus configured to use heat;

    a first plate type heat exchanger configured to exchange heat between the first refrigerant and the second refrigerant; and
    a temperature sensor configured to detect a temperature of the second refrigerant on an outlet side of the first plate type heat exchanger, wherein
    the heat-source-side first refrigerant circuit circulates the first refrigerant at least among the first compressor, the first heat exchanger, the first diaphragm mechanism, and the first plate type heat exchanger, and
    the load-side refrigerant circuit circulates the second refrigerant in one direction at least among the pump, the load apparatus, and the first plate type heat exchanger,
    the refrigeration cycle apparatus further comprising a control device configured to diagnose a flow path for the second refrigerant in the first plate type heat exchanger using the temperature detected by the temperature sensor and a saturation temperature of the first refrigerant.

2. The refrigeration cycle apparatus according to claim 1, wherein the control device controls a frequency of the first compressor to adjust, to a set target temperature, the temperature of the second refrigerant on the outlet side of the first plate type heat exchanger.

3. The refrigeration cycle apparatus according to claim 1 or 2, wherein the control device diagnoses the flow path for the second refrigerant in the first plate type heat exchanger based on a temperature difference between the temperature detected by the temperature sensor and the saturation temperature of the first refrigerant.

4. The refrigeration cycle apparatus according to any one of claims 1 to 3, wherein the control device determines whether or not there is leakage of the first refrigerant.

5. The refrigeration cycle apparatus according to claim 4, wherein when diagnosing the flow path for the second refrigerant in the first plate type heat exchanger, the control device determines whether or not there is the leakage of the first refrigerant.

6. The refrigeration cycle apparatus according to claim 4 or 5, wherein when the first plate type heat exchanger functions as an evaporator for the first refrigerant, the control device determines whether or not there is the leakage of the first refrigerant, based on a degree of supercooling on the outlet side of the first heat exchanger and a degree of discharge superheating of the heat-source-side first refrigerant circuit.

7. The refrigeration cycle apparatus according to any one of claims 4 to 6, wherein when the first plate type heat exchanger functions as a condenser for the first refrigerant, the control device determines whether or not there is the leakage of the first refrigerant, based on a degree of discharge superheating of the heat-source-side first refrigerant circuit.

8. The refrigeration cycle apparatus according to any one of claims 1 to 7, wherein the control device outputs, to a display unit, a diagnosis result for the flow path for the second refrigerant in the first plate type heat exchanger.

9. The refrigeration cycle apparatus according to any one of claims 1 to 8, wherein

the load-side refrigerant circuit further comprises

a strainer, and
a differential manometer or a flowmeter,

when it is diagnosed that there is an abnormality in the flow path for the second refrigerant in the first plate type heat exchanger and it is determined that flow of the second refrigerant is lower than a reference value based on a measurement result of the differential manometer or the flowmeter, the control device determines that there is clogging in the flow path for the second refrigerant in the first plate type heat exchanger, and
when it is diagnosed that there is no abnormality in the flow path for the second refrigerant in the first plate type heat exchanger and it is determined that the flow of the second refrigerant is lower than the reference value based on the measurement result of the differential manometer or the flowmeter, the control device determines that there is clogging in the strainer.

10. The refrigeration cycle apparatus according to any one of claims 1 to 9, wherein

when it is diagnosed that there is an abnormality in the flow path for the second refrigerant in the first plate type heat exchanger while the first plate type heat exchanger functions as an evaporator for the first refrigerant, the control device determines whether or not the temperature detected by the temperature sensor reaches a freezing determination temperature, and
the control device does not accept an operation of decreasing the temperature of the second refrigerant when the temperature detected by the temperature sensor does not reach the freezing determination temperature.

11. The refrigeration cycle apparatus according to any one of claims 1 to 10, wherein

when it is diagnosed that there is an abnormality in the flow path for the second refrigerant in the first plate type heat exchanger while the first plate type heat exchanger functions as an evaporator for the first refrigerant, the control device determines whether or not the temperature detected by the temperature sensor reaches a freezing determination temperature, and
the control device increases the temperature of the second refrigerant when the temperature detected by the temperature sensor reaches the freezing determination temperature.

12. The refrigeration cycle apparatus according to any one of claims 1 to 11, further comprising:

a heat-source-side second refrigerant circuit having a second compressor, a second heat exchanger configured to exchange heat between the outside air and a third refrigerant, and a second diaphragm mechanism; and
a second plate type heat exchanger configured to exchange heat between the second refrigerant and each of the first refrigerant and the third refrigerant, wherein
the heat-source-side second refrigerant circuit circulates the third refrigerant at least among the second compressor, the second heat exchanger, the second diaphragm mechanism, and the second plate type heat exchanger,
the load-side refrigerant circuit circulates the second refrigerant in one direction at least among the pump, the load apparatus, the first plate type heat exchanger, and the second plate type heat exchanger, and
the first plate type heat exchanger and the second plate type heat exchanger are connected to the load-side refrigerant circuit in series.

13. The refrigeration cycle apparatus according to claim 12, wherein when it is diagnosed that there is an abnormality in the flow path for the second refrigerant in the first plate type heat exchanger and it is diagnosed that there is no abnormality in the flow path for the second refrigerant in the second plate type heat exchanger, the control device stops an operation of the first compressor and controls the second compressor to adjust, to a set target temperature, the temperature of the second refrigerant flowing on a downstream side with respect to the first plate type heat exchanger and the second plate type heat exchanger.

14. The refrigeration cycle apparatus according to any one of claims 1 to 13, further comprising a pressure sensor provided at a suction portion or discharge portion of the first compressor, wherein
the control device specifies the saturation temperature based on a detection value of the pressure sensor.

15. The refrigeration cycle apparatus according to any one of claims 1 to 13, further comprising a saturation temperature sensor configured to detect the saturation temperature of the first refrigerant, the saturation temperature sensor being disposed inside the first plate type heat exchanger, wherein
the control device specifies the saturation temperature based on a detection value of the saturation tem-

perature sensor.

16. The refrigeration cycle apparatus according to any one of claims 1 to 15, wherein

the load-side refrigerant circuit further comprises a flowmeter, and
the control device determines whether or not there is clogging in the flow path for the second refrigerant in the first plate type heat exchanger based on a measurement result of the flowmeter.

17. The refrigeration cycle apparatus according to any one of claims 1 to 15, wherein

the load-side refrigerant circuit further comprises a differential manometer, and
the control device determines whether or not there is clogging in the flow path for the second refrigerant in the first plate type heat exchanger based on a measurement result of the differential manometer.

18. The refrigeration cycle apparatus according to any one of claims 1 to 15, wherein the control device estimates a flow rate of the second refrigerant based on a predetermined calculation formula, and determines whether or not there is clogging in the flow path for the second refrigerant in the first plate type heat exchanger based on an estimation result.

FIG.1

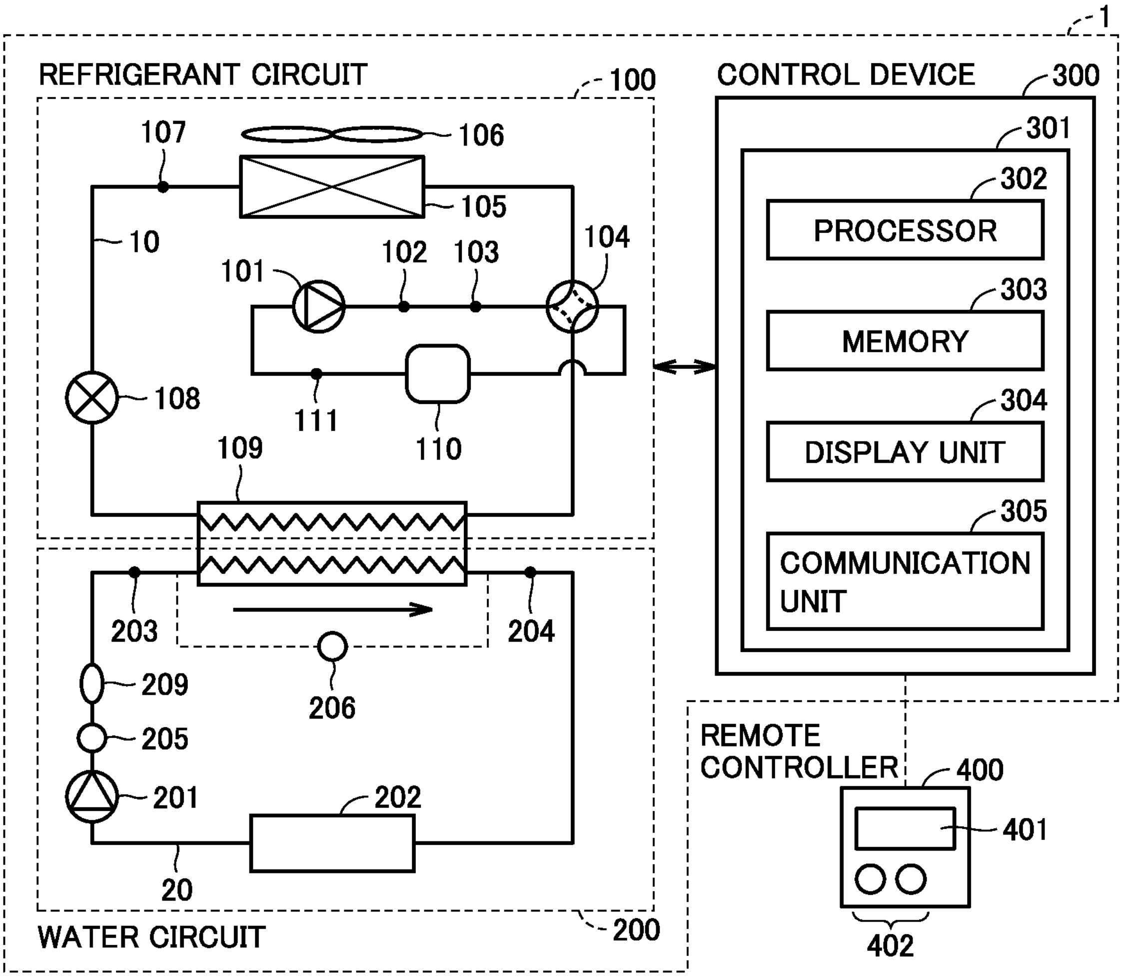

1
REFRIGERANT CIRCUIT
100
107
106
105
10
104
101
102
103
108
111
110
109
CONTROL DEVICE
300
301
302
PROCESSOR
303
MEMORY
304
DISPLAY UNIT
305
COMMUNICATION UNIT
203
204
209
206
205
201
202
20
WATER CIRCUIT
200
REMOTE CONTROLLER
400
401
402

FIG.2

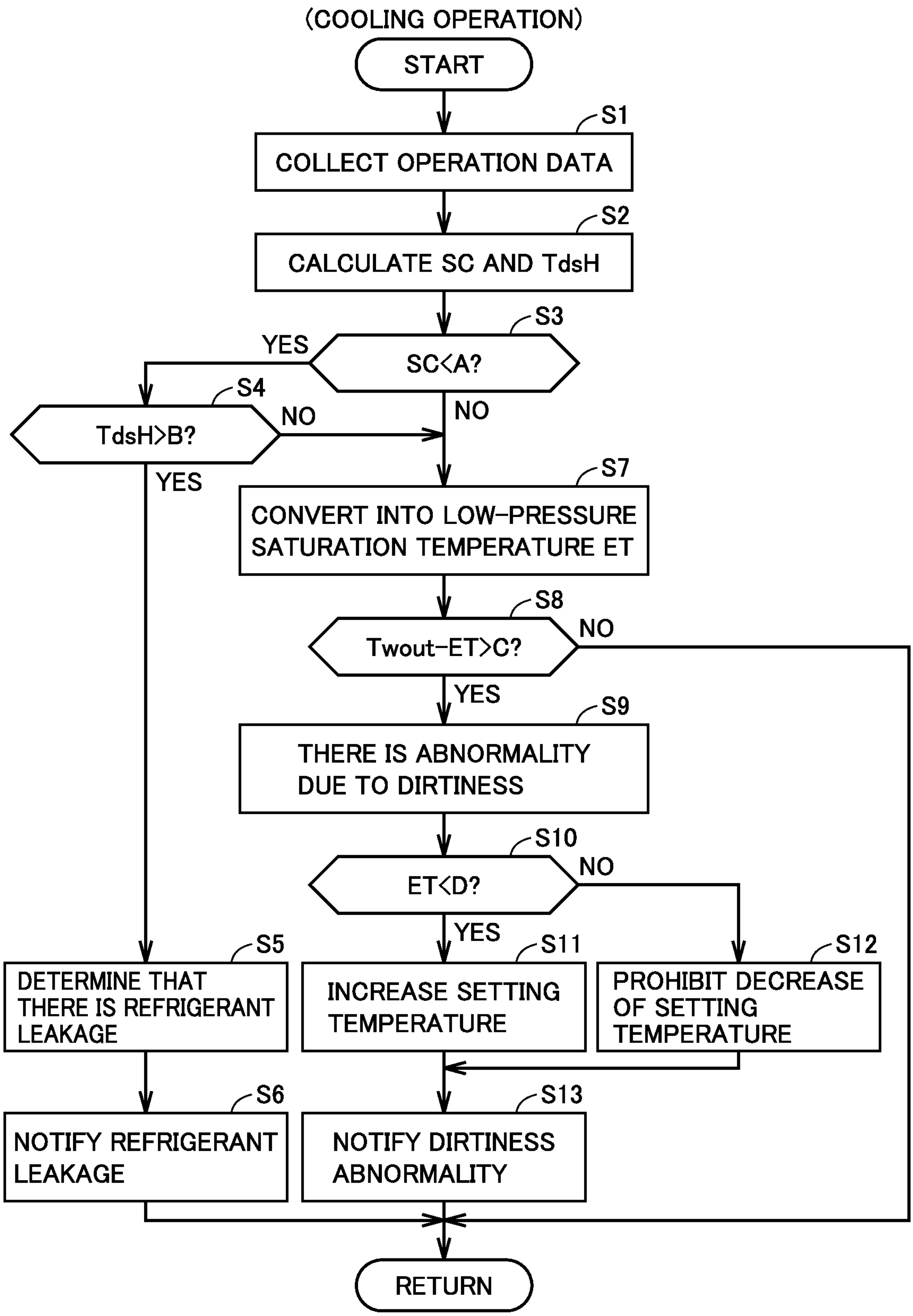

(COOLING OPERATION)
START
S1
COLLECT OPERATION DATA
S2
CALCULATE SC AND TdsH
S3
SC<A?
YES
NO
S4
TdsH>B?
NO
YES
S7
CONVERT INTO LOW-PRESSURE SATURATION TEMPERATURE ET
S8
Twout-ET>C?
NO
YES
S9
THERE IS ABNORMALITY DUE TO DIRTINESS
S10
ET<D?
NO
YES
S5
DETERMINE THAT THERE IS REFRIGERANT LEAKAGE
S11
INCREASE SETTING TEMPERATURE
S12
PROHIBIT DECREASE OF SETTING TEMPERATURE
S6
NOTIFY REFRIGERANT LEAKAGE
S13
NOTIFY DIRTINESS ABNORMALITY
RETURN

FIG.3

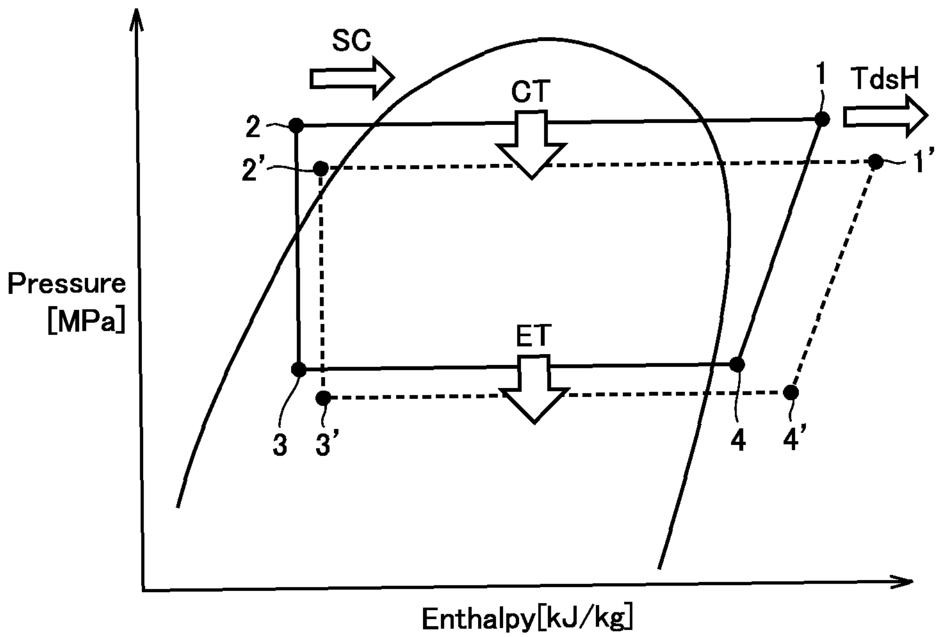


FIG.4

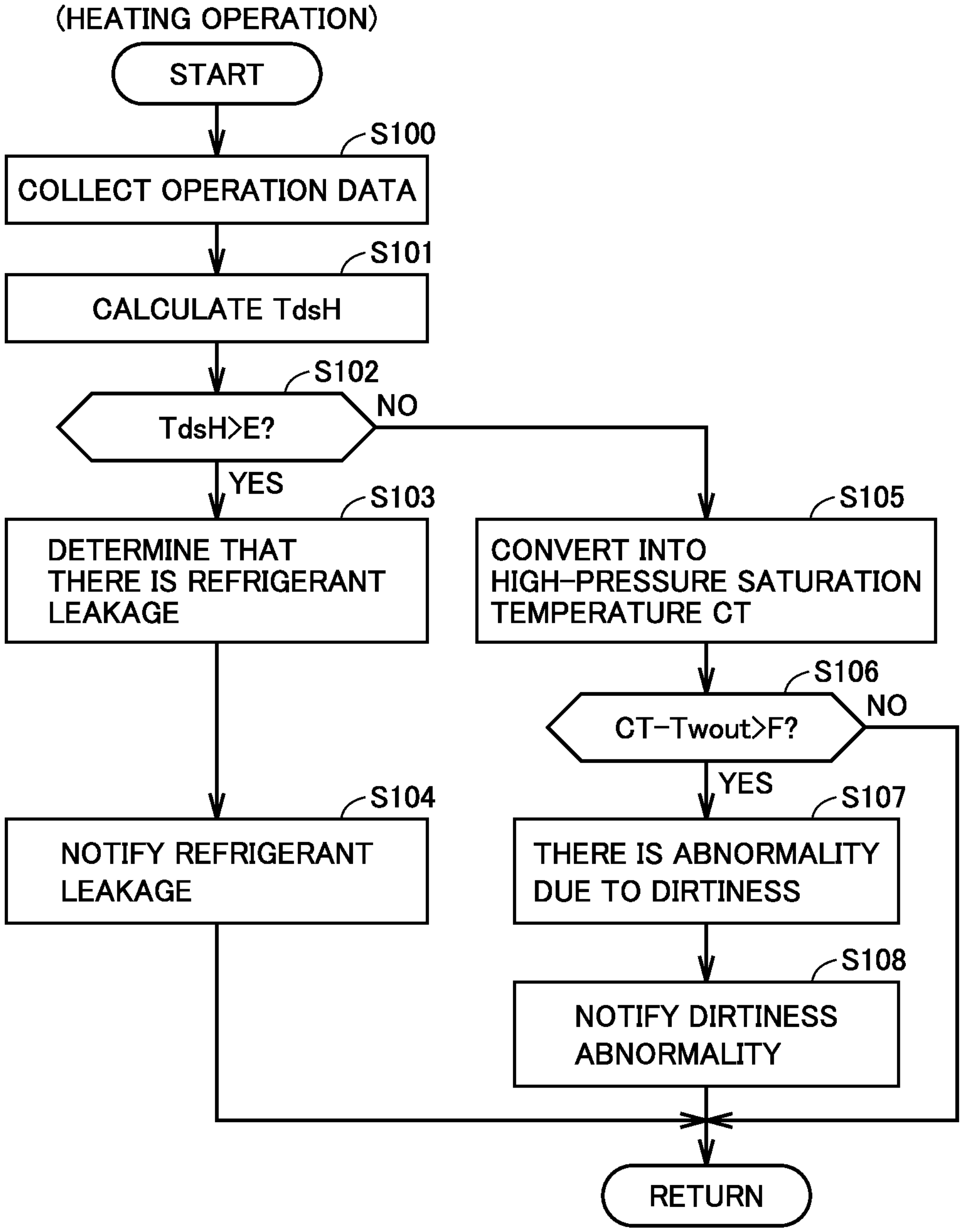

(HEATING OPERATION)
START
S100
COLLECT OPERATION DATA
S101
CALCULATE TdsH
S102
TdsH>E?
NO
YES
S103
DETERMINE THAT THERE IS REFRIGERANT LEAKAGE
S105
CONVERT INTO HIGH-PRESSURE SATURATION TEMPERATURE CT
S106
CT-Twout>F?
NO
YES
S104
NOTIFY REFRIGERANT LEAKAGE
S107
THERE IS ABNORMALITY DUE TO DIRTINESS
S108
NOTIFY DIRTINESS ABNORMALITY
RETURN

FIG.5

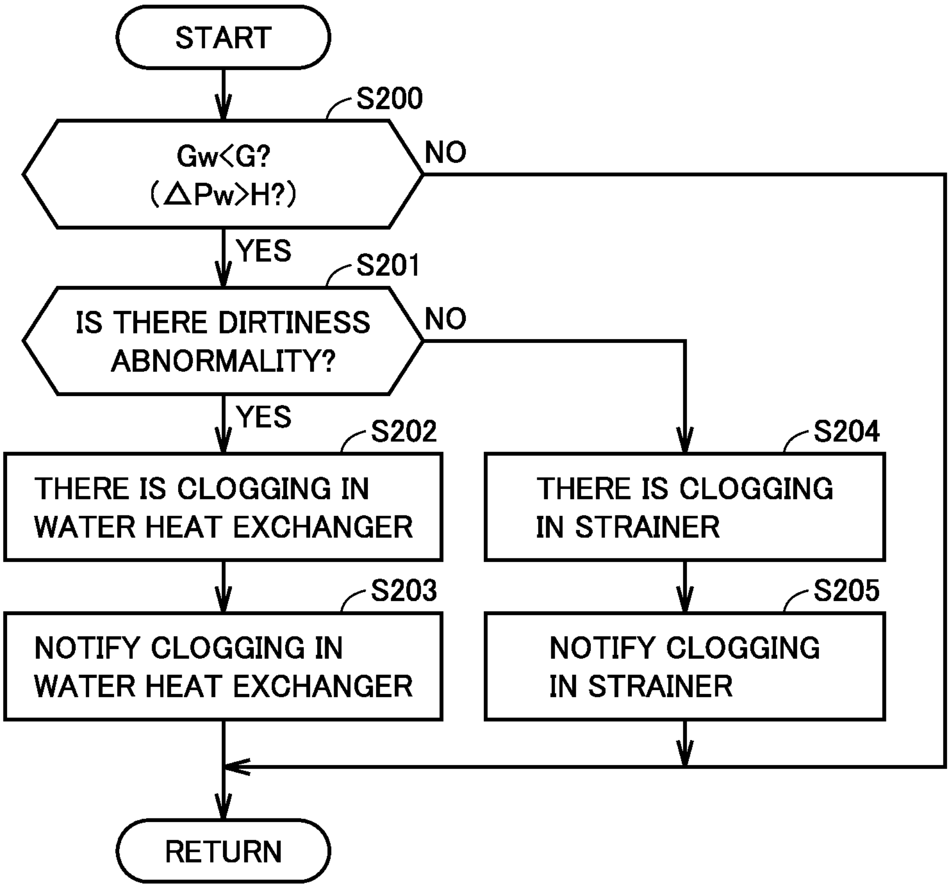

START
S200
Gw<G?
(ΔPw>H?)
NO
YES
S201
IS THERE DIRTINESS ABNORMALITY?
NO
YES
S202
THERE IS CLOGGING IN WATER HEAT EXCHANGER
S204
THERE IS CLOGGING IN STRAINER
S203
NOTIFY CLOGGING IN WATER HEAT EXCHANGER
S205
NOTIFY CLOGGING IN STRAINER
RETURN

FIG.6

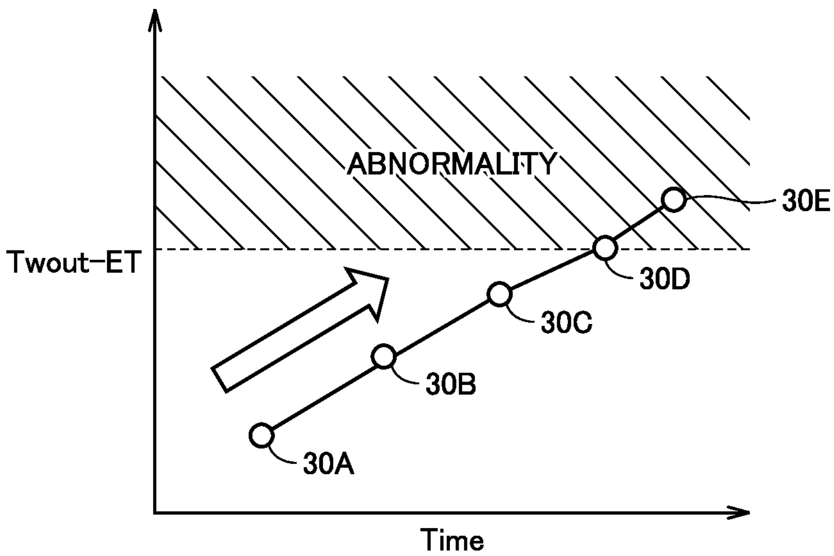


FIG.7

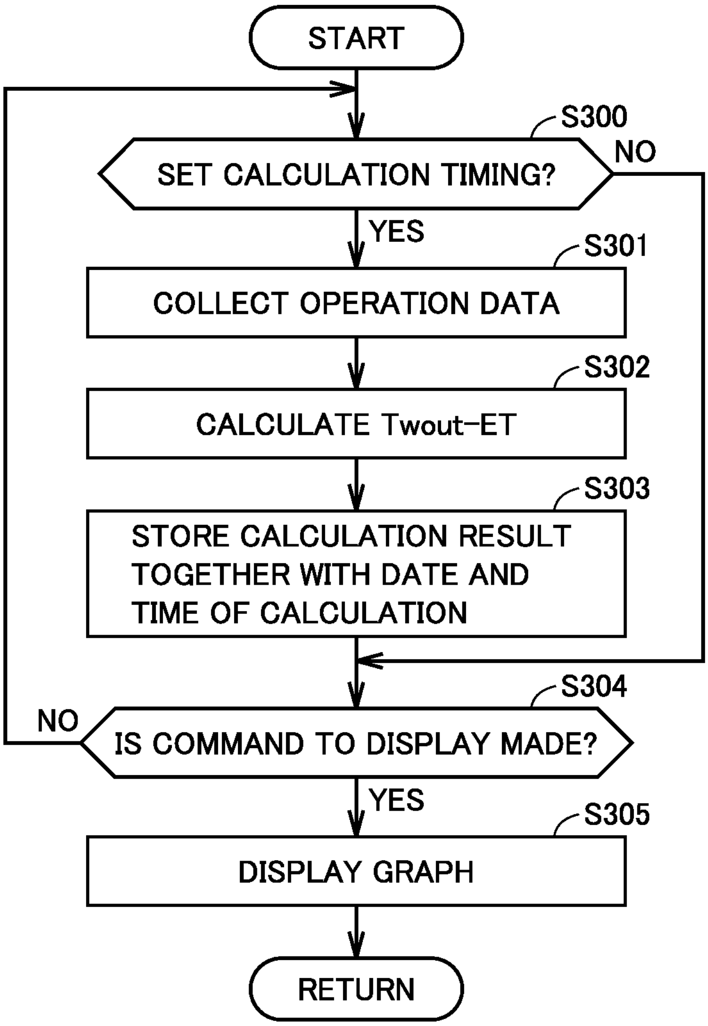

START
S300
SET CALCULATION TIMING?
NO
YES
S301
COLLECT OPERATION DATA
S302
CALCULATE Twout-ET
S303
STORE CALCULATION RESULT TOGETHER WITH DATE AND TIME OF CALCULATION
S304
NO
IS COMMAND TO DISPLAY MADE?
YES
S305
DISPLAY GRAPH
RETURN

FIG.8

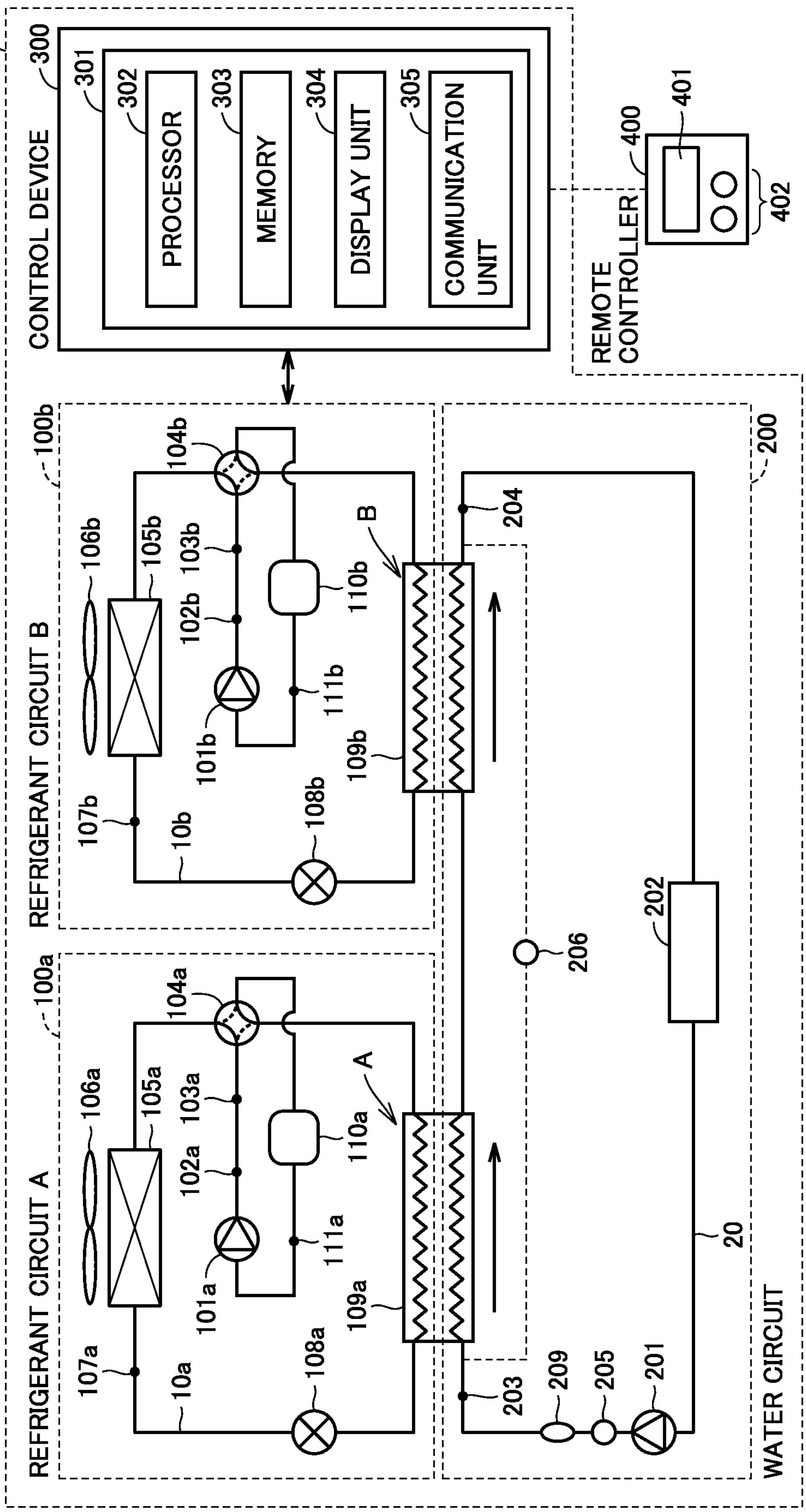

2
CONTROL DEVICE
300
301
302
PROCESSOR
303
MEMORY
304
DISPLAY UNIT
305
COMMUNICATION UNIT
REMOTE CONTROLLER
400
401
402
REFRIGERANT CIRCUIT B
100b
106b
105b
103b
104b
102b
101b
110b
111b
107b
10b
108b
109b
B
REFRIGERANT CIRCUIT A
100a
106a
105a
103a
104a
102a
101a
110a
111a
107a
10a
108a
109a
A
WATER CIRCUIT
200
204
206
202
203
209
205
201
20

FIG.9

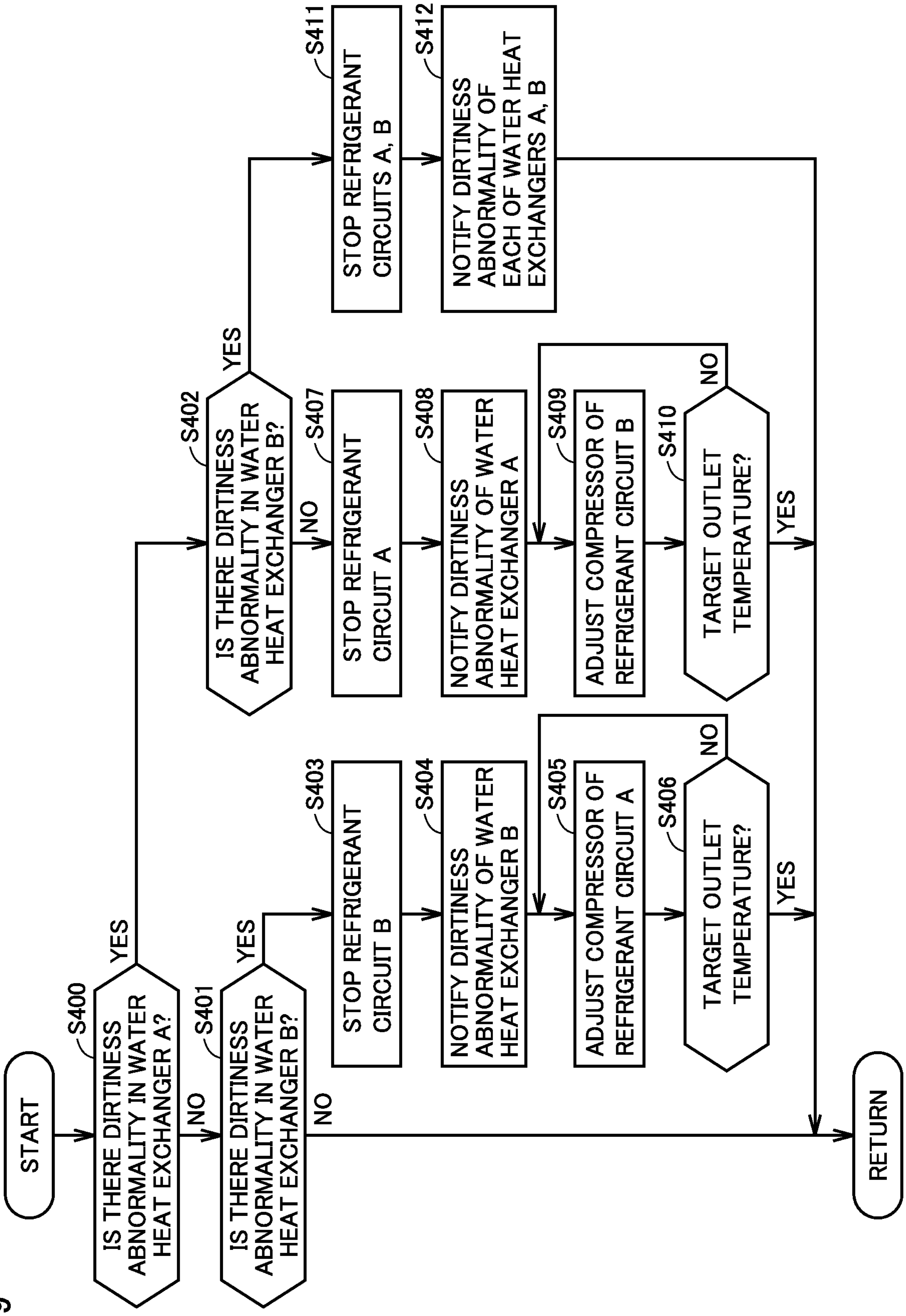

START
S400
IS THERE DIRTINESS ABNORMALITY IN WATER HEAT EXCHANGER A?
YES
NO
S401
IS THERE DIRTINESS ABNORMALITY IN WATER HEAT EXCHANGER B?
YES
NO
S402
IS THERE DIRTINESS ABNORMALITY IN WATER HEAT EXCHANGER B?
YES
NO
S403
STOP REFRIGERANT CIRCUIT B
S404
NOTIFY DIRTINESS ABNORMALITY OF WATER HEAT EXCHANGER B
S405
ADJUST COMPRESSOR OF REFRIGERANT CIRCUIT A
S406
TARGET OUTLET TEMPERATURE?
YES
NO
S407
STOP REFRIGERANT CIRCUIT A
S408
NOTIFY DIRTINESS ABNORMALITY OF WATER HEAT EXCHANGER A
S409
ADJUST COMPRESSOR OF REFRIGERANT CIRCUIT B
S410
TARGET OUTLET TEMPERATURE?
YES
NO
S411
STOP REFRIGERANT CIRCUITS A, B
S412
NOTIFY DIRTINESS ABNORMALITY OF EACH OF WATER HEAT EXCHANGERS A, B
RETURN

FIG.10

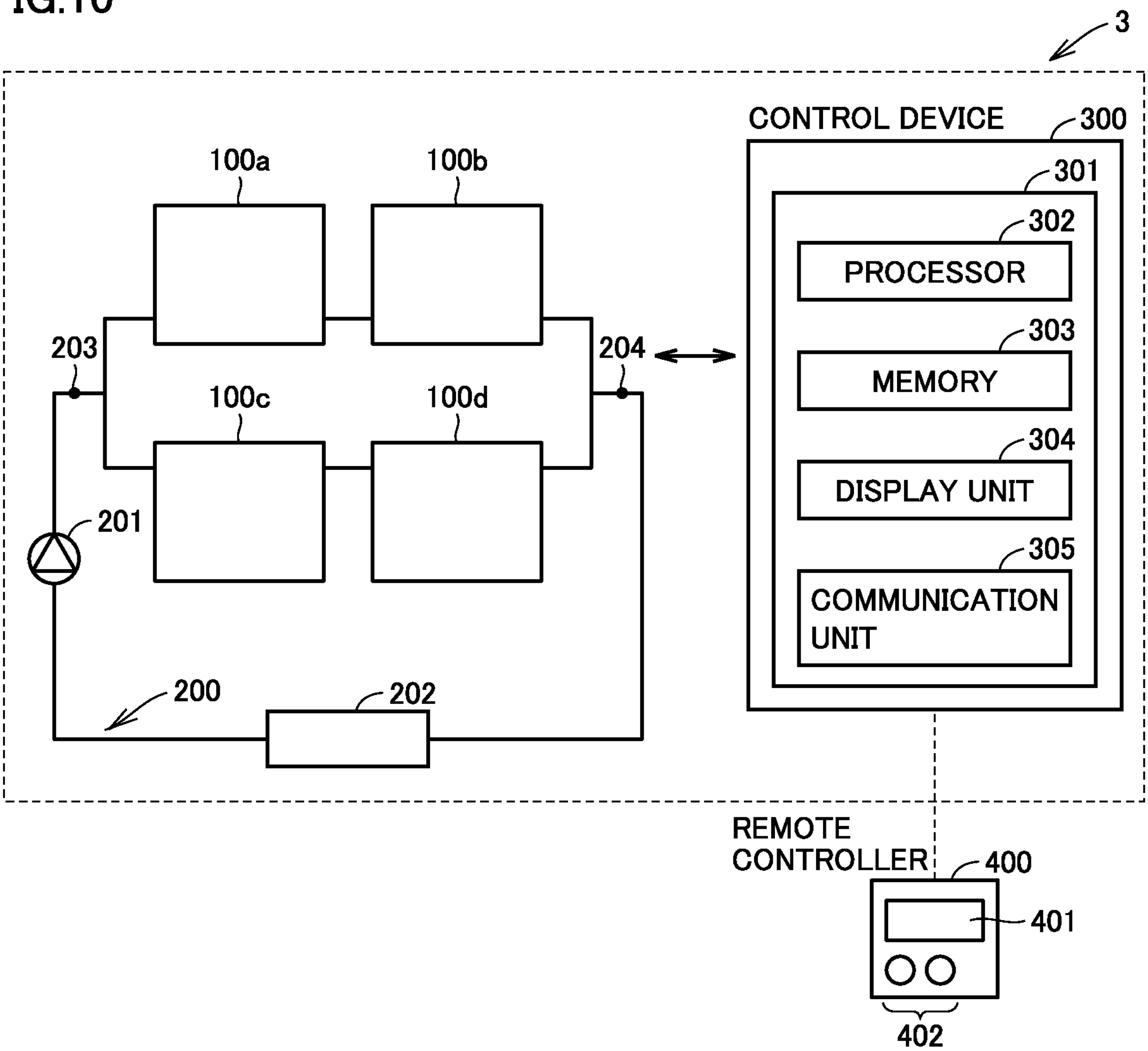
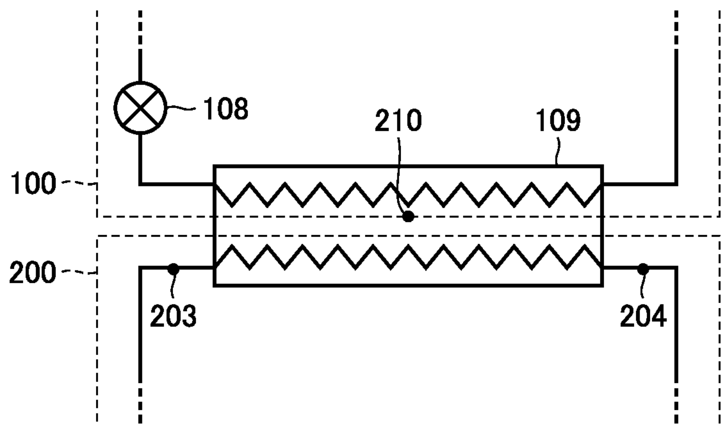

3
CONTROL DEVICE
300
301
302
PROCESSOR
303
MEMORY
304
DISPLAY UNIT
305
COMMUNICATION UNIT
100a
100b
100c
100d
203
204
201
200
202
REMOTE CONTROLLER
400
401
402

FIG.11



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2020/022734

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F25B49/02(2006.01)i, F25B1/00(2006.01)i
FI: F25B1/00 399Y, F25B49/02 510Z, F25B49/02 520M, F25B49/02 570Z, F25B1/00 361A
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)
Int. Cl. F25B49/02, F25B1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2020
Registered utility model specifications of Japan 1996-2020
Published registered utility model applications of Japan 1994-2020

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.
X Y A	JP 2012-159251 A (MITSUBISHI ELECTRIC CORP.) 23 August 2012, paragraphs [0011]-[0144], fig. 1-14, paragraphs [0011]-[0144], fig. 1-14, paragraphs [0011]-[0144], fig. 1-14	1-3, 8, 14-17 4-7, 9, 11-13, 16-18 10
X Y A	JP 2012-083084 A (MITSUBISHI ELECTRIC CORP.) 26 April 2012, paragraphs [0014]-[0082], fig. 1-8, paragraphs [0014]-[0082], fig. 1-8, paragraphs [0014]-[0082], fig. 1-8	1-3, 8, 11, 14-15 4-7, 9, 11-13, 16-18 10
Y	JP 2019-060602 A (MITSUBISHI ELECTRIC CORP.) 18 April 2019, paragraphs [0109]-[0145], fig. 10	4-7

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
05.08.2020	18.08.2020

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/022734

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2018/186106 A1 (DENSO CORP.) 11 October 2018, paragraphs [0035], [0060], [0061], fig. 2, 4	6-7
Y	WO 2017/145218 A1 (MITSUBISHI ELECTRIC CORP.) 31 August 2017, paragraphs [0010]-[0015], [0044]-[0048], fig. 1	9
Y	WO 2013/038577 A1 (MITSUBISHI ELECTRIC CORP.) 21 March 2013, paragraphs [0023]-[0034], fig. 5-7	12-13
Y	JP 2019-152347 A (OSAKA GAS CO., LTD.) 12 September 2019, paragraphs [0024], [0034], fig. 1	18

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/022734

Patent Documents referred to in the Report	Publication Date	Patent Family	Publication Date
JP 2012-159251 A	23.08.2012	(Family: none)	
JP 2012-083084 A	26.04.2012	US 2013/0167567 A1 paragraphs [0023]-[0104], fig. 1-8 WO 2012/049820 A1 EP 2629025 A1 CN 103154625 A	
JP 2019-060602 A	18.04.2019	(Family: none)	
WO 2018/186106 A1	11.10.2018	JP 2018-179488 A CN 110382980 A	
WO 2017/145218 A1	31.08.2017	GB 2562654 A paragraphs [0010]-[0015], [0044]-[0048], fig. 1	
WO 2013/038577 A1	21.03.2013	US 2014/0196483 A1 paragraphs [0057]-[0092], fig. 5-7 EP 2759787 A1 CN 103797317 A	
JP 2019-152347 A	12.09.2019	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003050067 A **[0004]**