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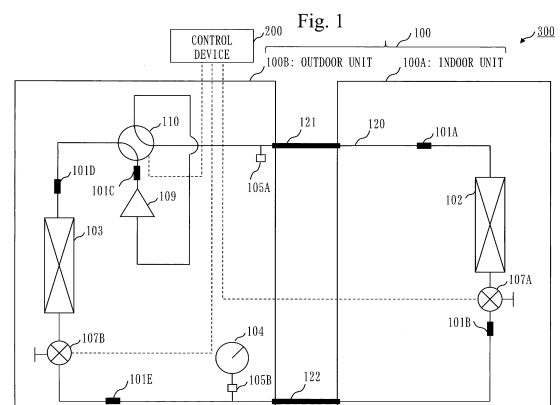
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(54) **REFRIGERANT LEAKAGE DETERMINATION DEVICE, CONTROL DEVICE, REFRIGERANT LEAKAGE DETERMINATION PROGRAM, AND REFRIGERANT LEAKAGE DETERMINATION METHOD**

(57) A refrigerant leak determination apparatus (300) is provided with a refrigeration cycle device (100), connection devices (105A and 105B), and a control device (200). The refrigeration cycle device (100) is configured with an indoor unit (100A) and an outdoor unit (100B). The refrigeration cycle device (100) includes a refrigerant circuit (120), and performs a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit (120). Each of the connection devices (105A and 105B) has a communication opening to an internal space of the refrigerant circuit (120), and is connected to a pressure sensor (104) that measures a refrigerant pressure in the internal space. The control device (200) causes the refrigeration cycle device (100) to perform oil recovery operation to collect oil inside the refrigerant circuit (120) in a compressor (109), and determines a leak of the refrigerant from the refrigerant circuit (120), by comparing a reference pressure with the refrigerant pressure measured by the pressure sensor (104) after the oil recovery operation.



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## Description

### Technical Field

[0001] The present disclosure relates to a refrigerant leak determination apparatus, a control device, a refrigerant leak determination program, and a refrigerant leak determination method.

### Background Art

[0002] Conventionally, there is a technique to diagnose based on a pressure reduction, presence or absence of a refrigerant leak in a refrigeration device, by comparing a vapor-liquid equilibrium pressure to be calculated from a measured ambient temperature with a pressure measured using a pressure detection means (for example, Patent Literature 1).

### Citation List

#### Patent Literature

[0003] Patent Literature 1: JP H04-225769 A

### Summary of Invention

#### Technical Problem

[0004] When the method of Patent Literature 1 is used to detect a refrigerant leak in a refrigeration device during suspension of operation, for example, a distribution of oil for a refrigerator in a refrigerant circuit differs depending on an installation environment of the refrigerator. An amount of the oil and an environmental temperature affect an amount of a refrigerant to be dissolved in the oil. Therefore, depending on a situation of the distribution of the oil for the refrigerator, there is a risk that an amount of pressure reduction to be detected may be uncertain, the amount of pressure reduction being a basis for determining the refrigerant leak. Accordingly, with the method of diagnosing the refrigerant leak disclosed in Patent Literature 1, depending on the distribution of the oil in the refrigeration device, there is a risk that dispersion of measured pressure occurs, and a measurement error in a pressure occurs.

[0005] The present disclosure aims to reduce a measurement error in measured pressure.

#### Solution to Problem

[0006] A refrigerant leak determination apparatus according to the present disclosure includes:

a refrigeration cycle device that includes a refrigerant circuit in which a compressor, a condenser, an expansion valve and an evaporator are connected, and that performs a refrigeration cycle in which a refrigerant

circulates through the refrigerant circuit; a connection device that includes a communication opening to an internal space of the refrigerant circuit, and that is connected to a pressure sensor that measures a refrigerant pressure in the internal space; and a control device including:

an operation control unit that causes the refrigeration cycle device to perform oil recovery operation to collect oil inside the refrigerant circuit in the compressor; and a determination unit to determine a leak of the refrigerant from the refrigerant circuit, by comparing a reference pressure for comparison, with the refrigerant pressure measured by the pressure sensor after the oil recovery operation.

### Advantageous Effects of Invention

[0007] In a refrigerant leak determination apparatus according to the present disclosure, a control device causes a refrigeration cycle device to perform oil recovery operation. After the oil recovery operation, a pressure of a refrigerant is measured. Accordingly, it is possible to suppress dispersion of the measured pressure, and to detect a refrigerant leak more reliable than before.

### Brief Description of Drawings

#### [0008]

Fig. 1 is a diagram of Embodiment 1 and a configuration diagram of a refrigerant leak determination apparatus 300.

Fig. 2 is a diagram of Embodiment 1 and a block configuration diagram of a control device 200.

Fig. 3 is a diagram of Embodiment 1 and a hardware configuration diagram of the control device 200.

Fig. 4 is a diagram of Embodiment 1 and a flowchart illustrating operation of the refrigerant leak determination apparatus 300.

Fig. 5 is a diagram of Embodiment 1 and a configuration diagram of the refrigerant leak determination apparatus 300 of Modification 1.

Fig. 6 is a diagram of Embodiment 1 and a lowchart illustrating operation of Modification 1.

Fig. 7 is a diagram of Embodiment 1 and a lowchart illustrating operation of Modification 2.

### Description of Embodiments

[0009] In the description and drawings of embodiments, the same or equivalent portions are denoted by the same reference sign. A description of a portion denoted by the same reference sign will be suitably omitted or simplified. In the following embodiments, "unit" may be interpreted as "circuit", "step", "procedure", "process",

or "circuitry", as necessary.

#### Embodiment 1.

**[0010]** A refrigeration cycle device 100 illustrated through Figs. 1 to 4 is assumed to be the refrigeration cycle device 100 in which pressure in a refrigerant circuit is equalized during suspension of operation. In Figs. 5 and 6 of Modification 1, the refrigeration cycle device 100 is assumed to be the refrigeration cycle device 100 in which pressure in the refrigerant circuit is not equalized during suspension of operation. Further, while a refrigerant leak determination apparatus 300 illustrated through Figs. 1 to 4 and the refrigerant leak determination apparatus 300 of Modification 1 calculate saturation pressure, Modification 2 indicates a configuration where the saturation pressure is not calculated.

**[0011]** Fig. 1 is a configuration diagram of the refrigerant leak determination apparatus 300 of Embodiment 1. A configuration of the refrigerant leak determination apparatus 300 will be described with reference to Fig. 1. The refrigerant leak determination apparatus 300 is provided with the refrigeration cycle device 100 and a control device 200. The refrigeration cycle device 100 is configured with an indoor unit 100A and an outdoor unit 100B. Fig. 1 illustrates a configuration of a refrigerant circuit 120 of the refrigeration cycle device 100, and installation positions of a temperature sensor 101 and a pressure sensor 104, which are detection means.

**[0012]** The refrigeration cycle device 100 includes the refrigerant circuit 120 in which a compressor 109, a condenser, expansion valves 107A and 107B, and an evaporator are connected. The refrigeration cycle device 100 performs a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit 120. As described below, an indoor heat exchanger 102 functions as the evaporator during cooling operation and functions as the condenser during heating operation. An outdoor heat exchanger 103 functions as the condenser during the cooling operation and functions as the evaporator during the heating operation.

#### <Refrigerant Circuit 120>

**[0013]** In the refrigeration cycle device 100, the compressor 109, a four-way valve 110, the outdoor heat exchanger 103, the expansion valve 107B, the expansion valve 107A, and the indoor heat exchanger 102 are connected with pipes, and form the refrigerant circuit 120 in which the refrigerant circulates. A plurality of temperature sensors 101 are installed in the refrigerant circuit 120. Further, connection devices 105A and 105B to be described below are installed in the refrigerant circuit 120.

#### <Indoor Unit 100A>

**[0014]** The indoor unit 100A includes a temperature sensor 101A, the indoor heat exchanger 102, the expan-

sion valve 107A, and a temperature sensor 101B, in the refrigerant circuit 120.

#### <Outdoor Unit 100B>

**[0015]** The outdoor unit 100B includes the connection device 105A, the compressor 109, a temperature sensor 101C, the four-way valve 110, a temperature sensor 101D, the outdoor heat exchanger 103, the expansion valve 107B, a temperature sensor 101E, the connection device 105B, and the pressure sensor 104, in the refrigerant circuit 120.

#### <Temperature Sensor 101>

**[0016]** The temperature sensors 101A to 101E measure a temperature of the refrigerant in the refrigerant circuit 120. Since the temperature sensors 101A to 101E have the same function, the temperature sensors 101A to 101E may be referred to as the temperature sensor 101 when there is no need to distinguish between them. The temperature sensor 101 is preferably a thermistor. Further, the temperature sensor 101 is preferably covered with a heat insulating material in order to prevent the temperature sensor 101 from being affected by outside air temperature. As a measurement principle, as temperature rises, a resistance value of the thermistor decreases by a constant value. The temperature can be detected by measuring the resistance value.

#### <Indoor Heat Exchanger 102>

**[0017]** In the indoor heat exchanger 102, indoor air exchanges heat with the refrigerant that passes through the indoor heat exchanger 102. The indoor heat exchanger 102 functions as the evaporator during the cooling operation by the refrigeration cycle device 100, and functions as the condenser during the heating operation by the refrigeration cycle device 100.

#### <Outdoor Heat Exchanger 103>

**[0018]** In the outdoor heat exchanger 103, outdoor air exchanges heat with the refrigerant that passes through the outdoor heat exchanger 103. By switching the four-way valve 110, the outdoor heat exchanger 103 functions as the condenser during the cooling operation by the refrigeration cycle device 100, and functions as the evaporator during the heating operation by the refrigeration cycle device 100.

#### <Pressure Sensor 104>

**[0019]** The pressure sensor 104 measures a refrigerant pressure. As the pressure sensor 104, it is preferable to use a fine pressure sensor. It is assumed that a pressure reduction due to a reduction in solubility of refrigerant oil (hereinafter referred to as oil) is about several

tens of kPa. Accordingly, many of pressure gauges for conventional gauge manifolds have a pressure range of 0 kPa to 5 MPa, and a resolution of about 100 KPa. Therefore, the pressure reduction of several tens of kPa cannot be detected. Accordingly, as the pressure sensor 104, it is preferable to use the fine pressure sensor that maintains a resolution of 5 to 10 kPa. In Embodiment 1, the pressure sensor 104 has a resolution in a range from 5 kPa inclusive to 10 kPa inclusive.

<Connection Device 105A and Connection Device 105B>

**[0020]** Each of the connection device 105A and the connection device 105B has a communication opening to an internal space of the refrigerant circuit 120, and is connected to the pressure sensor 104 that measures the refrigerant pressure in the internal space.

**[0021]** Each of the connection device 105A and the connection device 105B is a pressure sensor connecting opening to which the pressure sensor 104 is connected. Since the connection device 105A and the connection device 105B have the same function, the connection device 105A and the connection device 105B is referred to as a connection device 105 when there is no need to distinguish between them. The connection device 105 communicates with the inside of the refrigerant circuit. The connection device 105 is preferably, for example, a service port. Pressure measurement is performed in a pressure equalization state in which the refrigeration cycle device 100 is suspended. Therefore, there is no consideration on a position of the connection device 105, which is the service port to which the pressure sensor 104 is connected. Either of the connection devices 105 is used in the pressure equalization state.

<Expansion Valve 107A and Expansion Valve 107B>

**[0022]** Each of the expansion valve 107A and the expansion valve 107B is an electronic expansion valve. Since the expansion valve 107A and the expansion valve 107B have the same function, it is referred to as an expansion valve 107 when there is no need to distinguish between them. The expansion valve 107 is controlled by the control device 200, and efficiently controls an amount of refrigerant flow. During oil recovery operation to be described below, each of the expansion valve 107A and the expansion valve 107B is opened at a certain opening degree, and flows into a gas pipe 121, a gas-liquid two-phase refrigerant that includes a liquid refrigerant. By flowing the liquid refrigerant into the gas pipe 121, the oil is recovered inside the compressor 109 together with the liquid refrigerant.

**[0023]** The gas pipe will be described. The oil recovery operation will be described below in step S301. In Embodiment 1, the indoor unit 100A is assumed to be a refrigerator. That is, the cooling operation in which the indoor heat exchanger 102 functions as the evaporator

is normal operation. In the cooling operation, a gas refrigerant flows out from the indoor heat exchanger 102 which is the evaporator, and the outflowed gas refrigerant flows into the compressor 109 via the gas pipe 121 and the four-way valve 110. During the cooling operation, the liquid refrigerant flows through a liquid pipe 122 illustrated below the gas pipe 121, from the outdoor unit 100B to the indoor unit 100A.

10 <Compressor 109>

**[0024]** The compressor 109 circulates the refrigerant in the refrigerant circuit 120 by increasing the pressure of the refrigerant.

15 <Four-Way Valve 110>

**[0025]** The four-way valve 110 is a valve that switches the refrigeration cycle device 100 between the cooling operation and the heating operation. Fig. 1 illustrates a time of the cooling operation in which the indoor heat exchanger 102 functions as the evaporator. A case where the indoor heat exchanger 102 functions as the condenser is a time of the heating operation.

25 <Control Device 200>

\*\*\* Description of Configuration \*\*\*

30 **[0026]** Fig. 2 illustrates a functional block of the control device 200. Fig. 3 illustrates a hardware configuration of the control device 200. First, Fig. 2 will be described. The control device 200 is provided with an operation control unit 211, a leak determination unit 212, and a storage unit 213.

35 **[0027]** The operation control unit 211 causes the refrigeration cycle device 100 to perform the oil recovery operation in which the oil inside the refrigerant circuit 120 is collected in the compressor. The leak determination unit 212 which is a determination unit, determines whether or not the refrigerant leaks from the refrigerant circuit 120, by comparing a reference pressure P1 which is a subject to comparison, with a refrigerant pressure P2 measured by the pressure sensor 104 after the oil recovery operation. A specific description will be given below.

<Operation Control Unit 211>

40 **[0028]** The operation control unit 211 controls operation of the refrigeration cycle device 100. The operation control unit 211 controls the expansion valves 107A and 107B, the compressor 109, and the four-way valve 110 of the refrigeration cycle device 100. The operation control unit 211 controls, for example, the opening degrees of the expansion valves 107A and 107B. Further, the operation control unit 211 obtains a suspension signal to suspend the refrigeration cycle device 100. The operation control unit 211 obtains the number of rotations of

the compressor 109, as the suspension signal. Suspension in the suspension signal is a state in which the compressor 109 suspends and the refrigerant does not circulate through the refrigerant circuit 120.

#### <Storage Unit 213>

**[0029]** The storage unit 213 stores various data such as the actual measured value P2 measured by the pressure sensor 104 and the saturation pressure P1 to be described below.

#### <Leak Determination Unit 212>

**[0030]** The leak determination unit 212 obtains from the temperature sensor 101 and the pressure sensor 104, measurement data on the temperature sensor 101 and the pressure sensor 104, and stores the obtained measurement data into the storage unit 213. The leak determination unit 212 extracts the lowest temperature data from among pieces of temperature data obtained by the temperature sensor 101. The leak determination unit 212 calculates the saturation pressure P1 from the lowest temperature among the pieces of temperature data obtained by the temperature sensor 101. The leak determination unit 212 calculates a difference P1-P2 between the saturation pressure P1 and the pressure value P2 measured by the pressure sensor 104. When the difference between the saturation pressure P1 and the pressure value P2 is greater than a resolution of a differential pressure gauge, the leak determination unit 212 determines that there is a leak. When the difference between the saturation pressure P1 and the pressure value P2 is smaller than the resolution of the differential pressure gauge, the leak determination unit 212 determines that there is no leak. In Embodiment 1, the resolution is assumed to be 5 kPa. The leak determination unit 212 notifies a user or a worker of refrigerant leak abnormality.

**[0031]** The hardware configuration of the control device 200 will be described with reference to Fig. 3. The control device 200 is a computer. The control device 200 is provided with a processor 210. The control device 200 is provided with, in addition to the processor 210, other pieces of hardware such as a main storage device 220, an auxiliary storage device 230, an input IF 240, an output IF 250, and a communication IF 260. IF is an abbreviation for interface. The processor 210 is connected to the other pieces of hardware via a signal line 270, and controls the other pieces of hardware.

**[0032]** The control device 200 is provided with the operation control unit 211 and the leak determination unit 212, as functional components. Functions of the operation control unit 211 and the leak determination unit 212 are implemented by a refrigerant leak determination program 201.

**[0033]** The processor 210 is a device that executes the refrigerant leak determination program 201. The refrigerant leak determination program 201 is a program that

implements the functions of the operation control unit 211 and the leak determination unit 212. The processor 210 is an Integrated Circuit (IC) that performs arithmetic processing. A specific example of the processor 210 is a Central Processing Unit (CPU), a Digital Signal Processor (DSP), or a Graphics Processing Unit (GPU).

**[0034]** A specific example of the main storage device 220 is a Static Random Access Memory (SRAM), or a Dynamic Random Access Memory (DRAM). The main storage device 220 retains arithmetic results of the processor 210.

**[0035]** The auxiliary storage device 230 is a storage device that stores data in a nonvolatile manner. A specific example of the auxiliary storage device 230 is a Hard Disk Drive (HDD). Alternatively, the auxiliary storage device 230 may be a portable recording medium such as a Secure Digital (SD) (registered trademark) memory card, a NAND flash, a flexible disk, an optical disc, a compact disc, a Blu-ray (registered trademark) disc, or a Digital Versatile Disk (DVD). The auxiliary storage device 230 implements the storage unit 213. Further, the auxiliary storage device 230 stores the refrigerant leak determination program 201.

**[0036]** The input IF 240 is a port to which data is input from each device. The input IF 240 is connected to the temperature sensor 101 and the pressure sensor 104. The output IF 250 is a port to which each of various devices is connected, and from which data is output by the processor 210 to the each of various devices. The output IF 250 is connected to a notification device 500. The communication IF 260 is a communication port for the processor 210 to communicate with other devices. The communication IF 260 is connected to the compressor 109, the four-way valve 110, and the expansion valves 107A and 107B.

**[0037]** The processor 210 loads the refrigerant leak determination program 201 from the auxiliary storage device 230 to the main storage device 220, reads the refrigerant leak determination program 201 from the main storage device 220, and executes the refrigerant leak determination program 201. The main storage device 220 stores not only the refrigerant leak determination program 201 but also an Operating System (OS). The processor 210 executes the refrigerant leak determination program 201 while executing the OS. The control device 200 may be provided with a plurality of processors in place of the processor 210. The plurality of processors share execution of the refrigerant leak determination program 201. Each of the plurality of processors is, like the processor 210, a device that executes the refrigerant leak determination program 201. Data, information, a signal value, and a variable value that are used, processed, or output by the refrigerant leak determination program 201 are stored in the main storage device 220, the auxiliary storage device 230, or stored in a register or a cache memory in the processor 210.

**[0038]** The refrigerant leak determination program 201 is a program that causes the computer to execute each

process, each procedure, or each step, where "unit" in each of the operation control unit 211 and the leak determination unit 212 is interpreted as "process", "procedure", or "step".

**[0039]** Further, a refrigerant leak determination method is a method to be performed by the control device 200 which is the computer, executing the refrigerant leak determination program 201. The refrigerant leak determination program 201 may be provided as being stored in a computer readable recording medium or may be provided as a program product.

### \*\*\* Description of Operation \*\*\*

**[0040]** Fig. 4 is a flowchart illustrating operation of the refrigerant leak determination apparatus 300. The operation of the refrigerant leak determination apparatus 300 will be described with reference to Fig. 4. An operation procedure of the control device 200 in the refrigerant leak determination apparatus 300 is equivalent to a control method. A program that implements operation of the control device 200 is equivalent to the refrigerant leak determination program 201.

#### <Step S300>

**[0041]** In step S300, the operation control unit 211 receives as the number of rotations of the compressor 109 of the refrigeration cycle device 100, the suspension signal of the cooling operation or the heating operation of the refrigeration cycle device 100. Fig. 1 illustrates the state of the cooling operation. After receiving the suspension signal, the operation control unit 211 opens the expansion valve 107A and the expansion valve 107B, and shifts a heating operation mode or a cooling operation mode to an oil recovery operation mode.

#### <Step S301: Oil Recovery Operation>

**[0042]** When the operation control unit 211 causes the refrigeration cycle device 100 to perform operation in a mode different from the oil recovery operation, the operation control unit 211 causes the refrigeration cycle device 100 to continue to perform the oil recovery operation from the mode different from the oil recovery operation, and to suspend the operation of the refrigeration cycle device 100 after the oil recovery operation is performed. A specific description will be given below.

**[0043]** In step S301, the operation control unit 211 opens the expansion valves 107A and 107B, and starts the oil recovery operation.

**[0044]** Here, the oil recovery operation will be described. During the cooling operation, some of oil inside the compressor 109 flow out from the compressor 109 slightly, together with the gas refrigerant. A large amount of oil that has flowed out from the compressor 109 especially stay between an outlet of the indoor heat exchanger 102 which is the evaporator and a suction opening of the

compressor 109. That is, during the cooling operation, the large amount of oil stay in the gas pipe 121. In the cooling operation, the gas refrigerant flows out from the outlet of the indoor heat exchanger 102 which is the evaporator. Therefore, in the oil recovery operation, the operation control unit 211 controls the opening degrees of the expansion valves 107A and 107B, so that the gas-liquid two-phase refrigerant flows out from the indoor heat exchanger 102. The liquid refrigerant of the gas-liquid two-phase refrigerant recovers the oil to the compressor 109 with shearing force like dragging the oil inside the gas pipe 121. The liquid refrigerant also flows into the compressor 109, but its amount is small. Therefore, there is no problem such as failure in the compressor 109. The oil is recovered to the compressor 109 by the oil recovery operation, and a trouble such as poor lubrication of the compressor 109 is avoided.

**[0045]** As described above, the operation control unit 211 recovers the oil inside the refrigerant circuit 120 by the oil recovery operation, to the compressor 109 installed inside the outdoor unit 100B. The operation control unit 211 controls the opening degrees of the expansion valves during the oil recovery operation, so that the liquid refrigerant flows through a pipe in an area where the refrigerant flows from the evaporator to the compressor, and a pipe in an area where the refrigerant flows from the compressor to the condenser, in the refrigerant circuit 120. A specific description will be given below.

**[0046]** Specifically, the operation control unit 211 performs oil recovery by widening the opening degrees of the expansion valves 107A and 107B, increasing an inverter frequency of the compressor 109, and increasing a supply amount of the liquid refrigerant into the gas pipe. The operation control unit 211 ends the oil recovery operation after ten minutes pass from start of the oil recovery operation.

#### <Step S302>

**[0047]** In step S302, when ten minutes have passed from the start of the oil recovery operation, the operation control unit 211 suspends the oil recovery operation. That is, the operation control unit 211 suspends operation of the compressor 109, and suspends the operation of the refrigeration cycle device 100.

#### <Step S303>

**[0048]** In step S303, the leak determination unit 212 measures the temperature by the temperature sensor 101 installed in the refrigerant circuit 120, and stores the measured temperature in the storage unit 213.

#### <Step S304>

**[0049]** In step S304, the leak determination unit 212 determines whether or not the temperature measured in the refrigerant circuit 120 is stable. The leak determina-

tion unit 212 determines that, for example, the temperature is stable when the temperature of the refrigerant circuit 120 is periodically measured, and a temperature change value is less than or equal to  $\pm 0.5$  °C.

<Step S305>

**[0050]** In step S305, the leak determination unit 212 extracts the lowest measured value in the refrigerant circuit 120 from among pieces of measured temperature data, and stores the lowest measured value in the storage unit 213.

<Step S306>

**[0051]** The refrigeration cycle device 100 is provided with the temperature sensor 101 that measures the refrigerant temperature of the refrigerant circuit 120. The leak determination unit 212 which is the determination unit, calculates from the refrigerant temperature measured by the temperature sensor 101, the saturation pressure of the refrigerant, and uses the calculated saturation pressure as the reference pressure P1. A specific description will be given below.

**[0052]** In step S306, the leak determination unit 212 calculates the saturation pressure P1 using the lowest temperature stored in step S305, and stores the calculated saturation pressure P1 in the storage unit 213. The saturation pressure P1 is a function of the temperature t. The leak determination unit 212 calculates P1(tmin) of the measured lowest temperature tmin, using P1(t). A formula of P1(t) is stored in the auxiliary storage device 230.

<Step S307>

**[0053]** In step S307, the pressure sensor 104 is connected to the connection device 105 by a maintenance worker. The pressure sensor 104 may be connected to either the connection device 105A or the connection device 105B.

<Step S308>

**[0054]** The leak determination unit 212 which is the determination unit, uses the measured value of the pressure sensor 104 at the suspended state of the refrigeration cycle device 100 after the oil recovery operation is performed. A specific description will be given below.

**[0055]** In step S308, the leak determination unit 212 obtains from the pressure sensor 104, the refrigerant pressure P2 when at the operation suspended state of the refrigeration cycle device 100. The leak determination unit 212 stores the measured value P2 into the storage unit 213.

<Step S309>

**[0056]** In step S309, the leak determination unit 212 calculates P1-P2 which is the difference between the saturation pressure P1 measured in step S306 and the measured pressure P2 obtained in step S308. The leak determination unit 212 determines whether or not the difference is greater than the resolution of the pressure sensor 104. The resolution is assumed to be 5 kPa. When the difference in the pressure is greater than 5 kPa which is the resolution, the leak determination unit 212 determines in step S310 that "there is refrigerant leak". When the difference in the pressure is less than or equal to the resolution, the leak determination unit 212 determines if the state in which the difference in the pressure is less than or equal to the resolution has passed for one or more hours from the start of the measurement by the pressure sensor 104 (step S311). When one or more hours have not passed, steps S308, S309, and S311 are repeated. When one or more hours have passed, the leak determination unit 212 determines that "there is no refrigerant leak" in step S312.

<Step S313>

**[0057]** In step S313, the leak determination unit 212 issues a notification of a result of step S310 or step S312 by the notification device 500.

**[0058]** The refrigerant leak determination apparatus 300 has been described above. The operation of the refrigerant leak determination apparatus 300 can be grasped as a refrigerant leak determination method as follows:

That is, the operation of the refrigerant leak determination apparatus 300 can be grasped as "a refrigerant determination method including:

a step (step S300) to connect the pressure sensor 104 to the connection devices 105A and 105B after the oil recovery operation to collect oil inside the refrigerant circuit 120 in the compressor 109, the oil recovery operation being performed by the refrigeration cycle device 100 including the refrigerant circuit 120 in which the compressor, a condenser, an expansion valve, and an evaporator are connected, performing a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit, and including the connection devices 105A and 105B each of which includes a communication opening to an internal space of the refrigerant circuit 120, and each of which is connected to the pressure sensor 104 that measures a refrigerant pressure in the internal space; and

a step (steps S309 and S311) to determine a leak of the refrigerant from the refrigerant circuit 120, by comparing the reference pressure P1

for comparison, with the refrigerant pressure P2 measured by the pressure sensor 104".

**[0059]** Although a plurality of temperature sensors 101 are illustrated in Fig. 1, at least one temperature sensor 101 is sufficient for calculating the saturation pressure in step S306. When there is one temperature sensor 101, the leak determination unit 212 treats the measurement data of the only one temperature sensor 101 as the lowest temperature.

\*\*\* Description of Effects of Embodiment 1 \*\*\*

**[0060]**

(1) The refrigerant leak determination apparatus 300 calculates the saturation pressure from the lowest temperature data among the pieces of temperature data obtained by the temperature sensor 101. Then, the refrigerant leak determination apparatus 300 diagnoses a refrigerant leak from a pressure difference between the calculated saturation pressure and the actual measured value measured by the pressure sensor 104. As a result, the refrigerant leak can be diagnosed even when the refrigeration cycle device 100 is suspended. Therefore, a leak can be determined throughout a year.

(2) The refrigerant leak determination apparatus 300 performs the oil recovery operation before suspending the cooling operation or the heating operation, and suspends the operation of the refrigeration cycle device 100 after the oil is recovered to the compressor 109 by the oil recovery operation. Accordingly, the refrigerant leak determination apparatus 300 can reduce a measurement error caused by dispersion of the distribution of the oil when measuring the pressure reduction due to dissolution of the refrigerant gas into the oil.

(3) The pressure sensor 104 connected to the connection device 105 is capable of detecting even a minute pressure of about several tens of kPa, and uses a high-precision sensor with a resolution of 5 kPa to 10 kPa. As a result, it is possible to detect even a minute pressure changes due to the dissolution of the refrigerant gas into the oil.

(4) The pressure sensor 104 connected to the connection device 105 starts to measure a pressure at a stage when the operation of the refrigeration cycle device 100 is suspended, oil recovery in the refrigerant circuit 120 is completed, and the temperature of the refrigerant circuit 120 is stable. As a result, it is possible to reliably detect a reduction in the refrigerant pressure, and prevent erroneous detection or undetection of the refrigerant leak.

(5) Each of the expansion valves 107A and 107B provided in the refrigeration cycle device 100 is opened at a certain opening degree in the oil recovery operation, and returns the oil to the condenser

together with the liquid refrigerant by flowing the liquid refrigerant into the gas pipe. As a result, the oil inside the refrigerant circuit 120 can be recovered smoothly and in a short time.

(6) At least one or more temperature sensors 101 are preferably provided in the refrigerant circuit 120, on each of the indoor unit 100A side and the outdoor unit 100B side. In this case, the temperature sensor 101 obtains the temperature of the side surface of the pipe that forms the refrigerant circuit 120. As a result, the temperature of the refrigerant inside the refrigerant circuit 120 can be detected.

(7) When the leak determination unit 212 of the control device 200 determines that there is a refrigerant leak, the leak determination unit 212 displays an abnormality code on the notification device 500, and notifies a user or a worker of the abnormality code. As a result, even when the refrigeration cycle device 100 is in a suspension period, the user or the worker can be aware of abnormality due to the refrigerant leak, and can take an immediate response.

(8) After recovering the oil, the control device 200 of Embodiment 1 performs determination for the refrigerant leak using the pressure. Accordingly, in any of a plurality of refrigeration devices, there is no dispersion of the distribution of the oil when the oil is recovered to the compressor. Therefore, by measuring the pressure after the oil is recovered, there is no dispersion in the measured pressure between each of the refrigeration devices. Thus, the determination for the refrigerant leak is possible with high accuracy.

<Modification 1>

**[0061]** Modification 1 of the refrigerant leak determination apparatus 300 of Embodiment 1 will be described with reference to Figs. 5 and 6. In Modification 1, it is assumed to have the refrigeration cycle device 100 in which the pressure in the refrigerant circuit 120 differs between the indoor unit 100A side and the outdoor unit 100B side when the operation of the refrigeration cycle device 100 is suspended.

**[0062]** In the refrigeration cycle device 100 such as a refrigerator, there is a model in which the pressure is separated between the outdoor unit 100B side and the indoor unit 100A side, by pump-down operation, and the pressure differs between a high-pressure side and a low-pressure side. In this case, when the pressure is measured on the indoor unit 100A side, it may be determined that the pressure reduction that exceeds the resolution is undetected. Therefore, a position for measuring the pressure is limited to the outdoor unit 100B side.

<Configurations of Refrigerant Circuit and Connection Positions of Temperature Sensor 101 and Pressure Sensor 104>

**[0063]** Fig. 5 illustrates a configuration of the refriger-

ant leak determination apparatus 300 of the embodiment. A configuration of a refrigerant circuit of the refrigeration cycle device 100, and installation positions of the temperature sensor 101 and the pressure sensor 104, in the refrigerant leak determination apparatus 300 of Modification 1 are basically the same as those in the refrigerant leak determination apparatus 300 of Embodiment 1. The configuration of Fig. 5 is the same as the configuration of Fig. 1. However, in Modification 1, the connection device 105 to which a pressure sensor 404 is to be connected is limited to the connection device 105B installed at a connecting opening to the inside of a system on the outdoor unit 100B side. In Fig. 5, this matter is clearly indicated by enclosing the connection device 105B using a frame 400 of a dashed line.

The control device 200 is also the same as that in Embodiment 1.

**[0064]** Fig. 6 is a flowchart illustrating operation of the refrigerant leak determination apparatus 300 of Modification 1. The operation of the refrigerant leak determination apparatus 300 of Modification 1 will be described with reference to Fig. 6. The flowchart of Fig. 6 differs from the flowchart of Fig. 4 of Embodiment 1 in that step S301A is added, and in the content of step S307. Since other steps are the same as those in Fig. 4, a description thereof will be omitted.

<Step S301A>

**[0065]** The refrigeration cycle device 100 of the modification requires the pump-down operation before the operation is suspended. The connection device 105B to which the pressure sensor 104 is connected, communicates with the inside of a system of the outdoor heat exchanger 103 that functions as the condenser. A specific description will be given below.

**[0066]** In step S301A, the operation control unit 211 performs the pump-down operation, and recovers the liquid refrigerant to the compressor 109 installed inside the outdoor unit 100B. The operation control unit 211 fully opens the expansion valves 107A and 107B, performs forced cooling operation, and recovers the liquid refrigerant to the compressor 109. After a certain period of time passes from the start of the operation, processing ends.

**[0067]** In step S302, after the pump-down operation is completed, the operation control unit 211 suspends the operation of the refrigeration cycle device 100.

**[0068]** In step S307, a maintenance worker connects the pressure sensor 404 to the connection device 105B that communicates with the inside of the system on the outdoor unit 100B side. Steps after step S307 are the same as those in Fig. 4.

\*\*\* Effects of Modification 1 \*\*\*

**[0069]** According to the refrigerant leak determination apparatus 300 of Modification 1, when connecting to a model that performs the pump-down operation before the operation of the refrigeration cycle device 100 is suspended, the pressure sensor 104 is connected to a connection device that communicates with the inside of the system on the outdoor unit 100B side.

**[0070]** As a result, in addition to the effects of Embodiment 1, it is possible to prevent the pressure reduction from not being detected in the model that performs the pump-down operation.

15 <Modification 2>

**[0071]** Fig. 7 is a flowchart illustrating operation of the refrigerant leak determination apparatus 300 of Modification 2. Modification 2 will be described with reference to Fig. 7. The configuration of the refrigerant leak determination apparatus 300 is the same as that in Embodiment 1. That is, the refrigeration cycle device 100 and the control device 200 are the same as those in Embodiment 1. The flowchart of Fig. 7 differs from the flowchart of Fig. 4 in that there are no steps S305 and S306, and in the content of step S309. Other than these, Fig. 7 is the same as Fig. 4. This is because the refrigerant pressure at suspension time in the refrigerant circuit 120 at time of factory shipment is used in place of the saturation pressure P1 as follows.

**[0072]** A refrigeration leak may be detected from a pressure difference between a refrigerant pressure at suspension time in the refrigerant circuit 120 of the refrigeration cycle device 100 at the time of factory shipment, and a refrigerant pressure measured by a pressure sensor 1004. The refrigerant pressure at the suspension time at the time of factory shipment is stored in the auxiliary storage device 230. This pressure is referred to as P1.

**[0073]** The flowchart of Fig. 7 is the same as the flowchart of Fig. 4 of Embodiment 1 except that steps S305 and S306 have been deleted, and the content of step S309 differs. Therefore, step S309 will be described, and a description of other steps will be omitted.

45 <Step S309>

**[0074]** The leak determination unit 212 which is the determination unit, uses as the reference pressure P1, the refrigerant pressure retained in advance at the time of factory shipment. A specific description will be given below.

**[0075]** In step S309, the leak determination unit 212 calculates the difference (P1-P2) between the pressure P1 at the time of factory shipment stored in the auxiliary storage device 230 and the pressure P2 obtained in step S308. Steps after step S309 are the same as those in Fig. 4.

## \*\*\* Effects of Modification 2 \*\*\*

[0076] In Modification 2, it is possible to omit step S305 in which the lowest temperature sensor value in the refrigerant circuit 120 is extracted, and step S306 in which the saturation pressure is calculated. Therefore, Modification 2 can determine a refrigerant leak faster than usual.

[0077] Embodiment 1 that includes Modification 1 and Modification 2 has been described above. Two or more technical matters of these embodiments may be combined for implementation. Alternatively, one technical matter of Embodiment 1 may be partially implemented.

## Reference Signs List

[0078] 100: refrigeration cycle device; 100A: indoor unit; 100B: outdoor unit; 101A, 101B, 101C, 101D, 101E: temperature sensor; 102: indoor heat exchanger; 103: outdoor heat exchanger; 104: pressure sensor; 105A, 105B: connection device; 107A, 107B: expansion valve; 109: compressor; 110: four-way valve; 120: refrigerant circuit; 121: gas pipe; 122: liquid pipe; 200: control device; 201: refrigerant leak determination program; 210: processor; 211: operation control unit; 212: leak determination unit; 213: storage unit; 220: main storage device; 230: auxiliary storage device; 240: input IF; 250: output IF; 260: communication IF; 270: signal line; 300: refrigerant leak determination apparatus; 400: frame; 500: notification device.

## Claims

1. A refrigerant leak determination apparatus comprising:

a refrigeration cycle device that includes a refrigerant circuit in which a compressor, a condenser, an expansion valve and an evaporator are connected, and that performs a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit;

a connection device that includes a communication opening to an internal space of the refrigerant circuit, and that is connected to a pressure sensor that measures a refrigerant pressure in the internal space; and

a control device including:

an operation control unit that causes the refrigeration cycle device to perform oil recovery operation to collect oil inside the refrigerant circuit in the compressor; and

a determination unit to determine a leak of the refrigerant from the refrigerant circuit, by comparing a reference pressure for comparison, with the refrigerant pressure meas-

ured by the pressure sensor after the oil recovery operation.

2. A control device comprising:

an operation control unit that causes a refrigeration cycle device to perform oil recovery operation to collect oil inside a refrigerant circuit of the refrigeration cycle device in a compressor, the refrigeration cycle device including the refrigerant circuit in which the compressor, a condenser, an expansion valve, and an evaporator are connected, performing a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit, and including a connection device that includes a communication opening to an internal space of the refrigerant circuit, and that is connected to a pressure sensor that measures a refrigerant pressure in the internal space; and

a determination unit to determine a leak of the refrigerant from the refrigerant circuit, by comparing a reference pressure for comparison, with the refrigerant pressure measured by the pressure sensor after the oil recovery operation.

3. The control device according to claim 2, wherein when causing the refrigeration cycle device to perform operation in a mode different from the oil recovery operation, the operation control unit causes the refrigeration cycle device to continuously perform the oil recovery operation from the mode different from the oil recovery operation, and causes the refrigeration cycle device to suspend operation of the refrigeration cycle device after the oil recovery operation is performed.

4. The control device according to claim 2 or claim 3, wherein a resolution of the pressure sensor is in a range from 5 kPa inclusive to 10 kPa inclusive.

5. The control device according to claim 3, wherein the determination unit uses a measured value of the pressure sensor in a suspended state of the refrigeration cycle device after the oil recovery operation is performed.

6. The control device according to any one of claims 2 to 5, wherein

the refrigeration cycle device requires pump-down operation before operation is suspended, and

the connection device to which the pressure sensor is connected, communicates with inside of a system in the condenser in the refrigerant circuit.

7. The control device according to any one of claims 2 to 6, wherein  
the operation control unit controls an opening degree of the expansion valve during the oil recovery operation, so that a liquid refrigerant flows into a pipe in an area where the refrigerant is directed from the evaporator to the compressor, and a pipe from the compressor to the condenser, in the refrigerant circuit. 5
8. The control device according to any one of claims 2 to 7, wherein 10
- the refrigeration cycle device includes a temperature sensor that measures a refrigerant temperature of the refrigerant circuit, and the determination unit calculates a saturation pressure of the refrigerant from the refrigerant temperature measured by the temperature sensor, and uses the calculated saturation pressure as the reference pressure. 15 20
9. The control device according to any one of claims 2 to 7, wherein 25
- the determination unit uses as the reference pressure, a refrigerant pressure retained in advance at time of factory shipment.
10. A refrigerant leak determination program causing a computer to execute: 30
- an operation control process that causes a refrigeration cycle device to perform oil recovery operation to collect oil inside a refrigerant circuit of the refrigeration cycle device in a compressor, the refrigeration cycle device including the refrigerant circuit in which the compressor, a condenser, an expansion valve, and an evaporator are connected, performing a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit, and including a connection device that includes a communication opening to an internal space of the refrigerant circuit, and that is connected to a pressure sensor that measures a refrigerant pressure in the internal space; and 35 40 45
- a determination process to determine a leak of the refrigerant from the refrigerant circuit, by comparing a reference pressure for comparison, with the refrigerant pressure measured by the pressure sensor after the oil recovery operation. 50
11. A refrigerant leak determination method comprising:
- connecting a pressure sensor to a connection device after oil recovery operation to collect oil inside a refrigerant circuit in a compressor, the oil recovery operation being performed by a re-

frigeration cycle device including the refrigerant circuit in which the compressor, a condenser, an expansion valve, and an evaporator are connected, performing a refrigeration cycle in which a refrigerant circulates through the refrigerant circuit, and including a connection device that includes a communication opening to an internal space of the refrigerant circuit, and that is connected to the pressure sensor that measures a refrigerant pressure in the internal space; and determining a leak of the refrigerant from the refrigerant circuit, by comparing a reference pressure for comparison, with the refrigerant pressure measured by the pressure sensor.

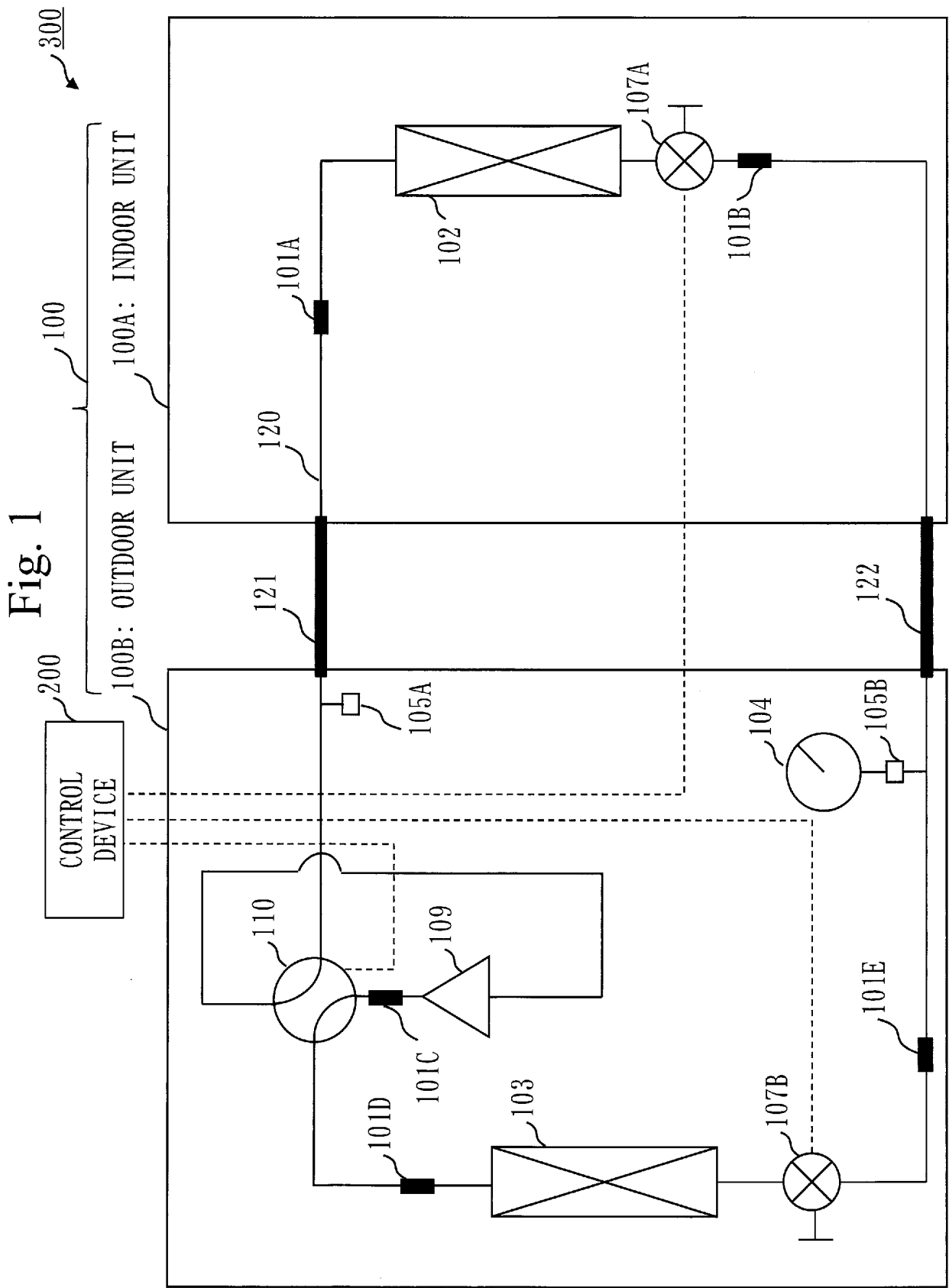


Fig. 2

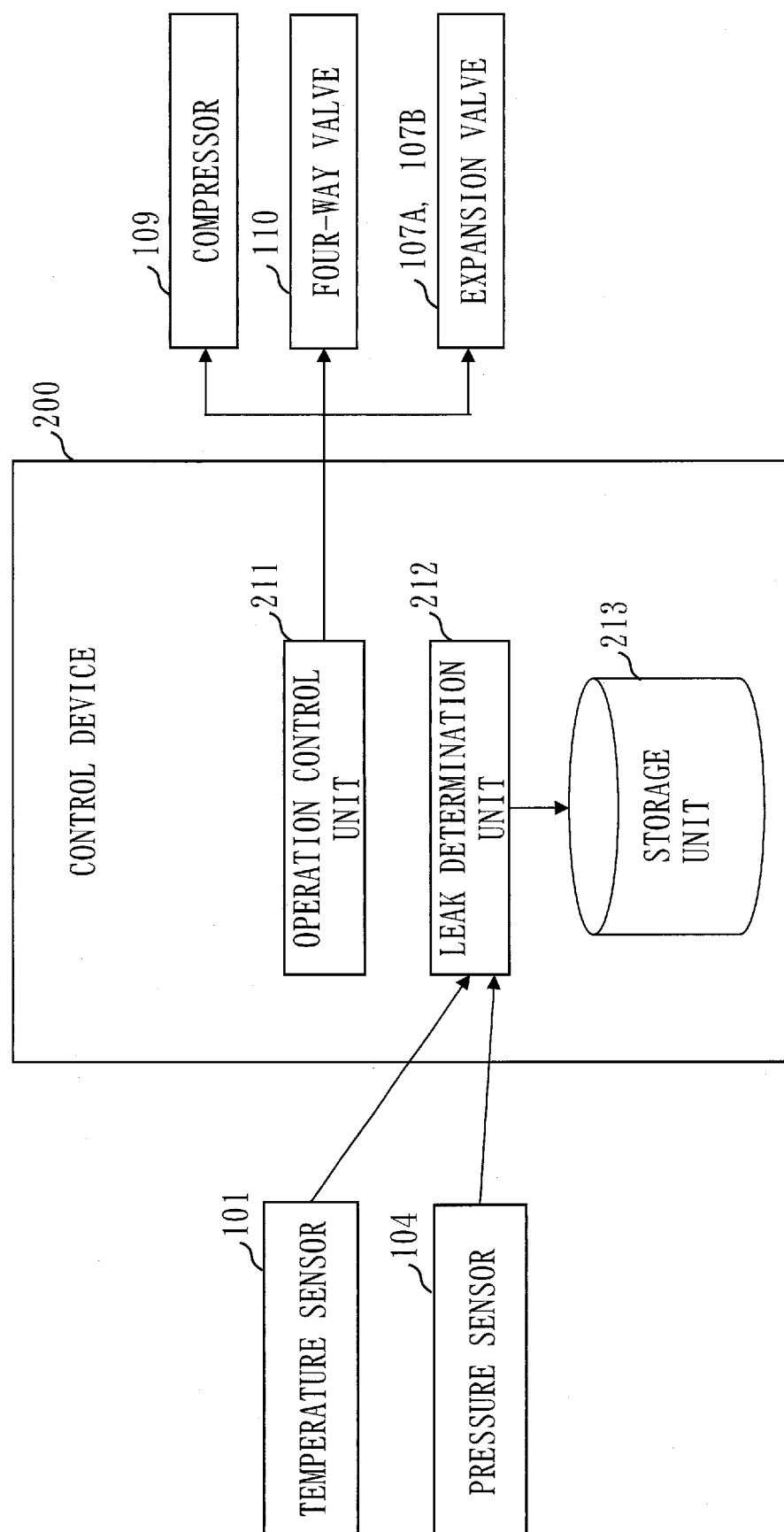


Fig. 3

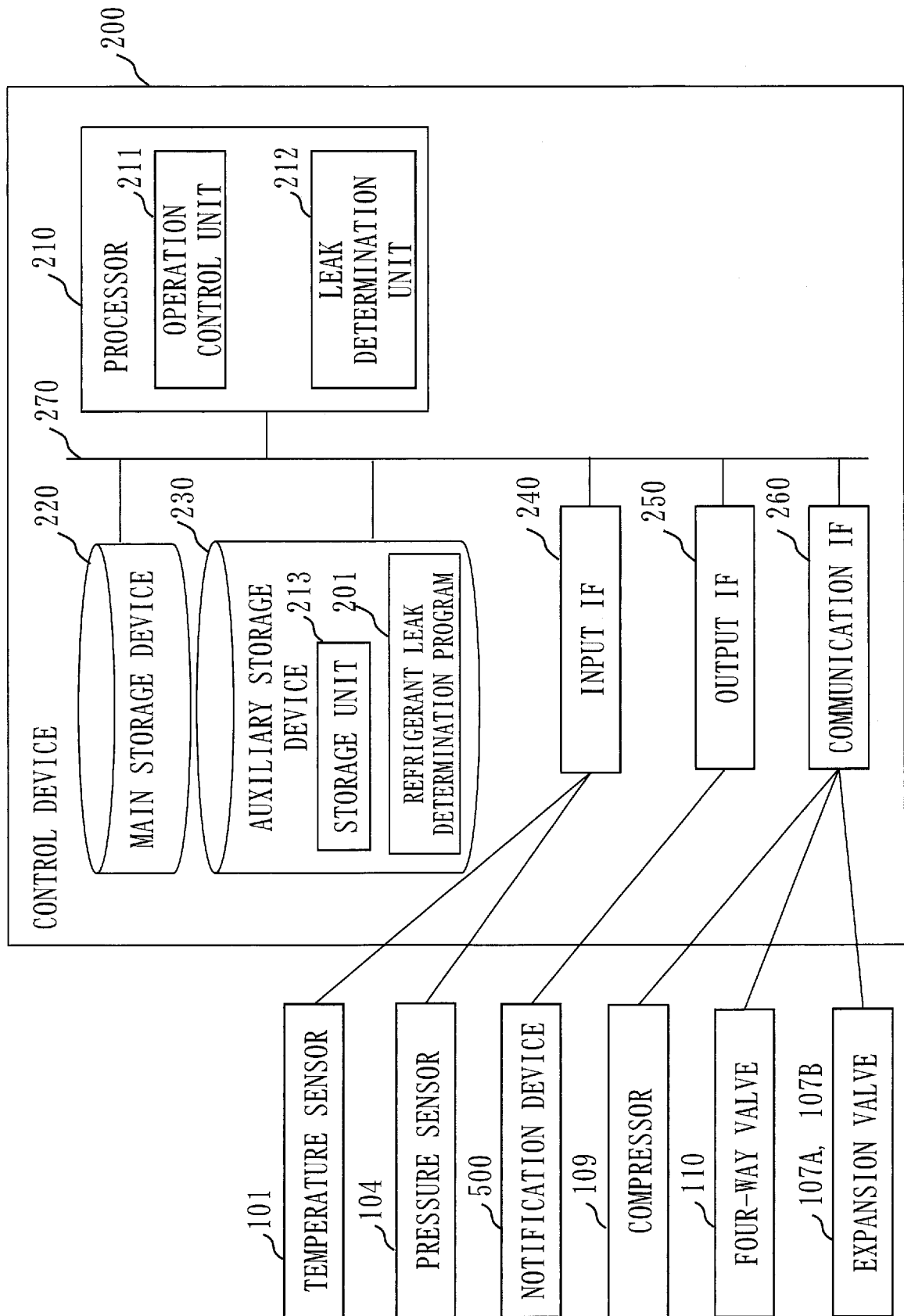
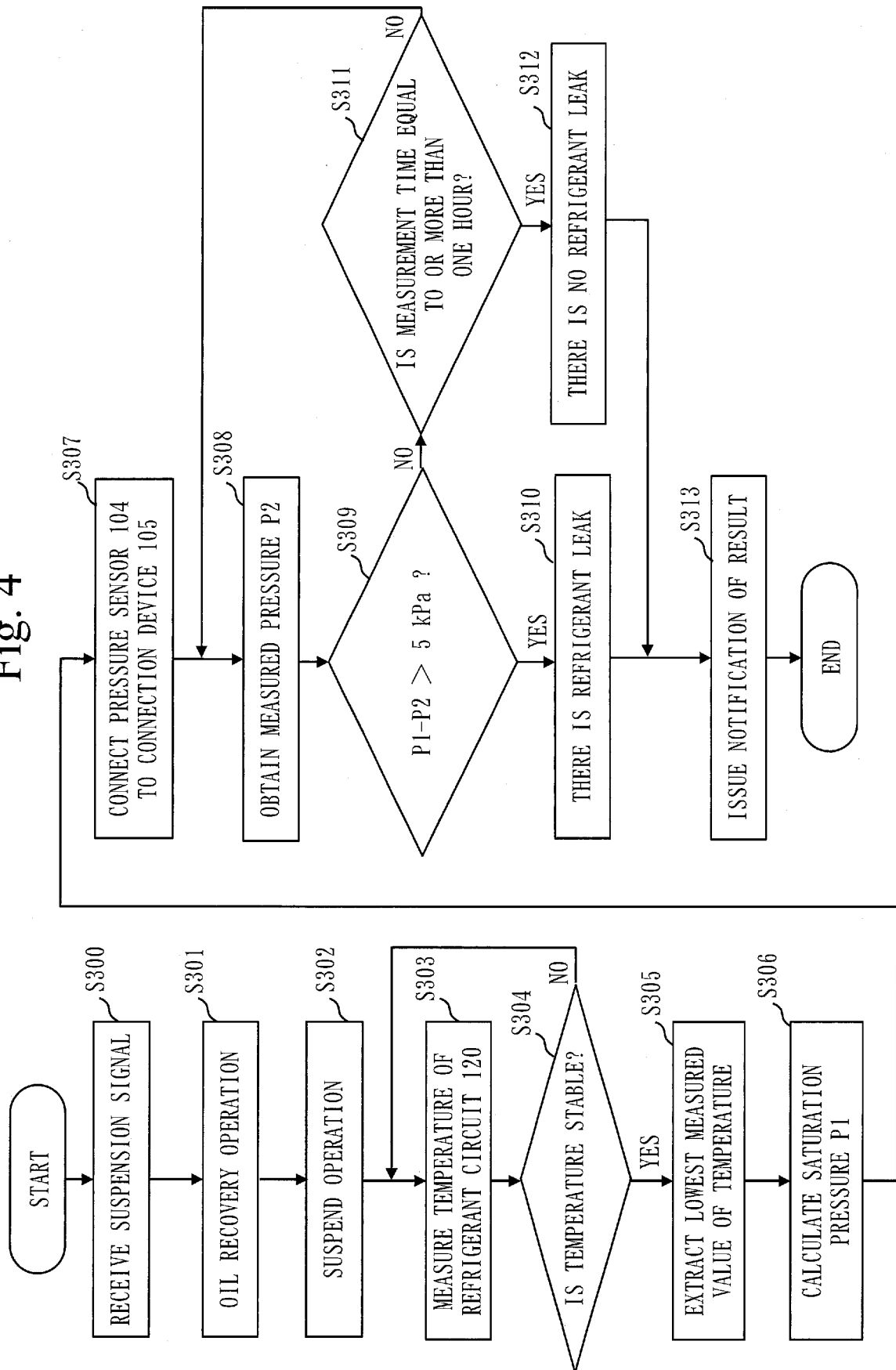


Fig. 4



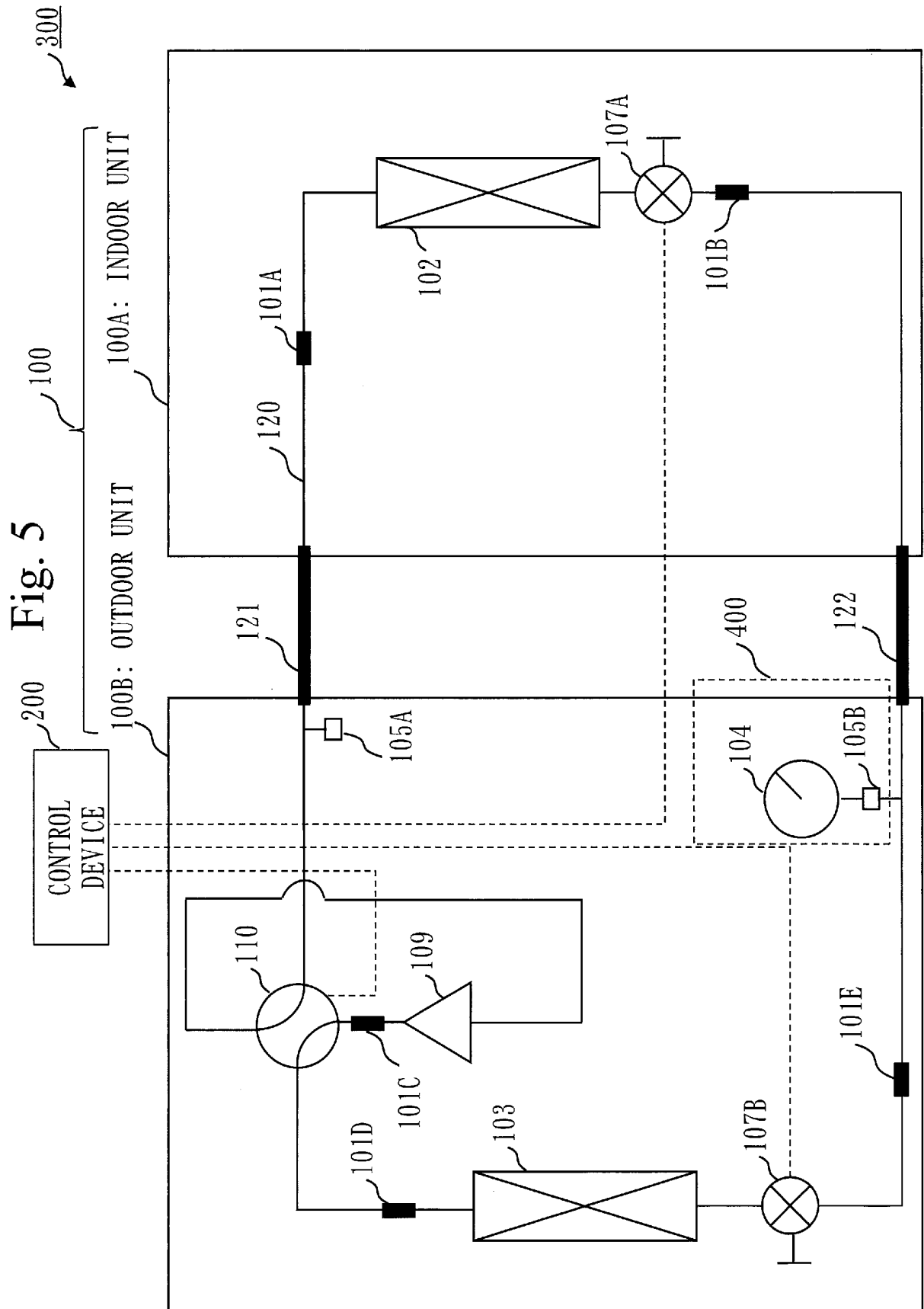


Fig. 6

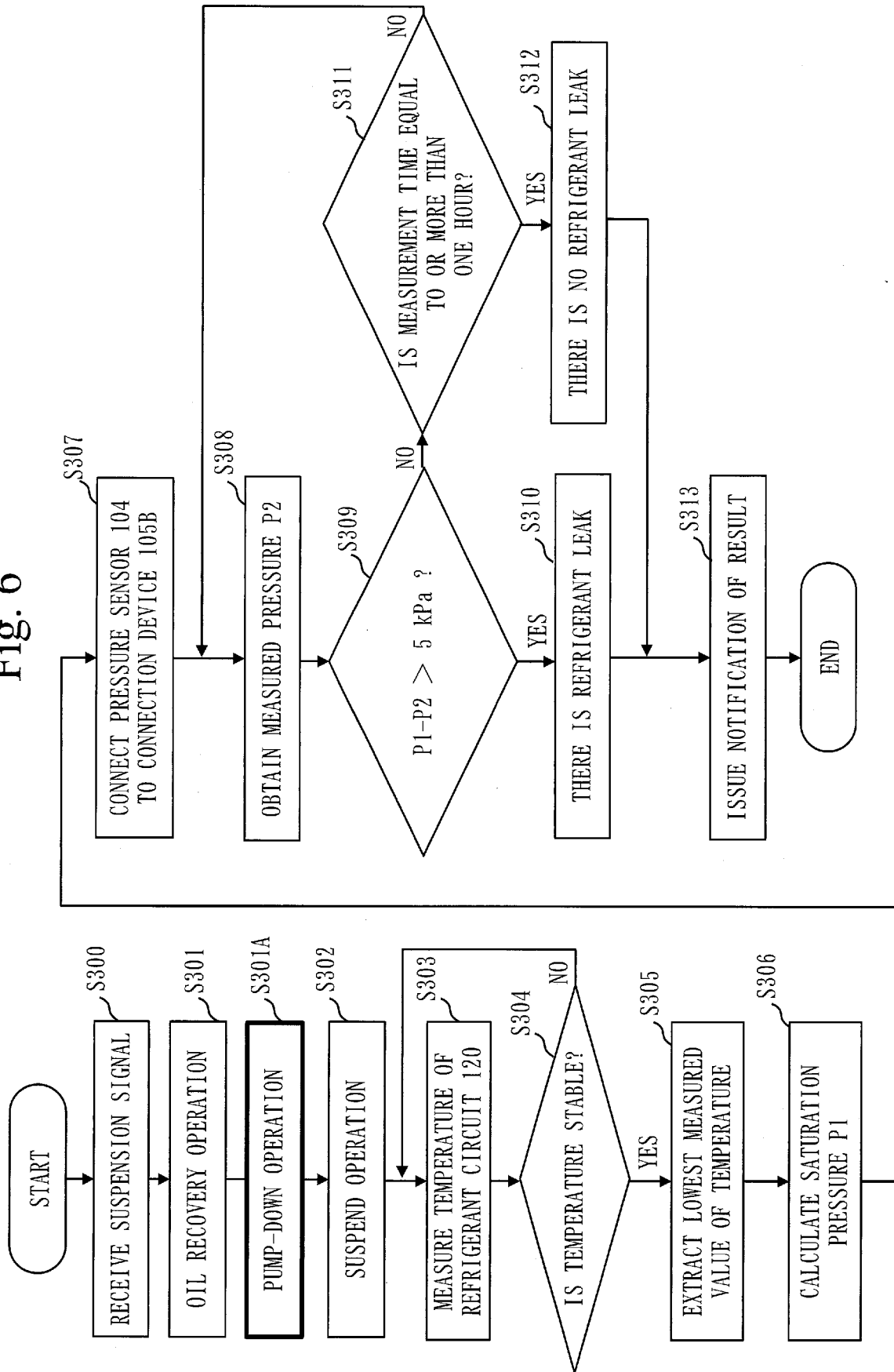
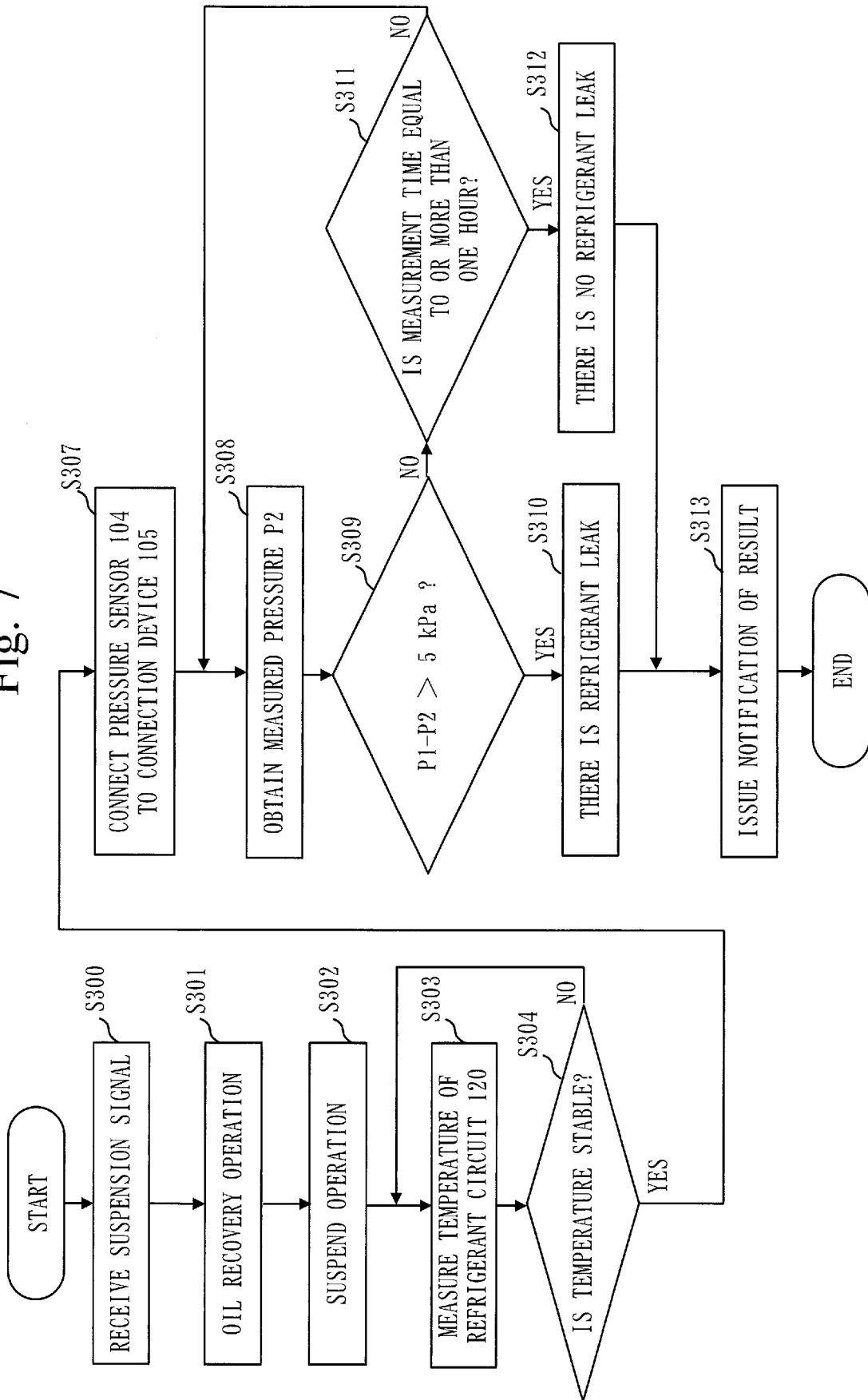


Fig. 7



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2021/020162

**A. CLASSIFICATION OF SUBJECT MATTER****F25B 49/02**(2006.01); **F25B 1/00**(2006.01);

FI: F25B49/02 520B; F25B1/00 387L

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)

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 1971-2021  
 Registered utility model specifications of Japan 1996-2021  
 Published registered utility model applications of Japan 1994-2021

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         | JP 2007-163107 A (DAIKIN IND LTD) 28 June 2007 (2007-06-28)<br>claim 1, paragraphs [0014]-[0017], [0025]-[0031], [0037]-[0039], fig. 1-2, 4 | 1-11                  |
| Y         | JP 4-225769 A (MITSUBISHI HEAVY IND LTD) 14 August 1992 (1992-08-14)<br>claim 1, paragraphs [0033]-[0037], fig. 1-4, 9                      | 1-11                  |
| Y         | JP 2002-213847 A (BEHR GMBH & CO) 31 July 2002 (2002-07-31)<br>claim 1, paragraphs [0019]-[0020], fig. 1-2                                  | 1-11                  |
| Y         | JP 2009-243719 A (MITSUBISHI HEAVY IND LTD) 22 October 2009 (2009-10-22)<br>paragraphs [0034], [0039]                                       | 7-9                   |
| Y         | JP 7-332806 A (NIPPONDENSO CO LTD) 22 December 1995 (1995-12-22)<br>paragraph [0065]                                                        | 7-9                   |

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

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Date of the actual completion of the international search

22 June 2021

Date of mailing of the international search report

06 July 2021

Name and mailing address of the ISA/JP

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 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915  
 Japan

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Telephone No.

**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No.

**PCT/JP2021/020162**

| Patent document<br>cited in search report | Publication date<br>(day/month/year) | Patent family member(s)                                                                                                                                                                                               | Publication date<br>(day/month/year) |
|-------------------------------------------|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|
| JP 2007-163107 A                          | 28 June 2007                         | US 2009/0308088 A1<br>claim 1, paragraphs [0036]-[0040], [0049]-[0059], [0070]-[0074], fig. 1-2, 4<br>WO 2007/069625 A1<br>EP 1965159 A1<br>KR 10-2008-0071602 A<br>CN 101331371 A<br>AU 2006324542 A<br>ES 2640864 T |                                      |
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| JP 7-332806 A                             | 22 December 1995                     | US 5619861 A<br>column 14, lines 17-28<br>US 5706666 A                                                                                                                                                                |                                      |

Form PCT/ISA/210 (patent family annex) (January 2015)

**REFERENCES CITED IN THE DESCRIPTION**

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- JP H04225769 A [0003]