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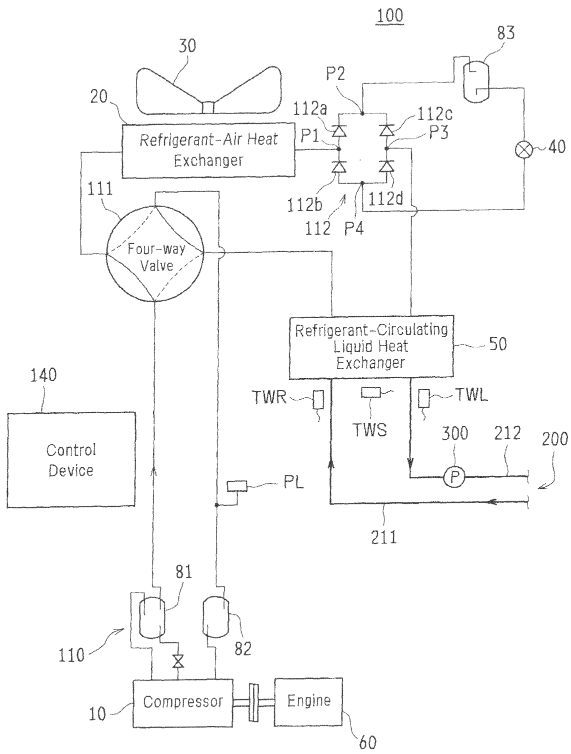
(54) **HEAT PUMP TYPE CHILLER**

(57) A heat pump type chiller (100) includes a compressor (10), a refrigerant-air heat exchanger (20), an expansion valve (40), and a refrigerant-circulating liquid heat exchanger (50) and cools a circulating liquid by heat exchange between the circulating liquid and a refrigerant. Temperature sensors (TWR, TWL, TWS) are provided respectively at a circulating liquid inlet port, at a circulating liquid outlet port, and on a surface portion of the refrigerant-circulating liquid heat exchanger (50). A pressure sensor (PL) is provided in a refrigerant suction path of the compressor (10). If it is detected that any one of temperatures detected by the three temperature sensors (TWR, TWL, TWS) and a refrigerant evaporation temperature calculated by converting a pressure detected by the pressure sensor (PL) is less than or equal to a predetermined temperature, the compressor (10) is stopped, and a circulation pump (300) for circulating the circulating liquid is activated.

FIG.1



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Description

Technical Field

[0001] The present invention relates to heat pump type chillers for cooling a liquid to be cooled, by heat exchange with a refrigerant circulated in a refrigeration cycle.

Background Art

[0002] Patent Document 1 discloses, as a conventional heat pump type chiller, a configuration shown in FIG. 9, which is intended to prevent freezing in the chiller including a refrigerating machine. The chiller of Patent Document 1 implements a refrigeration cycle using a compressor 501, a condenser 502, an expansion valve 503, and an evaporator 504 in order to cool a liquid to be cooled, by heat exchange with a refrigerant circulated in the cycle.

[0003] In the chiller of Patent Document 1, there is provided a liquid electromagnetic valve 505 on the primary side of the expansion valve 503. A first temperature sensor 506 monitors temperature on the primary side of the liquid electromagnetic valve 505 at start-up. If the temperature detected by the first temperature sensor 506 is less than or equal to a first specified value, a bypass valve 507 is opened with the liquid electromagnetic valve 505 closed so that the refrigerant exhausted from the compressor 501 can bypass the condenser 502 and the expansion valve 503, reaching the secondary side of the expansion valve 503. This bypassing of the refrigerant prohibits the refrigerant from circulating in the refrigeration cycle, thereby preventing the circulating water (liquid to be cooled) supplied from a cold water tank 510 from freezing in the evaporator (heat exchanger) 504.

Citation List

Patent Document

[0004] Patent Document 1: JP 5098472 B

Summary of Invention

Technical Problem

[0005] However, in the configuration of Patent Document 1 described above, the temperature on the primary side of the liquid electromagnetic valve 505 rises in steady-state operation. It is therefore difficult to borrow the above-described technique to prevent freezing during operation.

[0006] The present invention has an object to provide a heat pump type chiller capable of preventing a liquid to be cooled from freezing from start-up throughout operation thereof.

Solution to Problem

[0007] To achieve this object, the present invention is directed to a heat pump type chiller including: a compressor for sucking and exhausting a refrigerant; a refrigerant-air heat exchanger; an expansion valve; a refrigerant-circulating liquid heat exchanger for exchanging heat between a circulating liquid and the refrigerant; and a circulation pump provided in a flow path for the circulating liquid, the heat pump type chiller further including: a temperature sensor provided at a circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger; a temperature sensor provided at a circulating liquid outlet port of the refrigerant-circulating liquid heat exchanger; a temperature sensor provided on a surface portion of the refrigerant-circulating liquid heat exchanger; and a pressure sensor provided in a refrigerant suction path of the compressor, wherein when it is detected that any one of temperatures detected by the three temperature sensors and a refrigerant evaporation temperature calculated by converting a pressure detected by the pressure sensor is less than or equal to a predetermined temperature, the compressor is stopped, and the circulation pump is activated.

[0008] According to this configuration, temperatures that correspond to circulating liquid temperature are monitored. The configuration can therefore prevent freezing of the circulating liquid throughout the chiller's operation period.

[0009] The heat pump type chiller may be configured so that a plurality of controllers receives sensing signals from the three temperature sensors and the pressure sensor in a distributed manner.

[0010] According to this configuration, sensor signals are received by a plurality of controllers in a distributed manner. The configuration therefore allows for reducing risks in the occurrence of a controller malfunction.

[0011] The heat pump type chiller may be configured so that a first controller receives signals from the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the pressure sensor provided in the refrigerant suction path of the compressor, and a second controller receives signals from the temperature sensors provided at the circulating liquid outlet port and on the surface portion of the refrigerant-circulating liquid heat exchanger, wherein the first controller has a function to detect an abnormality in a received signal per se, wherein at start-up of the chiller, the circulation pump is activated before the compressor is driven, wherein when it is detected, before the compressor starts to be driven after activation of the circulation pump, either that a temperature difference between the temperature detected by the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the temperature detected by the temperature sensor provided at the circulating liquid outlet port of the refrigerant-circulating liquid heat exchanger has an absolute value greater than or equal to a first predetermined value or that a temperature difference between the temperature detected by the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the temperature detected by the temperature sensor provided on the surface portion of the refrigerant-circulating liquid heat exchanger has an absolute value greater than or equal to a second predetermined value that is greater than the first predetermined value, the compressor stops being driven.

[0012] According to this configuration, the temperature sensors can be checked for malfunctions before the compressor is driven. The configuration therefore improves the reliability of freeze-preventing detection.

[0013] The heat pump type chiller may be configured so that a first controller receives signals from the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the pressure sensor provided in the refrigerant suction path of the compressor, and a second controller receives signals from the temperature sensors provided at the circulating liquid outlet port and on the surface portion of the refrigerant-circulating liquid heat exchanger, wherein the heat pump type chiller further includes: a first connection relay provided between the circulation pump and a power supply, the first connection relay opened and closed by the first controller, and a second connection relay provided between the circulation pump and the power supply, the second connection relay opened and closed by the second controller, the first connection relay and the second connection relay provided in parallel with each other.

[0014] According to this configuration, power can be delivered from any one of the controllers (the first controller and the second controller) to the circulation pump. The configuration improves operational safety of the circulation pump in the occurrence of a controller malfunction.

Advantageous Effects of Invention

[0015] A heat pump type chiller of the present invention includes temperature sensors provided respectively at a circulating liquid inlet port, at a circulating liquid outlet port, and on a surface portion of a refrigerant-circulating liquid heat exchanger and also a pressure sensor provided in a refrigerant suction path of a compressor. When it is detected that any one of temperatures detected by the three temperature sensors and a refrigerant evaporation temperature calculated by converting a pressure detected by the pressure sensor is less than or equal to a predetermined temperature, the compressor is stopped, and the circulation pump is activated.

[0016] This configuration allows monitoring of temperatures that correspond to circulating liquid temperature and thus enables circulating liquid freezing prevention control to be performed based on these temperatures. The configuration can hence advantageously prevent freezing of a circulating liquid throughout the chiller's operation period.

Brief Description of Drawings

[0017]

[FIG. 1] FIG. 1 is a schematic block diagram of a configuration of a heat pump type chiller in accordance with the present embodiment.

[FIG. 2] FIG. 2 is a block diagram of a control system that performs circulating liquid freezing prevention control in the heat pump type chiller in accordance with the present embodiment.

[FIG. 3] FIG. 3 is a diagram illustrating freezing prevention control in the control system shown in FIG. 2 in normal operation.

[FIG. 4] FIG. 4 is a diagram illustrating freezing prevention control in the control system shown in FIG. 2 when a main CPU malfunctions.

[FIG. 5] FIG. 5 is a diagram illustrating freezing prevention control in the control system shown in FIG. 2 when a sensor input to the main CPU is abnormal.

[FIG. 6] FIG. 6 is a diagram illustrating how freezing prevention control works in the control system shown in FIG. 2 when a sub-CPU malfunctions.

[FIG. 7] FIG. 7 is a diagram illustrating freezing prevention control in the control system shown in FIG. 2 when a sensor input to the sub-CPU is abnormal.

[FIG. 8] FIG. 8 a flow chart depicting a sensor malfunction detection operation in the heat pump type chiller in accordance with the present embodiment.

[FIG. 9] FIG. 9 is a schematic block diagram of a configuration of a conventional heat pump type chiller.

Description of Embodiments

[0018] The following will describe embodiments of the present invention in reference to drawings. FIG. 1 is a schematic block diagram of a configuration of a heat pump type chiller (hereinafter, referred to simply as a "chiller") 100 in accordance with the present embodiment. The chiller 100 broadly includes a refrigerant circuit 110 that distributes a refrigerant and a circulating liquid circuit 200 that distributes a circulating liquid. A control device 140 controls all operations of the chiller 100.

[0019] The refrigerant circuit 110 includes a compressor 10, a refrigerant-air heat exchanger 20, an expansion valve 40, and a refrigerant-circulating liquid heat exchanger 50. The chiller 100 implements a refrigeration cycle by circulating the refrigerant through the compressor 10, the refrigerant-air heat exchanger 20, the expansion valve 40, and the refrigerant-circulating liquid heat exchanger 50 in this order. The chiller 100 cools the circulating liquid by heat exchange between the circulating liquid and the refrigerant in the refrigerant-circulating liquid heat exchanger 50 (cooling operation).

[0020] In the refrigerant circuit 110, the compressor 10 sucks and compresses the refrigerant and then exhausts the compressed refrigerant. The refrigerant-air heat exchanger 20 exchanges heat between the refrigerant and air (specifically, outside air). The expansion valve 40 enables the refrigerant compressed by the compressor 10 to expand. The refrigerant-circulating liquid heat exchanger 50 exchanges heat between the circulating liquid and the refrigerant. The compressor 10 may include a plurality of parallel-connected compressors. Likewise, the refrigerant-air heat exchanger 20 may include a plurality of parallel-connected refrigerant-air heat exchangers.

[0021] The expansion valve 40 can adjust the opening degree thereof in response to an instruction signal from the control device 140. The expansion valve 40 can thus adjust the amount of circulation of the refrigerant in the refrigerant circuit 110. The expansion valve 40, described in more detail, includes a plurality of parallel-connected expansion valves each capable of being closed. This structure enables the expansion valve 40 to adjust the amount of circulation of the refrigerant in the refrigerant circuit 110 by means of a combination of open expansion valves.

[0022] In the chiller 100 shown in FIG. 1, a refrigerant-air heat exchanger fan 30 is provided for efficient heat exchange in the refrigerant-air heat exchanger 20. An engine 60 is provided as a driving power source for driving the compressor 10. It should be understood that in the present invention, the driving power source for driving the compressor 10 is not necessarily an engine and may be another kind of driving power source (e.g., an electric motor).

[0023] The chiller 100 in accordance with the present embodiment is configured to be capable of performing heating operation as well as performing the cooling operation. The chiller 100 therefore includes a four-way valve 111 on the refrigerant exhausting side of the compressor 10. The chiller 100 also includes a bridge circuit 112.

[0024] The four-way valve 111 switches the flow direction of the refrigerant in response to instruction signals from the control device 140, depending on whether the chiller 100 is in the cooling operation or in the heating operation. Namely, in the cooling operation, the four-way valve 111 connects an inlet port (bottom port in FIG. 1) to a first connection port (left port in FIG. 1) and connects a second connection port (right port in FIG. 1) to an outlet port (top port in FIG. 1), thereby forming solid-line passages shown in FIG. 1. On the other hand, in the heating operation, the four-way valve 111 connects the inlet port (bottom port in FIG. 1) to the second connection port (right port in FIG. 1) and connects the first connection port (left port in FIG. 1) to the outlet port (top port in FIG. 1), thereby forming broken-line passages shown in FIG. 1.

[0025] The flow direction of the refrigerant in the bridge circuit 112 is automatically switched depending on whether the chiller 100 is in the cooling operation or in the heating operation. The bridge circuit 112 includes four check valves: a first check valve 112a, a second check valve 112b, a third check valve 112c, and a fourth check valve 112d. The first check valve 112a and the second check valve 112b are connected in series with each other so that the refrigerant can flow in the same direction through both valves 112a and 112b, thereby forming a first check valve array. The third check valve 112c and the fourth check valve 112d are connected in series with each other so that the refrigerant can flow in the same direction through both valves 112c and 112d, thereby forming a second check valve array. The first check valve array and the second check valve array are connected in parallel with each other so that the refrigerant can flow in the same direction through both arrays.

[0026] In the bridge circuit 112, a connection point between the first check valve 112a and the second check valve 112b provides a first middle connection point P1, a connection point between the first check valve 112a and the third check valve 112c provides an outflow connection point P2, a connection point between the third check valve 112c and the fourth check valve 112d provides a second middle connection point P3, and a connection point between the second check valve 112b and the fourth check valve 112d provides an inflow connection point P4.

[0027] When the chiller 100 is in the cooling operation, the refrigerant flows from the compressor 10 through the four-way valve 111, the refrigerant-air heat exchanger 20, the bridge circuit 112 (from P1 to P2), the expansion valve 40, the bridge circuit 112 (from P4 to P3), the refrigerant-circulating liquid heat exchanger 50, and the four-way valve 111 then back to the compressor 10, which completes the refrigeration cycle. On the other hand, when the chiller 100 is in the heating operation, the refrigerant flows from the compressor 10 through the four-way valve 111, the refrigerant-circulating liquid heat exchanger 50, the bridge circuit 112 (from P3 to P2), the expansion valve 40, the bridge circuit 112 (from P4 to P1), the refrigerant-air heat exchanger 20, and the four-way valve 111 then back to the compressor 10, which completes a heating cycle.

[0028] In the present embodiment, the chiller 100 further includes an oil separator 81, an accumulator 82, and a receiver 83. The oil separator 81 separates lubrication oil for the compressor 10 from the refrigerant to feed the separated lubrication oil back to the compressor 10. The accumulator 82 separates out the refrigerant that does not evaporate and thus remains in liquid form in the refrigerant-circulating liquid heat exchanger 50 and the refrigerant-air heat exchanger 20, both heat exchangers effectively operating as an evaporator. The receiver 83 temporarily stores the high pressure liquid refrigerant fed from the bridge circuit 112.

[0029] Since the chiller 100 in accordance with the present embodiment includes the four-way valve 111 and the bridge circuit 112, the chiller 100 is capable of switching between the cooling operation and the heating operation. The present invention is however characterized by the cooling operation. Therefore, the present invention is also applicable to chillers capable of only performing cooling operation.

[0030] The circulating liquid circuit 200 is described next. The circulating liquid flowing in the circulating liquid circuit 200, in the cooling operation, acts as the liquid to be cooled by heat exchange in the refrigerant-circulating liquid heat exchanger 50 and in the heating operation, acts as a liquid to be heated by heat exchange in the refrigerant-circulating liquid heat exchanger 50. This circulating liquid is used as cold water or warm water, for example, in an air conditioning system for buildings. The circulating liquid is, for example, water, which by no means is limiting the present invention; alternatively, the circulating liquid may be an aqueous solution of, for example, antifreeze.

[0031] The circulating liquid circuit 200 includes an inflow tube 211, an outflow tube 212, and a circulation pump 300. The circulating liquid is introduced to the refrigerant-circulating liquid heat exchanger 50 via the inflow tube 211 and adjusted in temperature in the refrigerant-circulating liquid heat exchanger 50. The temperature-adjusted circulating liquid is discharged from the chiller 100 via the outflow tube 212. Note that the circulating liquid circuit 200, constituting a part of the chiller 100, basically forms only a part of a closed circuit in which the circulating liquid flows. Namely, in those cases where the chiller 100 in accordance with the present embodiment is used in an air conditioning system for a building, the circulating liquid circuit 200 in the chiller 100 is connected to a circulating liquid circuit in the air conditioning system to form a closed circuit in which the circulating liquid flows. The circulation pump 300 is a pump for circulating the circulating liquid in this closed circuit. The circulation pump 300, in the configuration shown in FIG. 1, is provided in the outflow tube 212 and may alternatively be provided in the inflow tube 211.

[0032] The chiller 100 in accordance with the present embodiment includes an inflow circulating liquid temperature sensor TWR, an outflow circulating liquid temperature sensor TWL, a heat exchanger surface temperature sensor TWS, and a pressure sensor PL in order to prevent freezing of the circulating liquid in the cooling operation.

[0033] The inflow circulating liquid temperature sensor TWR is provided in the inflow tube 211 to detect the temperature of the circulating liquid flowing into the refrigerant-circulating liquid heat exchanger 50 (specifically, the circulating liquid in the inflow tube 211). The outflow circulating liquid temperature sensor TWL is provided in the outflow tube 212 to detect the temperature of the circulating liquid flowing out of the refrigerant-circulating liquid heat exchanger 50 (specifically, the circulating liquid in the outflow tube 212). The heat exchanger surface temperature sensor TWS is provided on a surface of the refrigerant-circulating liquid heat exchanger 50 to detect the surface temperature thereof. The pressure sensor PL is provided in a refrigerant suction path of the compressor 10 to detect the pressure of the refrigerant flowing out of the refrigerant-circulating liquid heat exchanger 50. The temperature at which the refrigerant flowing out of the refrigerant-circulating liquid heat exchanger 50 evaporates ("refrigerant evaporation temperature") is determined from the pressure detected by the pressure sensor PL.

[0034] The control device 140 performs the following control processes based on sensing signals from various sensors in order to prevent freezing of the circulating liquid in the cooling operation. Specifically, the control device 140 stops the compressor 10 and activates the circulation pump 300 if the control device 140 detects that either the temperature detected by any one of the inflow circulating liquid temperature sensor TWR, the outflow circulating liquid temperature sensor TWL, and the heat exchanger surface temperature sensor TWS or the refrigerant evaporation temperature calculated by converting the pressure detected by the pressure sensor PL is less than or equal to a predetermined temperature (e.g., 2°C).

[0035] In other words, if the control device 140 detects that at least any one of these four temperatures is less than or equal to a predetermined temperature (e.g., 2°C), the control device 140 determines that continuing the cooling operation could result in freezing of the circulating liquid and performs a control process to prevent this from happening. Specifically, the control device 140 stops the refrigeration cycle of the refrigerant circuit 110 by stopping the compressor 10 and renders the circulating liquid in the circulating liquid circuit 200 less likely to freeze by activating the circulation pump 300. This control process is continued until all the four temperatures are greater than or equal to the predetermined temperature. The chiller 100 in accordance with the present embodiment can therefore prevent freezing throughout the chiller's operation period by continuously monitoring temperatures that correspond to the circulating liquid temperature.

[0036] In the chiller 100 in accordance with the present embodiment, the control device 140 preferably includes a plurality of controllers so that the plurality of controllers receives sensing signals from the three temperature sensors and the pressure sensor in a distributed manner. This distributed reception of sensor signals by the plurality of controllers allows for reducing risks in the occurrence of a controller malfunction. The following will describe a configuration for the distributed reception by the controllers in more detail.

[0037] The control device 140 includes a main board 141 and a sub-board 142 as illustrated in FIG. 2. The main board 141 has mounted thereon a main CPU (first controller) 143, whereas the sub-board 142 has mounted thereon a sub-CPU (second controller) 144. The main CPU 143 and the sub-CPU 144 are connected to each other via communications lines 145 to enable communications therebetween.

[0038] In the example shown in FIG. 2, it is supposed that a sensing signal from the outflow circulating liquid temperature sensor TWL and a sensing signal from the pressure sensor PL are inputted to the main CPU 143 and also that a sensing signal from the inflow circulating liquid temperature sensor TWR and a sensing signal from the heat exchanger surface temperature sensor TWS are inputted to the sub-CPU 144.

[0039] Furthermore, the main CPU 143 is capable of controlling a connection relay RY1 (first connection relay) on a power board 146 to supply power to a motor 301. The sub-CPU 144 is capable of controlling a connection relay RY2 (second connection relay) and a connection relay RY (MC) (second connection relay) to supply power to the motor 301. The motor 301 drives the circulation pump 300. The circulation pump 300 is activated when power is supplied to the motor 301. Specifically, the first connection relay (connection relay RY1) opened and closed under the control of the main CPU 143 and the second connection relay (the connection relay RY2 and the connection relay RY (MC)) opened and closed under the control of the sub-CPU 144 are provided in parallel with each other. Power can therefore be delivered from any one of the controllers (the main CPU 143 and the sub-CPU 144) to the motor 301 to activate the circulation pump. This configuration improves operational safety of the circulation pump 300 in the occurrence of a controller malfunction.

[0040] First, how freezing prevention control works in normal operation will be described in reference to FIG. 3. In normal operation, both the main CPU 143 and the sub-CPU 144 operate normally and are fed with normal sensing signals from all of the inflow circulating liquid temperature sensor TWR, the outflow circulating liquid temperature sensor TWL, the heat exchanger surface temperature sensor TWS, and the pressure sensor PL.

[0041] In this situation, the freezing prevention control is performed by the main CPU 143. The main CPU 143 is fed with sensing signals directly from the outflow circulating liquid temperature sensor TWL and the pressure sensor PL and also via the sub-CPU 144 from the inflow circulating liquid temperature sensor TWR and the heat exchanger surface temperature sensor TWS. The main CPU 143 monitors the temperatures detected from these four signals and if one of the temperatures is less than or equal to the predetermined temperature (e.g., 2°C), performs the freezing prevention control.

[0042] More specifically, the main CPU 143 supplies power to the motor 301 by controlling the connection relay RY1, to activate the circulation pump 300. The main CPU 143 also performs control for closing a gas valve GV The gas valve GV in the present example adjusts fuel supply to the engine 60. The engine 60 and the compressor 10 are stopped by closing the gas valve GV Note that closing the gas valve GV is a mere example of control for stopping the compressor 10. The present invention is by no means limited to this example. As another example, the compressor 10 may be driven by an engine in such a manner that when the compressor 10 needs to be stopped before the engine completely starts driving, power supply to the engine starter is stopped. Alternatively, the compressor 10 may be driven by a motor, in which case power supply to the motor is stopped.

[0043] Next, how the freezing prevention control works in the occurrence of a malfunction of the main CPU 143 will be described in reference to FIG. 4. When the main CPU 143 malfunctions, the sensing signals inputted from the outflow circulating liquid temperature sensor TWL and the pressure sensor PL to the main CPU 143 become undetectable. In this situation, if the freezing prevention control is performed based only on the other sensing signals, the freezing prevention control could be inappropriate, and the circulating liquid may therefore freeze. Hence, when the main CPU 143 malfunctions, the sub-CPU 144 performs the freezing prevention control regardless of detection results of the sensors.

[0044] In this situation, the sub-CPU 144 detects the malfunction of the main CPU 143 based on an error that occurs in communications with the main CPU 143. If the sub-CPU 144 detects the malfunction of the main CPU 143, the sub-CPU 144 controls the connection relay RY2 and the connection relay RY (MC) to supply power to the motor 301, which in turn activates the circulation pump 300.

[0045] To stop the compressor 10, the sub-CPU 144 may perform control for closing the gas valve GV Alternatively, an auxiliary CPU 147 may perform that control, which will be described as an example in the following. The auxiliary CPU 147 can detect the malfunction of the main CPU 143 based on an error that occurs in communications with the main CPU 143. If the auxiliary CPU 147 detects the malfunction of the main CPU 143, the auxiliary CPU 147 closes the gas valve GV to stop the compressor 10.

[0046] Next, how the freezing prevention control works when a sensor input to the main CPU 143 is abnormal will be described in reference to FIG. 5. An abnormal sensor input to the main CPU 143 refers to those cases where the outflow circulating liquid temperature sensor TWL or the pressure sensor PL outputs no sensing signals due to a malfunction thereof and those cases where sensing signals from these sensors are not inputted to the main CPU 143 due to a broken signal line. In these cases, if the freezing prevention control is performed based only on incomplete sensor inputs, the freezing prevention control could again be inappropriate, and the circulating liquid may therefore freeze. Hence, the main CPU 143 performs the following freezing prevention control regardless of detection results of the sensors.

[0047] If no sensing signals are inputted from the outflow circulating liquid temperature sensor TWL or the pressure sensor PL to the main CPU 143, the main CPU 143 detects an abnormal sensor input. Upon detecting the abnormal sensor input, the main CPU 143 controls the connection relay RY1 to activate the circulation pump

300 and closes the gas valve GV to stop the compressor 10.

[0048] Next, how the freezing prevention control works in the occurrence of a malfunction of the sub-CPU 144 will be described in reference to FIG. 6. When the sub-CPU 144 malfunctions, the sensing signals inputted from the inflow circulating liquid temperature sensor TWR and the heat exchanger surface temperature sensor TWS to the sub-CPU 144 become undetectable. In this situation, if the freezing prevention control is performed based only on the other sensing signals, the freezing prevention control could be inappropriate, and the circulating liquid may therefore freeze. Hence, when the sub-CPU 144 malfunctions, the main CPU 143 performs the freezing prevention control regardless of detection results of the sensors.

[0049] In this situation, the main CPU 143 detects the malfunction of the sub-CPU 144 based on an error that occurs in communications with the sub-CPU 144. If the main CPU 143 detects the malfunction of the sub-CPU 144, the main CPU 143 controls the connection relay RY1 to activate the circulation pump 300 and closes the gas valve GV to stop the compressor 10.

[0050] Next, how the freezing prevention control works when a sensor input to the sub-CPU 144 is abnormal will be described in reference to FIG. 7. An abnormal sensor input to the sub-CPU 144 refers to those cases where the inflow circulating liquid temperature sensor TWR or the heat exchanger surface temperature sensor TWS outputs no sensing signals due to a malfunction thereof and those cases where sensing signals from these sensors are not inputted to the sub-CPU 144 due to a broken signal line. In these cases, if the freezing prevention control is performed based only on incomplete sensor inputs, the freezing prevention control could again be inappropriate, and the circulating liquid may therefore freeze. Hence, the main CPU 143 performs the following freezing prevention control regardless of detection results of the sensors.

[0051] If the sensing signals from the inflow circulating liquid temperature sensor TWR or the heat exchanger surface temperature sensor TWS are not inputted to the sub-CPU 144, these sensing signals are not inputted to the main CPU 143 either. The main CPU 143 thus detects an abnormal sensor input. Upon detecting the abnormal sensor input, the main CPU 143 controls the connection relay RY1 to activate the circulation pump 300 and closes the gas valve GV to stop the compressor 10.

[0052] In addition, the chiller 100 in accordance with the present embodiment has a function to detect, at the start-up thereof, a malfunction of the inflow circulating liquid temperature sensor TWR, the outflow circulating liquid temperature sensor TWL, the heat exchanger surface temperature sensor TWS, and the pressure sensor PL. This sensor malfunction detection operation will be described in reference to FIG. 8. At the start-up of the chiller 100, the control device 140 performs the process shown in the flow chart of FIG. 8 to detect a sensor malfunction.

[0053] At the start-up of the chiller 100, the control device 140 first performs the malfunction detection on the outflow circulating liquid temperature sensor TWL and the pressure sensor PL (step 1). Specifically, the control device 140 has a self-check function to detect abnormalities in the signals per se received by the main CPU 143 from the outflow circulating liquid temperature sensor TWL and the pressure sensor PL. In this situation, a malfunction of the outflow circulating liquid temperature sensor TWL and the pressure sensor PL are detected by the main CPU 143. This malfunction detection can be done, for example, by checking whether or not the outflow circulating liquid temperature sensor TWL and the pressure sensor PL output any detection signals or whether or not signal values are within a specified range. Specifically, a sensor can be determined to be malfunctioning if the sensor outputs no detection signal or outputs a signal that is outside a specified range. If the outflow circulating liquid temperature sensor TWL and the pressure sensor PL are operating normally (YES in step 1), the process proceeds to step 2. If the outflow circulating liquid temperature sensor TWL or the pressure sensor PL is malfunctioning (YES in step 1), the process proceeds to step 5. The compressor 10 is not driven until the sensor malfunction detection operation is completed.

[0054] In step 2, the control device 140 obtains detection temperatures, one from each of the inflow circulating liquid temperature sensor TWR, the outflow circulating liquid temperature sensor TWL, and the heat exchanger surface temperature sensor TWS.

[0055] Next, the control device 140 determines a difference between the detection temperature obtained from the inflow circulating liquid temperature sensor TWR and the detection temperature obtained from the outflow circulating liquid temperature sensor TWL and then determines whether or not this detection temperature difference has an absolute value greater than or equal to a first predetermined value (e.g., 2.0°C) (step 3). The difference between the detection temperature obtained from the inflow circulating liquid temperature sensor TWR and the detection temperature obtained from the outflow circulating liquid temperature sensor TWL should be almost zero immediately after the start-up of the chiller 100 because the circulating liquid is yet to be cooled or heated. Accordingly, if this detection temperature difference is greater than or equal to the predetermined temperature in step 3 (YES in step 3), it is determined that the inflow circulating liquid temperature sensor TWR is malfunctioning, and the process proceeds to step 5.

[0056] If the detection temperature difference is less than 2.0 in step 3 (NO in step 3), the control device 140 determines a difference between the detection temperature obtained from the outflow circulating liquid temperature sensor TWL and the detection temperature obtained from the heat exchanger surface temperature sensor TWS and then determines whether or not this detection temperature difference has an absolute value greater than or equal to a second predetermined value (> the first predetermined value; for example, 3.0°C) (step 4). If this detection temperature difference is greater than or equal to the predetermined temperature in step 4 (YES in step 4), it is determined that the heat exchanger surface temperature sensor TWS is malfunctioning, and the process proceeds to step 5.

[0057] In step 5, the control device 140 closes the gas valve GV to stop the compressor 10 (i.e., the compressor 10 does not start to be driven), activates the circulation pump 300, and produces an alarm alerting to the sensor malfunction. Meanwhile, if the detection temperature difference is less than the predetermined temperature in step 4 (NO in step 4), the process proceeds to step 6 where the chiller 100 is activated because all the sensors are operating normally.

[0058] The temperature sensors are checked for any malfunctions in this manner before the compressor 10 is driven, which enhances the reliability of the freeze-preventing detection.

[0059] The present invention may be implemented in various forms without departing from its spirit and main features. Therefore, the aforementioned examples are for illustrative purposes only in every respect and should not be subjected to any restrictive interpretations. The scope of the present invention is defined only by the claims and never bound by the specification. Those modifications and variations that may lead to equivalents of claimed elements are all included within the scope of the invention.

[0060] This application hereby claims priority to Patent Application No. 2014-129484 filed in Japan on June 24, 2014, the entire contents of which are hereby incorporated herein by reference.

Reference Signs List

[0061]

10	Compressor
20	Refrigerant-Air Heat Exchanger
30	Refrigerant-Air Heat Exchanger Fan
40	Expansion Valve
50	Refrigerant-Circulating Liquid Heat Exchanger
60	Engine
100	Heat Pump Type Chiller
110	Refrigerant Circuit
140	Control Device
143	Main CPU (First Controller)
144	Sub-CPU (Second Controller)
147	Auxiliary CPU
200	Circulating Liquid Circuit
211	Inflow Tube
212	Outflow Tube
300	Circulation Pump
TWR	Inflow Circulating Liquid Temperature Sensor
TWL	Outflow Circulating Liquid Temperature Sensor
TWS	Heat Exchanger Surface Temperature Sensor
PL	Pressure Sensor
GV	Gas Valve
RY1	Connection Relay (First Connection Relay)
RY2	Connection Relay (Second Connection Relay)
RY (MC)	Connection Relay (Second Connection Relay)

Claims

1. A heat pump type chiller comprising:

   a compressor for sucking and exhausting a refrigerant;
   a refrigerant-air heat exchanger;
   an expansion valve;
   a refrigerant-circulating liquid heat exchanger for exchanging heat between a circulating liquid and the refrigerant; and
   a circulation pump provided in a flow path for the circulating liquid,
   the heat pump type chiller further comprising:

      a temperature sensor provided at a circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger;
      a temperature sensor provided at a circulating liquid outlet port of the refrigerant-circulating liquid heat exchanger;
      a temperature sensor provided on a surface portion of the refrigerant-circulating liquid heat exchanger; and
      a pressure sensor provided in a refrigerant suction path of the compressor,
      wherein when it is detected that any one of temperatures detected by the three temperature sensors and a refrigerant evaporation temperature calculated by converting a pressure detected by the pressure sensor is less than or equal to a predetermined temperature, the compressor is stopped, and the circulation pump is activated.

2. The heat pump type chiller according to claim 1, wherein a plurality of controllers receives sensing signals from the three temperature sensors and the pressure sensor in a distributed manner.

3. The heat pump type chiller according to claim 2, wherein a first controller receives signals from the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the pressure sensor provided in the re-

frigerant suction path of the compressor, and a second controller receives signals from the temperature sensors provided at the circulating liquid outlet port and on the surface portion of the refrigerant-circulating liquid heat exchanger,
wherein the first controller has a function to detect an abnormality in a received signal per se,
wherein at start-up of the chiller, the circulation pump is activated before the compressor is driven,
wherein when it is detected, before the compressor starts to be driven after activation of the circulation pump, either that a temperature difference between the temperature detected by the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the temperature detected by the temperature sensor provided at the circulating liquid outlet port of the refrigerant-circulating liquid heat exchanger has an absolute value greater than or equal to a first predetermined value or that a temperature difference between the temperature detected by the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the temperature detected by the temperature sensor provided on the surface portion of the refrigerant-circulating liquid heat exchanger has an absolute value greater than or equal to a second predetermined value that is greater than the first predetermined value, the compressor stops being driven.

4. The heat pump type chiller according to claim 2, wherein a first controller receives signals from the temperature sensor provided at the circulating liquid inlet port of the refrigerant-circulating liquid heat exchanger and the pressure sensor provided in the refrigerant suction path of the compressor, and a second controller receives signals from the temperature sensors provided at the circulating liquid outlet port and on the surface portion of the refrigerant-circulating liquid heat exchanger,
wherein the heat pump type chiller further comprises:

a first connection relay provided between the circulation pump and a power supply, the first connection relay opened and closed by the first controller, and
a second connection relay provided between the circulation pump and the power supply, the second connection relay opened and closed by the second controller,
the first connection relay and the second connection relay provided in parallel with each other.

FIG.1

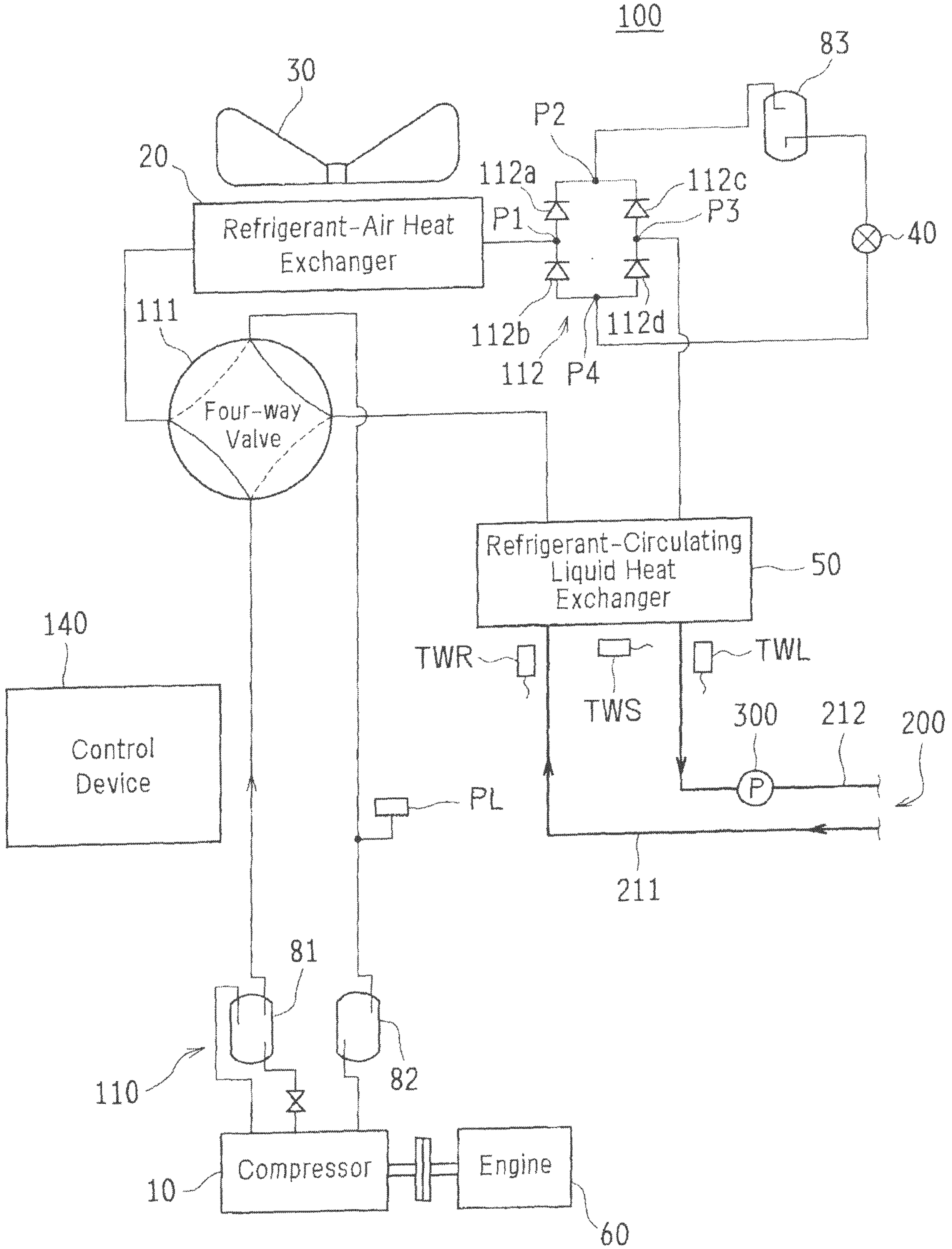
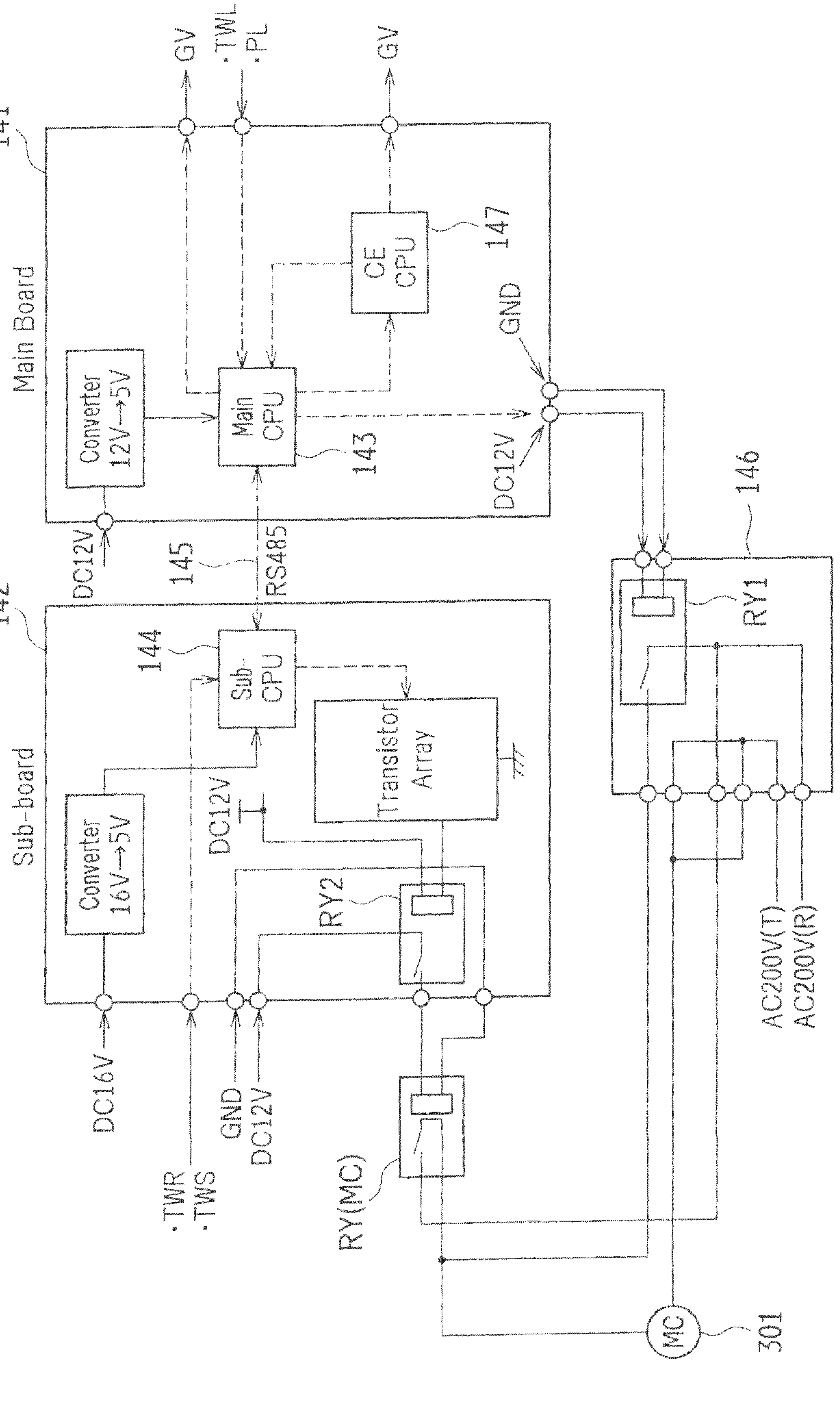
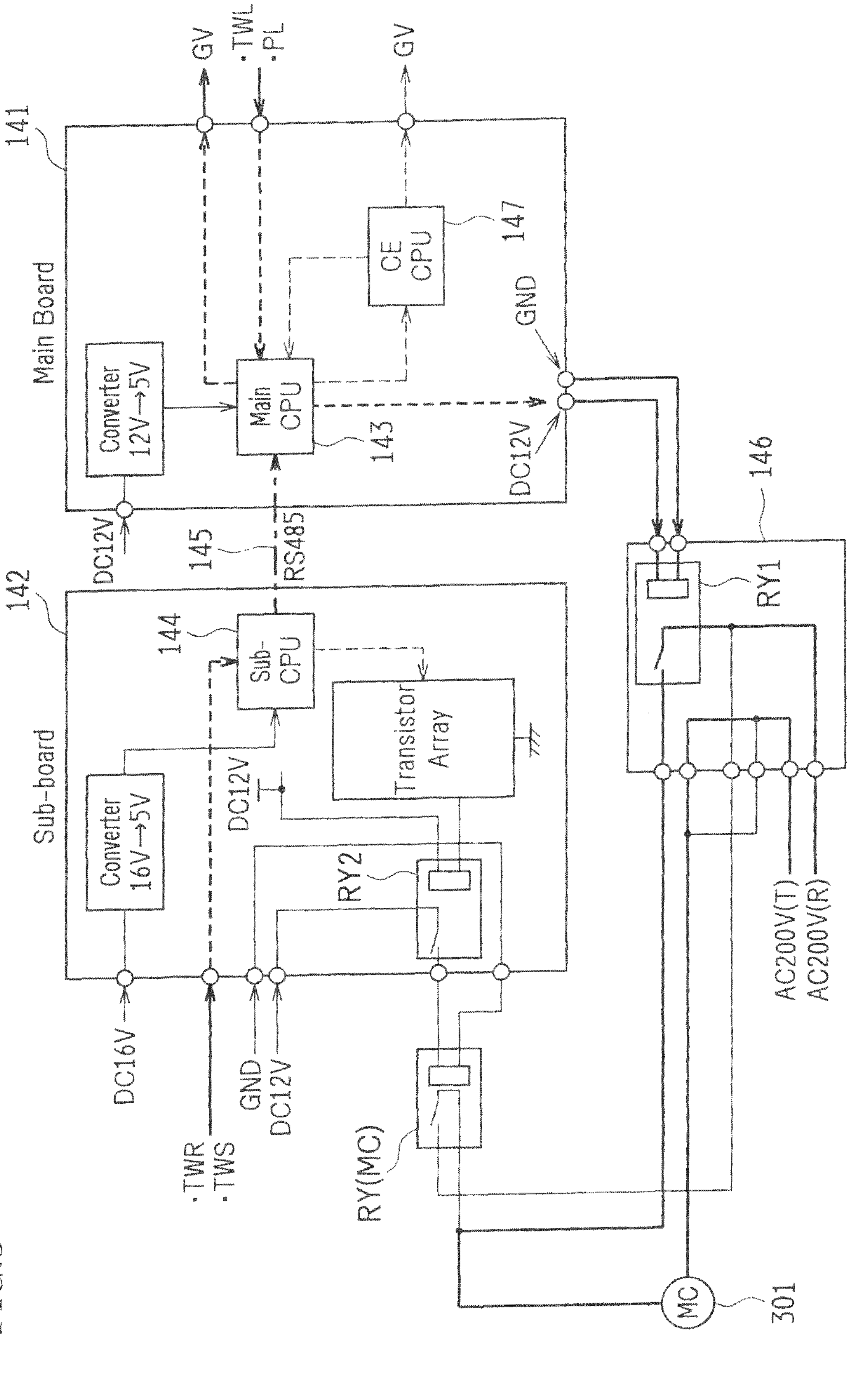

100
83
30
P2
20
112a
112c
Refrigerant-Air Heat Exchanger
P1
P3
40
111
112b
112d
112
P4
Four-way Valve
Refrigerant-Circulating Liquid Heat Exchanger
50
140
TWR
TWS
TWL
300
212
200
P
Control Device
PL
211
81
110
82
Compressor
Engine
10
60

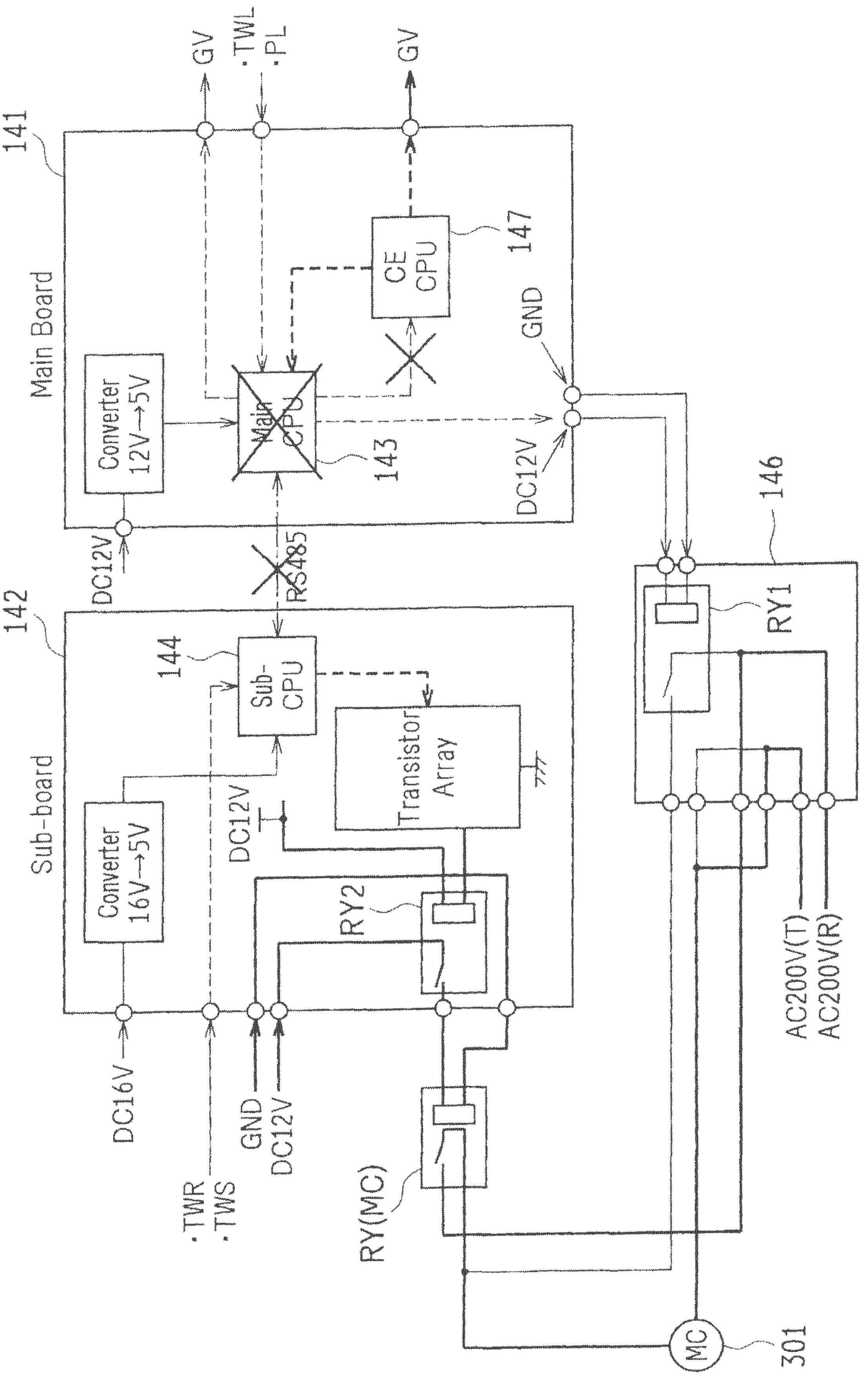
FIG.2


Main Board
141
Converter 12V→5V
Main CPU
143
CE CPU
147
GV
·TWL
·PL
GV
GND
DC12V
DC12V
145
RS485
142
Sub-board
Converter 16V→5V
Sub-CPU
144
Transistor Array
DC12V
RY2
DC16V
·TWR
·TWS
GND
DC12V
RY(MC)
146
RY1
AC200V(T)
AC200V(R)
MC
301



141
Main Board
GV
.TWL
.PL
GV
Converter
12V→5V
Main
CPU
143
CE
CPU
147
GND
DC12V
DC12V
145
RS485
142
Sub-board
144
Sub-
CPU
Converter
16V→5V
Transistor
Array
DC12V
RY2
DC16V
.TWR
.TWS
GND
DC12V
RY(MC)
146
RY1
AC200V(T)
AC200V(R)
MC
301

FIG.3


GV
·TWL
·PL
GV
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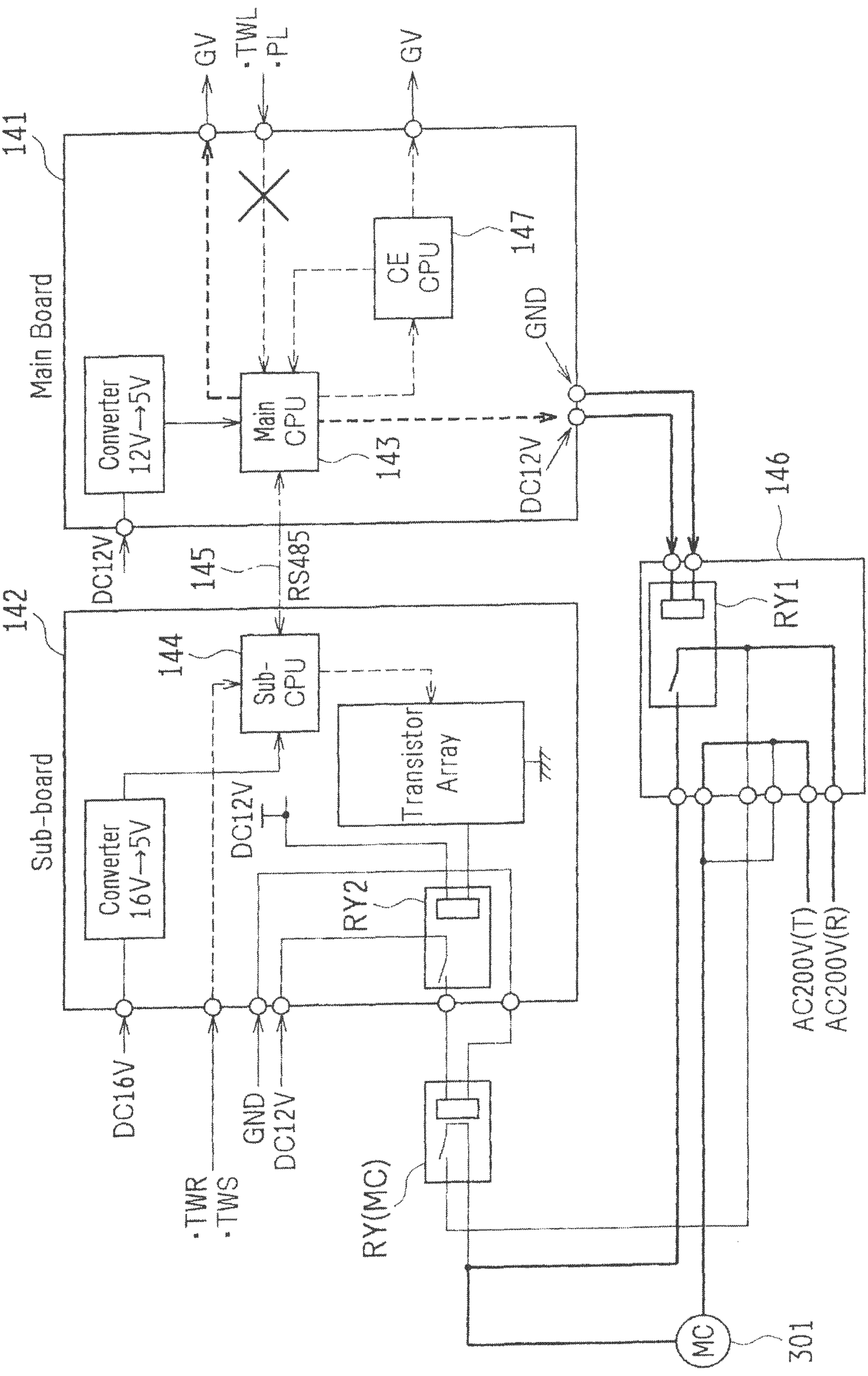
CPU
143
CE
CPU
147
GND
DC12V
DC12V
RS485
142
Sub-board
144
Sub-
CPU
Converter
16V→5V
Transistor
Array
DC12V
RY2
DC16V
·TWR
·TWS
GND
DC12V
RY(MC)
146
RY1
AC200V(T)
AC200V(R)
MC
301

FIG.4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·TWL
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GV
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Main CPU
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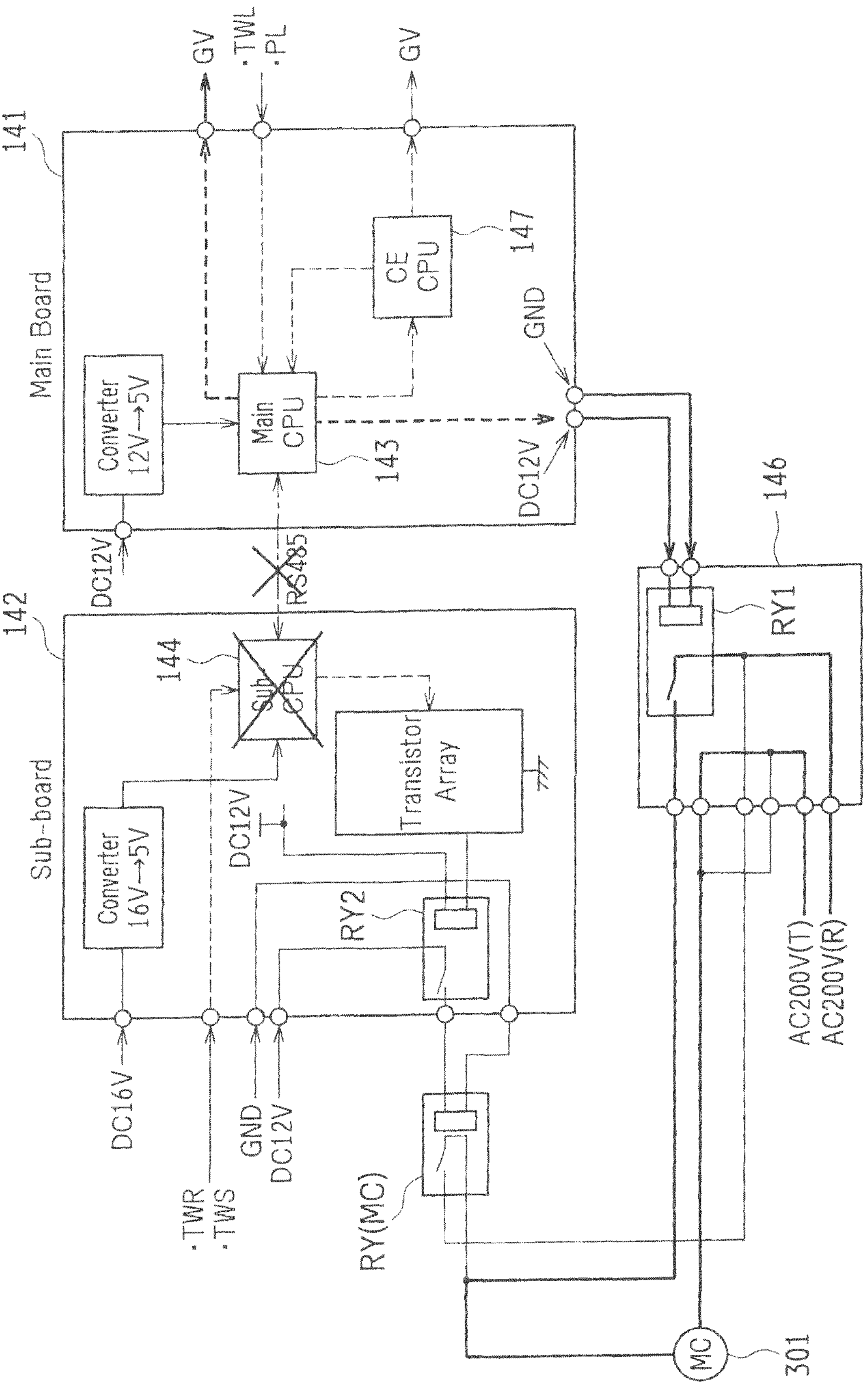
CE CPU
147
GND
DC12V
DC12V
145
RS485
146
RY1
142
Sub-board
144
Sub-CPU
Transistor Array
Converter 16V→5V
DC12V
RY2
DC16V
·TWR
·TWS
GND
DC12V
RY(MC)
AC200V(T)
AC200V(R)
MC
301

FIG.5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.PL
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GND
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DC12V
RS485
142
Sub-board
Converter 16V→5V
144
Sub CPU
Transistor Array
DC12V
RY2
DC16V
.TWR
.TWS
GND
DC12V
RY(MC)
146
RY1
AC200V(T)
AC200V(R)
MC
301

FIG.6

FIG.7

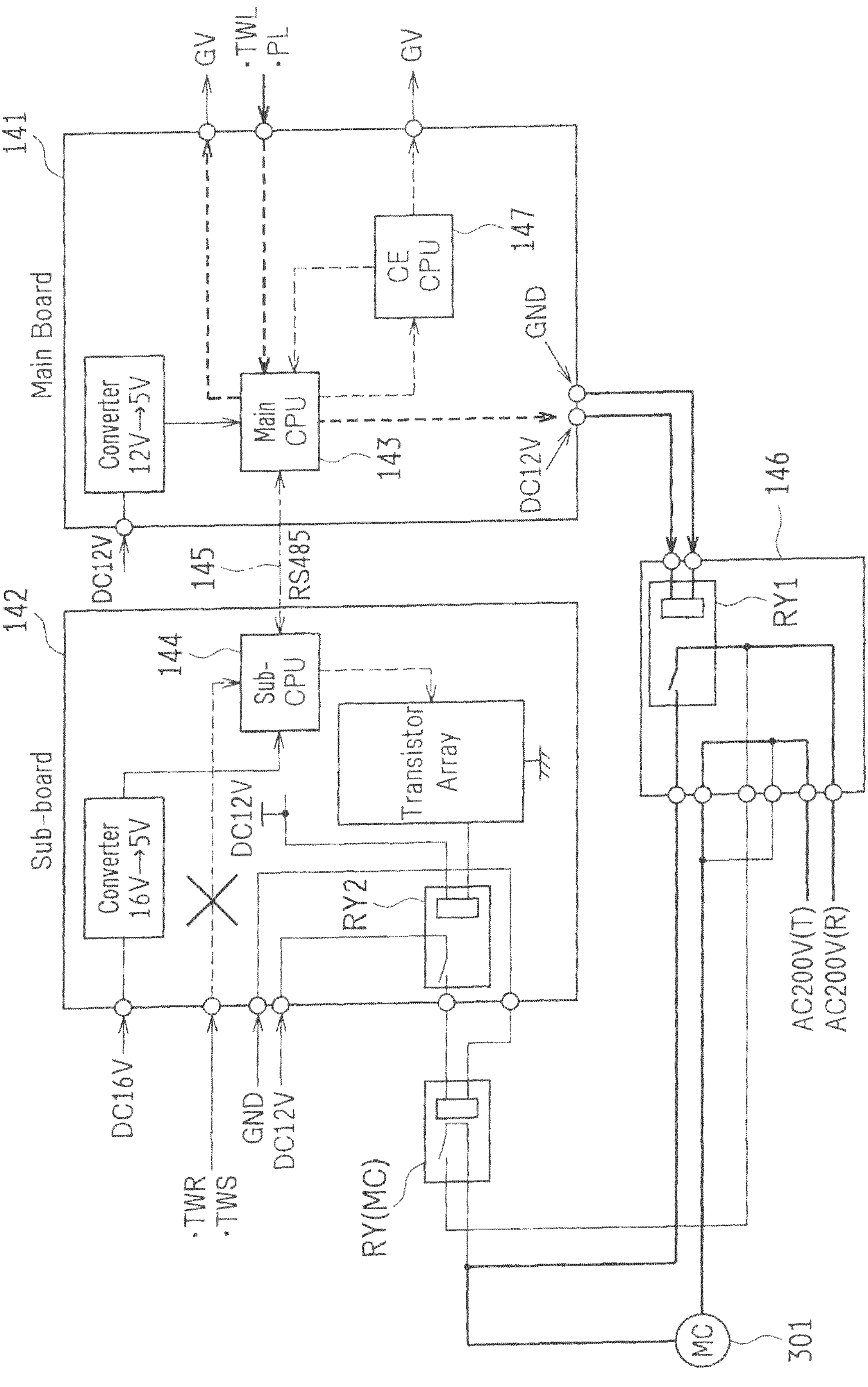
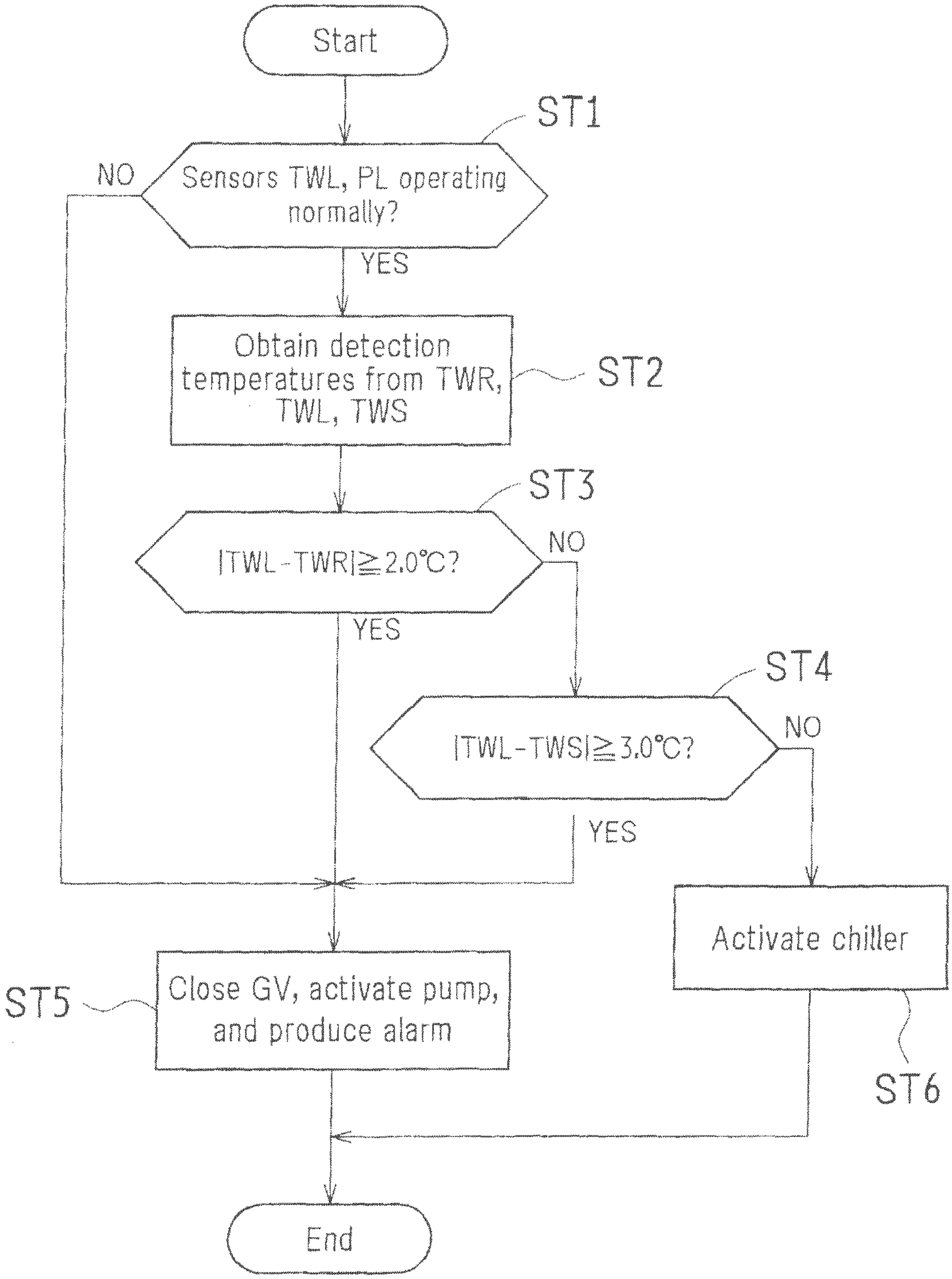
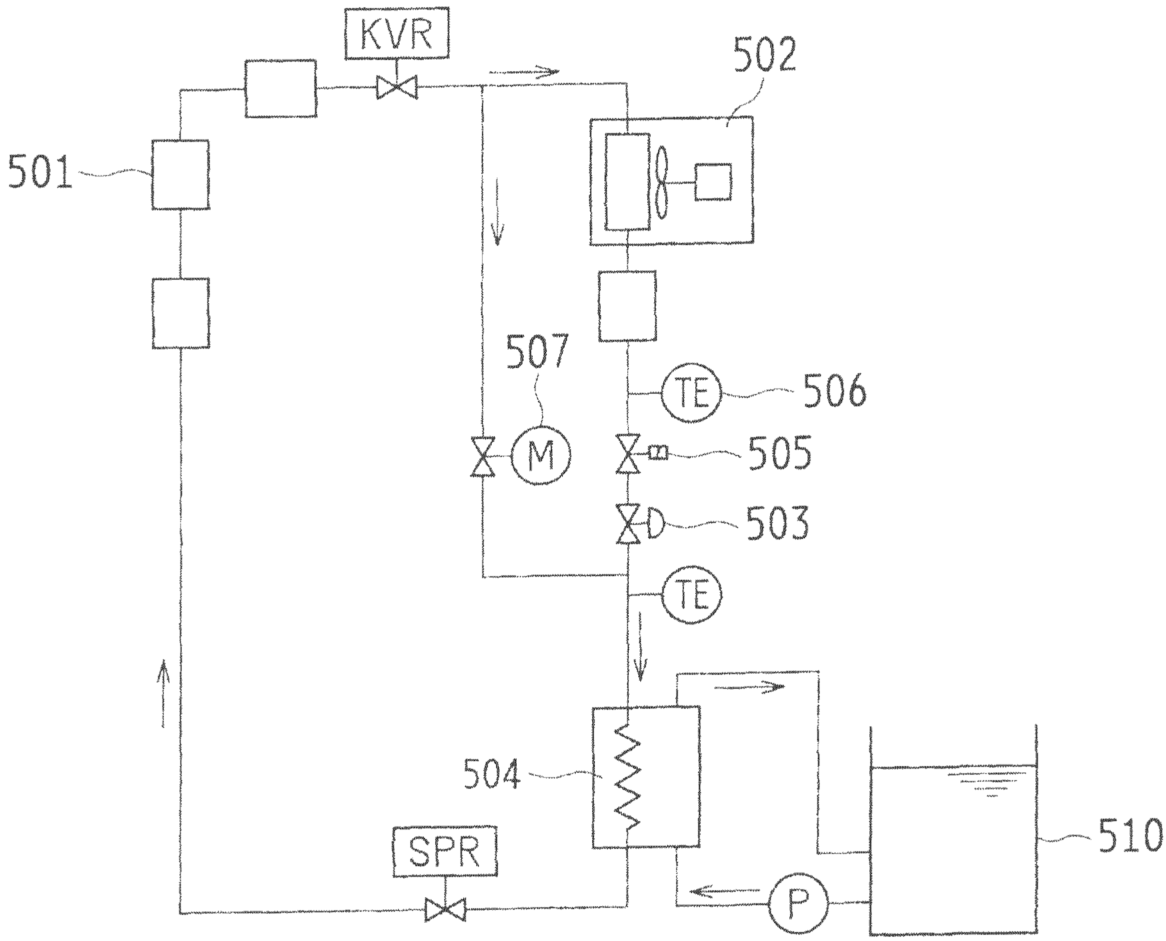

141
Main Board
GV
.TWL
.PL
GV
Converter
12V→5V
Main
CPU
143
CE
CPU
147
GND
DC12V
DC12V
145
RS485
142
Sub-board
Converter
16V→5V
Sub-
CPU
144
Transistor
Array
DC12V
RY2
DC16V
.TWR
.TWS
GND
DC12V
RY(MC)
146
RY1
AC200V(T)
AC200V(R)
MC
301

FIG.8



Start
ST1
Sensors TWL, PL operating normally?
NO
YES
Obtain detection temperatures from TWR, TWL, TWS
ST2
ST3
|TWL-TWR|≧2.0℃?
NO
YES
ST4
|TWL-TWS|≧3.0℃?
NO
YES
Activate chiller
ST6
ST5
Close GV, activate pump, and produce alarm
End

FIG.9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2015/064166

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

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 2014-052122 A (Yanmar Co., Ltd.), 20 March 2014 (20.03.2014), claims; paragraphs [0006], [0024]; fig. 1 & WO 2014/038469 A1	1-2 3-4
Y A	JP 2007-127307 A (Ebara Refrigeration Equipment & Systems Co., Ltd.), 24 May 2007 (24.05.2007), claims; paragraphs [0016] to [0019]; fig. 4 to 5 (Family: none)	1-2 3-4
Y A	JP 07-151429 A (Toshiba Corp.), 16 June 1995 (16.06.1995), claim 1; fig. 1, 3 (Family: none)	1-2 3-4

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 June 2015 (24.06.15)	07 July 2015 (07.07.15)

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/JP2015/064166

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 62-013962 A (Hitachi, Ltd.), 22 January 1987 (22.01.1987), claims; fig. 1 (Family: none)	1-2 3-4
Y A	JP 2014-088965 A (Toshiba Carrier Corp.), 15 May 2014 (15.05.2014), claim 1; paragraphs [0020] to [0021] & EP 2725305 A2	1-2 3-4
Y A	JP 02-503465 A (Sea Containers Ltd.), 18 October 1990 (18.10.1990), claims; fig. 1 & GB 8709096 A & WO 1988/008108 A1 & EP 380478 A & NO 885550 A & AU 1574288 A & BR 8807468 A & DK 509389 A & ZA 8802672 A & FI 894850 A	2 1,3-4
Y A	JP 11-031086 A (Mazda Motor Corp.), 02 February 1999 (02.02.1999), claims; fig. 4 to 8 (Family: none)	2 1,3-4
A	JP 10-078266 A (Nippon Pmac Co., Ltd.), 24 March 1998 (24.03.1998), entire text; all drawings (Family: none)	1-4
A	JP 2009-014298 A (Miura Co., Ltd., Miura Protech Ltd.), 22 January 2009 (22.01.2009), entire text; all drawings (Family: none)	1-4
A	WO 2011/092802 A1 (Mitsubishi Electric Corp.), 04 August 2011 (04.08.2011), entire text; all drawings & US 2012/0291460 A1 & EP 2530410 A1	1-4

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Patent documents cited in the description

- JP 5098472 B **[0004]**
- JP 2014129484 A **[0060]**