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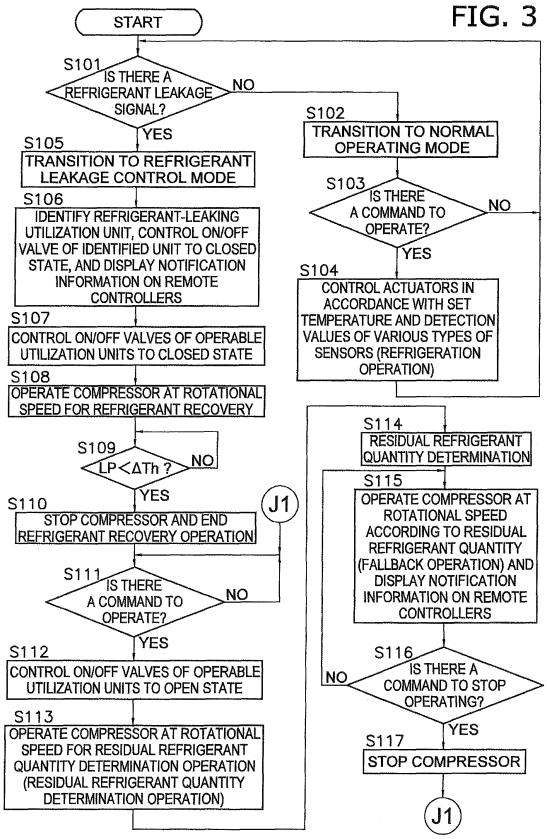
(54) REFRIGERATING DEVICE

(57) The purpose is to improve the security of a refrigeration apparatus including plural utilization units. A refrigeration apparatus (100) comprises: a refrigerant circuit (RC) that includes a heat source unit (10) which has a compressor (11), and plural utilization units (30), each of which has a utilization-side heat exchanger (32) and which are disposed in parallel to each other; plural on/off valves (36) that cut off a flow of supplied refrigerant in a closed state; and a controller (60) that controls the operation of the compressor (11) and each of the on/off valves (36) in accordance with a control mode. Each of the on/off valves (36) is disposed on a refrigerant inlet side of any of the utilization-side heat exchangers (32). The controller (60) is electrically connected to refrigerant leakage sensors (40) and, in a case where the refrigerant leakage sensors (40) have detected refrigerant leakage in any of the utilization units (30), transitions to a refrigerant leakage control mode, controls to the closed state the on/off valve (36) disposed on the inlet side of the utilization-side heat exchanger (32) of the refrigerant-leaking utilization unit (30), and causes the compressor (11) to operate at a predetermined rotational speed.

FIG. 3



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Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration apparatus.

BACKGROUND ART

[0002] Conventionally, a refrigeration apparatus having a refrigerant circuit where plural utilization units including utilization-side heat exchangers are connected in parallel to a heat source unit including a compressor has been known. For example, in the air conditioning system disclosed in patent document 1 (Japanese Laid-open Patent Publication No. 2013-24540), a refrigerant circuit where plural indoor units are connected in parallel to an outdoor unit including a compressor is configured.

SUMMARY OF THE INVENTION

<Technical Problem>

[0003] In this kind of refrigeration apparatus, there is the potential for refrigerant leakage caused by pipe damage or the like, in each of the utilization units. In a refrigeration apparatus having plural utilization units, the quantity of refrigerant contained in the refrigerant circuit is large compared to a refrigeration apparatus having a single utilization unit, so in a case where refrigerant leakage has occurred, cases are also assumed where the concentration of leaking refrigerant becomes greater in the spaces where those utilization units are installed. In such a case as this, when the leaking refrigerant is, for example, a mildly flammable refrigerant such as R32, a flammable refrigerant such as propane, or a toxic refrigerant such as ammonia, security is not ensured.

[0004] It is a problem of the present invention to improve the security of a refrigeration apparatus including plural utilization units.

<Solution to Problem>

[0005] A refrigeration apparatus pertaining to a first aspect of the present invention has a refrigerant circuit, a plurality of inlet valves, and a control unit. The refrigerant circuit is configured and arranged to include a heat source unit and a plurality of utilization units. The heat source unit has a compressor. Each of the utilization units has a utilization-side heat exchanger. The plurality of utilization units are disposed in parallel to each other. The inlet valves are configured and arranged to cut off a flow of supplied refrigerant in a closed state. The control unit is configured and arranged to transition to a predetermined control mode in accordance with the situation. The control unit is configured and arranged to control the operation of the compressor and each of the inlet valves in accordance with the control mode. Each of the inlet valves is disposed on a refrigerant inlet side of any of the utilization-side heat exchangers. The control unit is electrically connected to refrigerant leakage sensors. The refrigerant leakage sensor are configured and arranged to detect refrigerant leakage inside each of the utilization units. The control unit is configured and arranged to transition to a refrigerant leakage control mode in a case where the refrigerant leakage sensors have detected refrigerant leakage in any of the utilization units. The control unit is configured and arranged to, in the refrigerant leakage control mode, control to the closed state the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has been detected and cause the compressor to operate at a predetermined rotational speed.

[0006] In the refrigeration apparatus pertaining to the first aspect of the present invention, in a case where the refrigerant leakage sensors have detected refrigerant leakage in any of the utilization units, the control unit transitions to the refrigerant leakage control mode, controls to the closed state the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has been detected, and causes the compressor to operate at the predetermined rotational speed. Due to this, the supply of the refrigerant to the utilization unit in which the refrigerant leakage is occurring is stopped. As a result, even in a case where refrigerant leakage has occurred in any of the utilization units, an increase in the quantity of leaking refrigerant is restrained.

[0007] Furthermore, the compressor is operated in a state in which the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has been detected is closed, so the refrigerant remaining inside the utilization unit in which the refrigerant leakage is occurring is recovered to the heat source unit, so that an increase in the quantity of leaking refrigerant is restrained.

[0008] Thus, increasing the concentration of leaking refrigerant is restrained from becoming greater in the space where the utilization unit in which the refrigerant leakage is occurring is installed. Consequently, the security of the refrigeration

apparatus including the plural utilization units in the refrigerant circuit is improved.

[0009] It will be noted that the "inlet valves" may be disposed inside the utilization units or may be disposed outside the utilization units.

[0010] Furthermore, the refrigerant used in the "refrigerant circuit" is not particularly limited, and, for example, a mildly flammable refrigerant such as R32, or a flammable refrigerant such as propane, or a toxic refrigerant such as ammonia is assumed.

[0011] Furthermore, "cause the compressor to operate at a predetermined rotational speed" includes not only causing the compressor to operate at a fixed rotational speed determined beforehand but also causing the compressor to rotate at a rotational speed selected from among a predetermined range of rotational speeds defined beforehand (appropriately selecting a rotational speed according to the situation and causing the compressor to operate at that rotational speed).

[0012] A refrigeration apparatus pertaining to a second aspect of the present invention is the refrigeration apparatus pertaining to the first aspect, wherein in the refrigerant leakage control mode, the control unit is configured and arranged to control, to a predetermined opening degree for a refrigerant recovery operation, the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has not been detected.

[0013] Due to this, the refrigerant inside each of the utilization units including the utilization unit in which the refrigerant leakage is occurring is recovered to the heat source unit. As a result, a situation where the refrigerant flows into the utilization unit in which the refrigerant leakage is occurring from the other utilization unit so that the quantity of leaking refrigerant increases is restrained. Thus, the security of the refrigeration apparatus including the plural utilization units in the refrigerant circuit is further improved.

[0014] A refrigeration apparatus pertaining to a third aspect of the present invention is the refrigeration apparatus pertaining to the first aspect or the second aspect, further has a plurality of outlet valves. The outlet valves are configured and arranged to cut off, on refrigerant outlet sides of the utilization-side heat exchangers, a flow of the refrigerant from the outlet sides to the inlet sides. Each of the outlet valves is disposed on the outlet side of any of the utilization-side heat exchangers. The control unit is configured and arranged to, when it is assumed that recovery of the refrigerant from each of the utilization-side heat exchangers to the heat source unit has been completed in the refrigerant leakage control mode, cause a fallback operation of the compressor to be performed. The control unit is configured and arranged to control, in the fallback operation, to a predetermined opening degree for the fallback operation, the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has not been detected.

[0015] Due to this, the compressor is fallback-operated even in a case where refrigerant leakage has occurred in any of the utilization units. As a result, the refrigeration cycle is performed in the utilization unit in which the refrigerant leakage is not occurring. Thus, deterioration of products requiring temperature management or a reduction in comfort is restrained in the space where the utilization unit in which the refrigerant leakage is not occurring is installed.

[0016] A refrigeration apparatus pertaining to a fourth aspect of the present invention is the refrigeration apparatus pertaining to any of the first aspect to the third aspect, further has an information output unit. The information output unit is configured and arranged to be controlled by the control unit. The information output unit is configured and arranged to output information. The control unit is configured and arranged to, in the refrigerant leakage control mode, cause the information output unit to output predetermined notification information.

[0017] Due to this, in a case where refrigerant leakage has occurred in the utilization units, the predetermined notification information (e.g., information identifying the fact that refrigerant leakage has occurred and the utilization unit in which the refrigerant leakage is occurring) is output. As a result, in a case where refrigerant leakage has occurred in any of the utilization units, the manager can easily recognize this state of affairs and is urged to take action. Thus, security with respect to refrigerant leakage is further improved.

<Advantageous Effects of Invention>

[0018] In the refrigeration apparatus pertaining to the first aspect of the present invention, the supply of the refrigerant to the utilization unit in which the refrigerant leakage is occurring is stopped. As a result, even in a case where refrigerant leakage has occurred in any of the utilization units, an increase in the quantity of leaking refrigerant is restrained. Furthermore, the refrigerant remaining inside the utilization unit in which the refrigerant leakage is occurring is recovered to the heat source unit, so that an increase in the quantity of leaking refrigerant is restrained. Thus, increasing the concentration of leaking refrigerant is restrained from becoming greater in the space where the utilization unit in which the refrigerant leakage is occurring is installed. Consequently, the security of the refrigeration apparatus including the plural utilization units in the refrigerant circuit is improved.

[0019] In the refrigeration apparatus pertaining to the second aspect of the present invention, a situation where the refrigerant flows into the utilization unit in which the refrigerant leakage is occurring from the other utilization unit so that the quantity of leaking refrigerant increases is restrained. Thus, the security of the refrigeration apparatus including the plural utilization units in the refrigerant circuit is further improved.

[0020] In the refrigeration apparatus pertaining to the third aspect of the present invention, the refrigeration cycle is performed in the utilization unit in which the refrigerant leakage is not occurring. Thus, deterioration of products requiring temperature management or a reduction in comfort is restrained in the space where the utilization unit in which the refrigerant leakage is not occurring is installed.

[0021] In the refrigeration apparatus pertaining to the fourth aspect of the present invention, the predetermined notification information is output in a case where refrigerant leakage has occurred in the utilization units. As a result, in a case where refrigerant leakage has occurred in any of the utilization units, the manager can easily recognize this state of affairs and is urged to take action. Thus, security with respect to refrigerant leakage is further improved.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG. 1 is an overall configuration diagram of a refrigeration apparatus pertaining to an embodiment of the present invention.

FIG. 2 is a block diagram schematically showing the general configuration of a controller and units connected to the controller.

FIG. 3 is a flowchart showing an example of a flow of processes executed by the controller.

FIG. 4 is a timing chart showing an example of changes in the states of respective on/off valves and a compressor at the time of operation.

FIG. 5 is an overall configuration diagram of a refrigeration apparatus having a refrigerant circuit pertaining to modification A.

FIG. 6 is an overall configuration diagram of a refrigeration apparatus having a refrigerant circuit pertaining to modification B.

DESCRIPTION OF EMBODIMENTS

[0023] A refrigeration apparatus 100 pertaining to an embodiment of the present invention will be described below with reference to the drawings. It will be noted that the following embodiment is a specific example of the present invention, is not intended to limit the technical scope of the present invention, and can be appropriately changed to the extent that it does not depart from the spirit of the present invention.

(1) Refrigeration Apparatus 100

[0024] FIG. 1 is an overall configuration diagram of the refrigeration apparatus 100 pertaining to the embodiment of the present invention. The refrigeration apparatus 100 is a system that performs, by means of a vapor compression refrigeration cycle, refrigeration of utilization-side spaces such as interior spaces of refrigerated storage rooms or showcases in a store. The refrigeration apparatus 100 mainly has a heat source unit 10, plural (here, three) utilization units 30 (30a, 30b, 30c), a liquid refrigerant communication pipe L1 and a gas refrigerant communication pipe G1 that interconnect the heat source unit 10 and the utilization units 30, refrigerant leakage sensors 40 (40a, 40b, 40c) that detect refrigerant leakage inside each of the utilization units 30, plural remote controllers 50 (50a, 50b, 50c) serving as input devices and as display devices, and a controller 60 that controls the operation of the refrigeration apparatus 100.

[0025] In the refrigeration apparatus 100, a refrigerant circuit RC is configured as a result of the one heat source unit 10 and the plural (here, three) utilization units 30 being interconnected via the liquid refrigerant communication pipe L1 and the gas refrigerant communication pipe G1. In the refrigeration apparatus 100, a refrigeration cycle is performed wherein refrigerant contained inside the refrigerant circuit RC is compressed, cooled or condensed, reduced in pressure, heated or evaporated, and thereafter again compressed. In the present embodiment, the refrigerant circuit RC is charged with R32 as the refrigerant for performing the vapor compression refrigeration cycle.

(1-1) Heat Source Unit 10

[0026] The heat source unit 10 is connected to the utilization units 30 via the liquid refrigerant communication pipe L1 and the gas refrigerant communication pipe G1, and configures part of the refrigerant circuit RC. The heat source unit 10 mainly has a compressor 11, a heat source-side heat exchanger 12, a receiver 13, a sub-cooler 14, a heat source-side expansion valve 15 (expansion mechanism), an injection valve 16, a liquid-side shut-off valve 17, and a gas-side shut-off valve 18.

[0027] The heat source unit 10 has a first heat source-side gas refrigerant pipe P1 that interconnects the discharge side of the compressor 11 and the gas-side end of the heat source-side heat exchanger 12, a heat source-side liquid

refrigerant pipe P2 that interconnects the liquid-side end of the heat source-side heat exchanger 12 and the liquid refrigerant communication pipe L1, and a second heat source-side gas refrigerant pipe P3 that interconnects the suction side of the compressor 11 and the gas refrigerant communication pipe G1.

[0028] The heat source unit 10 has an injection pipe P4 that diverts some of the refrigerant flowing through the heat source-side liquid refrigerant pipe P2 and returns the diverted refrigerant to the compressor 11. The injection pipe P4 branches from the section of the heat source-side liquid refrigerant pipe P2 located on the downstream side of the sub-cooler 14, passes through the sub-cooler 14, and is then connected to the middle of the compression stroke of the compressor 11.

[0029] The compressor 11 is a device that compresses refrigerant at a low pressure in the refrigeration cycle to a high pressure. Here, as the compressor 11, a compressor with a closed structure in which a rotary, scroll or the like positive-displacement compression element (not shown in the drawings) is driven to rotate by a compressor motor M11 is used. Furthermore, the operating frequency of the compressor motor M11 can be controlled by an inverter, whereby the capacity of the compressor 11 can be controlled.

[0030] The heat source-side heat exchanger 12 is a heat exchanger that functions as a radiator or condenser of refrigerant at a high pressure in the refrigeration cycle. Here, the heat source unit 10 has a heat source-side fan 19 for sucking outside air (heat source-side air) into the heat source unit 10, causing the air to exchange heat with the refrigerant in the heat source-side heat exchanger 12, and thereafter discharge the air to the outside. The heat source-side fan 19 is a fan for supplying to the heat source-side heat exchanger 12 the heat source-side air serving as a cooling source for the refrigerant flowing through the heat source-side heat exchanger 12. The heat source-side fan 19 is driven to rotate by a heat source-side fan motor M19.

[0031] The receiver 13 is a vessel that temporarily stores the refrigerant condensed in the heat source-side heat exchanger 12, and is disposed in the heat source-side liquid refrigerant pipe P2.

[0032] The sub-cooler 14 is a heat exchanger that further cools the refrigerant temporarily stored in the receiver 13, and is disposed in the heat source-side liquid refrigerant pipe P2 (more specifically, in the section thereof on the downstream side of the receiver 13).

[0033] The heat source-side expansion valve 15 is an electrically powered expansion valve whose opening degree can be controlled, and is disposed in the heat source-side liquid refrigerant pipe P2 (more specifically, in the section thereof on the downstream side of the sub-cooler 14).

[0034] The injection valve 16 is disposed in the injection pipe P4 (more specifically, in the section thereof that leads to the inlet of the sub-cooler 14). The injection valve 16 is an electrically powered expansion valve whose opening degree can be controlled. The injection valve 16 reduces, in accordance with its opening degree, the pressure of the refrigerant flowing through the injection pipe P4 before allowing the refrigerant to flow into the sub-cooler 14.

[0035] The liquid-side shut-off valve 17 is a manual valve disposed in the section of the heat source-side liquid refrigerant pipe P2 connected to the liquid refrigerant communication pipe L1.

[0036] The gas-side shut-off valve 18 is a manual valve disposed in the section of the second heat source-side gas refrigerant pipe P3 connected to the gas refrigerant communication pipe G1.

[0037] Various types of sensors are disposed in the heat source unit 10. Specifically, a suction pressure sensor 20 which detects a suction pressure LP that is the pressure of the refrigerant on the suction side of the compressor 11, and a discharge pressure sensor 21 which detects a discharge pressure HP that is the pressure of the refrigerant on the discharge side of the compressor 11, are disposed in the vicinity of the compressor 11 of the heat source unit 10. Furthermore, a receiver outlet temperature sensor 22, which detects the receiver outlet temperature that is the temperature of the refrigerant at the outlet of the receiver 13, is disposed in the section of the heat source-side liquid refrigerant pipe P2 between the outlet of the receiver 13 and the inlet of the sub-cooler 14. Moreover, a heat source-side air temperature sensor 23, which detects the temperature of the heat source-side air sucked into the heat source unit 10, is disposed in the vicinity of the heat source-side heat exchanger 12 or the heat source-side fan 19.

[0038] The heat source unit 10 has a heat-source-unit control unit 25 that controls the operation of each part configuring the heat source unit 10. The heat-source-unit control unit 25 has a microcomputer including a CPU and a memory or the like. The heat source control unit 25 is connected via a communication line cb1 to utilization-unit control units 38 of each of the utilization units 30, and sends controls signals and so forth to, and receives control signals and so forth from, the utilization-unit control units 38.

(1-2) Utilization Units 30

[0039] The utilization units 30 are connected to the heat source unit 10 via the liquid refrigerant communication pipe L1 and the gas refrigerant communication pipe G1, and configure part of the refrigerant circuit RC. In the present embodiment, three utilization units 30 (30a, 30b, and 30c) are connected to one heat source unit 10. The utilization units 30 are disposed in parallel to each other.

[0040] Each of the utilization units 30 has a utilization-side expansion valve 31 and a utilization-side heat exchanger

32 (evaporator). Furthermore, each of the utilization units 30 has a utilization-side liquid refrigerant pipe P5 which interconnects the liquid-side end of the utilization-side heat exchanger 32 and the liquid refrigerant communication pipe L1, and a utilization-side gas refrigerant pipe P6 which interconnects the gas-side end of the utilization-side heat exchanger 32 and the gas refrigerant communication pipe G1.

[0041] The utilization-side expansion valve 31 is a throttling mechanism that functions as a means (expanding means) for reducing the pressure of the high-pressure refrigerant sent from the heat source unit 10. In the present embodiment, the utilization-side expansion valve 31 is a thermostatic expansion valve including a thermosensitive cylinder and operates (its opening degree is automatically determined) in accordance with changes in the temperature of the thermosensitive cylinder.

[0042] The utilization-side heat exchanger 32 is a heat exchanger that functions as an evaporator of the refrigerant at a low temperature in the refrigeration cycle to refrigerate the interior space air (utilization-side air). Here, the utilization unit 30 has a utilization-side fan 35 for sucking the utilization-side air into the utilization unit 30, causing the utilization-side air to exchange heat with the refrigerant in the utilization-side heat exchanger 32, and thereafter supplying the utilization-side air to the utilization-side space. The utilization-side fan 35 is a fan for supplying to the utilization-side heat exchanger 32 the utilization-side air serving as a heating source for the refrigerant flowing through the utilization-side heat exchanger 32. The utilization-side fan 35 is driven to rotate by a utilization-side fan motor M35.

[0043] Furthermore, each of the utilization units 30 has an on/off valve 36 (inlet valve) capable of cutting off the flow of refrigerant flowing into the utilization unit 30. The on/off valve 36 is disposed on the liquid refrigerant inlet side (the liquid refrigerant communication pipe L1 side) of the utilization unit 30. Specifically, the on/off valve 36 is disposed on nearer to the inlet side than the utilization-side heat exchanger 32. More specifically, the on/off valve 36 is disposed on nearer to the inlet side than the utilization-side expansion valve 31. In the present embodiment, the on/off valve 36 is an electromagnetic valve that is switched between an open state and a closed state. Specifically, the on/off valve 36 is switched from the open state to the closed state as a result of being powered. When the on/off valve 36 is switched to the closed state, the on/off valve 36 cuts off the flow of refrigerant flowing into the utilization unit 30 (more specifically, the utilization-side heat exchanger 32). The on/off valve 36 is controlled so as to normally be in the open state.

[0044] Furthermore, each of the utilization units 30 has a check valve 37 (outlet valve) capable of cutting off the flow of refrigerant flowing (back-flowing) into the utilization unit 30 from its outlet side. The check valve 37 is disposed on the refrigerant outlet side (the gas refrigerant communication pipe G1 side) of the utilization unit 30. Specifically, the check valve 37 is disposed on nearer to the outlet side than the utilization-side heat exchanger 32. The check valve 37 allows the flow of refrigerant from the utilization-side gas refrigerant pipe P6 to the gas refrigerant communication pipe G1 but cuts off the flow of refrigerant from the gas refrigerant communication pipe G1 to the utilization-side gas refrigerant pipe P6 (more specifically, nearer to the utilization-side heat exchanger 32 side than the check valve 37).

[0045] Furthermore, each of the utilization units 30 has a utilization-unit control unit 38 that controls the operation of each part configuring the utilization unit 30. The utilization-unit control unit 38 has a microcomputer including a CPU and a memory, or the like. The utilization-unit control unit 38 is connected via the communication line cb1 to the heat-source-unit control unit 25, and sends control signals and so forth to, and receives control signals and so forth from, the heat-source-unit control unit 25. The utilization-unit control unit 38 is electrically connected to the refrigerant leakage sensor 40, and signals from the refrigerant leakage sensor 40 are output to the utilization-unit control unit 38.

(1-3) Refrigerant Leakage Sensors 40

[0046] The refrigerant leakage sensors 40 are sensors for detecting refrigerant leakage inside the interior spaces where the utilization units 30 are disposed (more specifically, inside the spaces of the utilization units 30). In the present embodiment, a known general-purpose sensor is used for the refrigerant leakage sensors 40.

[0047] The refrigerant leakage sensors 40 are disposed inside casings of the corresponding utilization units 30. That is, the refrigerant leakage sensors 40 are disposed inside each of the utilization units 30, so that the refrigeration apparatus 100 has the same number of refrigerant leakage sensors 40 as utilization units 30.

[0048] The refrigerant leakage sensors 40 are electrically connected to the utilization-unit control units 38 of the corresponding utilization units 30. Specifically, the refrigerant leakage sensor 40a is connected to the utilization-unit control unit 38 of the utilization unit 30a, the refrigerant leakage sensor 40b is connected to the utilization-unit control unit 38 of the utilization unit 30b, and the refrigerant leakage sensor 40c is connected to the utilization-unit control unit 38 of the utilization unit 30c respectively. When the refrigerant leakage sensor 40 detects refrigerant leakage, the refrigerant leakage sensor 40 outputs to the utilization-unit control unit 38 to which it is connected an electrical signal (hereinafter called a "refrigerant leakage signal") indicating that refrigerant leakage is occurring.

(1-4) Remote Controllers 50 (Information Output Units)

[0049] The remote controllers 50 are input devices for users to input various types of instructions for switching the

operating state of the refrigeration apparatus 100. Furthermore, the remote controllers 50 also function as display devices for displaying the operating state of the refrigeration apparatus 100 and predetermined notification information. The remote controllers 50 are connected via communication lines cb2 to the utilization-unit control units 38, and send signals to, and receive signals from, the utilization-unit control units 38. Specifically, the remote controller 50a is connected to the utilization-unit control unit 38 of the utilization unit 30a, the remote controller 50b is connected to the utilization-unit control unit 38 of the utilization unit 30b, and the remote controller 50c is connected to the utilization-unit control unit 38 of the utilization unit 30c.

(1-5) Controller 60 (Control Unit)

[0050] In the refrigeration apparatus 100, the controller 60 that controls the operation of the refrigeration apparatus 100 is configured as a result of the heat-source-unit control unit 25 and the respective utilization-unit control units 38 being interconnected via the communication line cb1. Details of the controller 60 will be described in "(3) Details of Controller 60" below.

(2) Flow of Refrigerant in Refrigerant Circuit RC in Refrigeration operation

[0051] The flow of the refrigerant in the refrigerant circuit RC in each operating mode will be described below. In the refrigeration apparatus 100, at the time of operation, a refrigeration operation (refrigeration cycle operation) is performed wherein the refrigerant charged in the refrigerant circuit RC circulates mainly in the order of the compressor 11, the heat source-side heat exchanger 12 (radiator), the receiver 13, the sub-cooler 14, the heat source-side expansion valve 15 (expansion mechanism), the utilization-side expansion valves 31, and the utilization-side heat exchangers 32 (evaporators).

[0052] When the refrigeration operation is started, inside the refrigerant circuit RC the refrigerant is sucked into the compressor 11, compressed, and thereafter discharged. Here, the low pressure in the refrigeration cycle is the suction pressure LP detected by the suction pressure sensor 20, and the high pressure in the refrigeration cycle is the discharge pressure HP detected by the discharge pressure sensor 21.

[0053] In the compressor 11, capacity control according to the cooling load required by the utilization units 30 is performed. Specifically, a target value for the suction pressure LP is set in accordance with the cooling load required by the utilization units 30, and the operating frequency of the compressor 11 is controlled so that the suction pressure LP reaches the target value. The gas refrigerant discharged from the compressor 11 travels through the first heat source-side gas refrigerant pipe P1 and flows into the gas-side end of the heat source-side heat exchanger 12.

[0054] The gas refrigerant that has flowed into the gas-side end of the heat source-side heat exchanger 12 exchanges heat with the heat source-side air supplied by the heat source-side fan 19, radiates heat, condenses, and becomes liquid refrigerant in the heat source-side heat exchanger 12, and then the liquid refrigerant flows out from the liquid-side end of the heat source-side heat exchanger 12.

[0055] The liquid refrigerant that has flowed out from the liquid-side end of the heat source-side heat exchanger 12 travels through the section of the heat source-side liquid refrigerant pipe P2 between the heat source-side heat exchanger 12 and the receiver 13 and flows into the inlet of the receiver 13. The liquid refrigerant that has flowed into the receiver 13 is temporarily stored as liquid refrigerant in a saturated state in the receiver 13, and thereafter flows out from the outlet of the receiver 13.

[0056] The liquid refrigerant that has flowed out from the outlet of the receiver 13 travels through the section of the heat source-side liquid refrigerant pipe P2 between the receiver 13 and the sub-cooler 14 and flows into the inlet on the heat source-side liquid refrigerant pipe P2 side of the sub-cooler 14.

[0057] The liquid refrigerant that has flowed into the sub-cooler 14 exchanges heat with the refrigerant flowing through the injection pipe P4, is further cooled, and becomes liquid refrigerant in a sub-cooled state in the sub-cooler 14, and then the sub-cooled liquid refrigerant flows out from the outlet on the heat source-side liquid refrigerant pipe P2 side of the sub-cooler 14.

[0058] The liquid refrigerant that has flowed out from the outlet on the heat source-side liquid refrigerant pipe P2 side of the sub-cooler 14 travels through the section of the heat source-side liquid refrigerant pipe P2 between the sub-cooler 14 and the heat source-side expansion valve 15 and flows into the heat source-side expansion valve 15. At this time, some of the liquid refrigerant that has flowed out from the outlet on the heat source-side liquid refrigerant pipe P2 side of the sub-cooler 14 is diverted to the injection pipe P4 from the section of the heat source-side liquid refrigerant pipe P2 between the sub-cooler 14 and the heat source-side expansion valve 15.

[0059] The refrigerant flowing through the injection pipe P4 has its pressure reduced by the injection valve 16 to an intermediate pressure in the refrigeration cycle. The refrigerant flowing through the injection pipe P4 after its pressure has been reduced by the injection valve 16 flows into the inlet on the injection pipe P4 side of the sub-cooler 14. The refrigerant that has flowed into the inlet on the injection pipe P4 side of the sub-cooler 14 exchanges heat with the

refrigerant flowing through the heat source-side liquid refrigerant pipe P2, is heated, and becomes gas refrigerant in the sub-cooler 14. Then, the refrigerant heated in the sub-cooler 14 flows out from the outlet on the injection pipe P4 side of the sub-cooler 14 and is returned to the middle of the compression stroke of the compressor 11.

[0060] The liquid refrigerant that has flowed into the heat source-side expansion valve 15 from the heat source-side liquid refrigerant pipe P2 has its pressure reduced by the heat source-side expansion valve 15, thereafter travels through the liquid-side shut-off valve 17 and the liquid refrigerant communication pipe L1, and flows into the utilization units 30 that are in operation.

[0061] The refrigerant that has flowed into the utilization units 30 travels through the on/off valves 36 and part of the utilization-side liquid refrigerant pipes P5 and flows into the utilization-side expansion valves 31. The refrigerant that has flowed into the utilization-side expansion valves 31 has its pressure reduced by the utilization-side expansion valves 31 to a low pressure in the refrigeration cycle, travels through the utilization-side liquid refrigerant pipes P5, and flows into the liquid-side ends of the utilization-side heat exchangers 32.

[0062] The refrigerant that has flowed into the liquid-side ends of the utilization-side heat exchangers 32 exchanges heat with the utilization-side air supplied by the utilization-side fans 35, evaporates, and becomes gas refrigerant in the utilization-side heat exchangers 32, and then the gas refrigerant flows out from the gas-side ends of the utilization-side heat exchangers 32.

[0063] The gas refrigerant that has flowed out from the gas-side ends of the utilization-side heat exchangers 32 travels through the check valves 37, the utilization-side gas refrigerant pipes P6, the gas refrigerant communication pipe G1, the gas-side shut-off valve 18, and the second heat source-side gas refrigerant pipe P3, and is sucked back into the compressor 11.

(3) Details of Controller 60

[0064] In the refrigeration apparatus 100, the controller 60 is configured as a result of the heat-source-unit control unit 25 and the utilization-unit control units 38 being interconnected by the communication line cb1. FIG. 2 is a block diagram schematically showing the general configuration of the controller 60 and units connected to the controller 60.

[0065] The controller 60 has plural control modes and controls the operation of the refrigeration apparatus 100 in accordance with the control mode to which it has transitioned. For example, the controller 60 has, as control modes, a normal operating mode, to which it transitions during normal times, and a refrigerant leakage control mode, to which it transitions when refrigerant leakage has occurred.

[0066] The controller 60 is electrically connected to each of the actuators (specifically, the compressor 11 (the compressor motor M11), the heat source-side expansion valve 15, the injection valve 16, and the heat source-side fan 19 (the heat source-side fan motor M19)) included in the heat source unit 10 and the various types of sensors (the suction pressure sensor 20, the discharge pressure sensor 21, the receiver outlet temperature sensor 22, and the heat source-side air temperature sensor 23, etc.). Furthermore, the controller 60 is electrically connected to the actuators (specifically, the utilization-side fan motors M35 and the on/off valves 36) included in each of the utilization units 30 (30a, 30b, and 30c). Furthermore, the controller 60 is electrically connected to each of the refrigerant leakage sensors 40 (40a, 40b, and 40c) and each of the remote controllers 50 (50a, 50b, and 50c).

[0067] The controller 60 mainly has a storage component 61, a communication component 62, a mode control unit 63, an actuator control unit 64, and a display control unit 65. It will be noted that each of these components in the controller 60 is realized by components included in the heat-source-unit control unit 25 and/or the utilization-unit control units 38 integrally functioning.

(3-1) Storage Component 61

[0068] The storage component 61 is configured by a ROM, a RAM, and a flash memory, for example, and includes a volatile storage region and a nonvolatile storage region. Stored in the storage component 61 is a control program in which processing in each component of the controller 60 is defined. Furthermore, predetermined information (e.g., detection values of each of the sensors, commands that have been input to each of the remote controllers 50, etc.) is appropriately stored in predetermined storage regions of the storage component 61 by the components of the controller 60.

[0069] Furthermore, plural flags having a predetermined number of bits are provided in the storage component 61. For example, refrigerant leakage discrimination flags F1, F2, and F3 for discriminating whether or not refrigerant leakage is occurring inside each of the utilization units 30 are provided in the storage component 61. It will be noted that the refrigerant leakage discrimination flag F1 corresponds to the refrigerant leakage sensor 40a, the refrigerant leakage discrimination flag F2 corresponds to the refrigerant leakage sensor 40b, and the refrigerant leakage discrimination flag F3 corresponds to the refrigerant leakage sensor 40c.

[0070] Furthermore, a control mode discrimination flag F4 capable of discriminating the control mode to which the controller 60 has transitioned is provided in the storage component 61. The control mode discrimination flag F4 is set

in a case where the controller 60 has transitioned to the refrigerant leakage control mode.

(3-2) Communication Component 62

[0071] The communication component 62 is a functional component that fulfills a role as a communication interface for sending signals to and receiving signals from each of the devices connected to the controller 60. The communication component 62 receives requests from the actuator control unit 64 and sends predetermined signals to designated actuators. Furthermore, the communication component 62 receives signals that have been output from the various types of sensors (20 to 23), each of the refrigerant leakage sensors 40, and each of the remote controllers 50, and stores the signals in predetermined storage regions of the storage component 61.

[0072] Furthermore, when the communication component 62 receives the refrigerant leakage signals from the refrigerant leakage sensors 40, the communication component 62 raises the refrigerant leakage discrimination flags (F1, F2, or F3). Specifically, the communication component 62 raises the refrigerant leakage discrimination flag F1 in a case where it has received the refrigerant leakage signal from the refrigerant leakage sensor 40a, raises the refrigerant leakage discrimination flag F2 in a case where it has received the refrigerant leakage signal from the refrigerant leakage sensor 40b, and raises the refrigerant leakage discrimination flag F3 in a case where it has received the refrigerant leakage signal from the refrigerant leakage sensor 40c. That is, the refrigerant leakage discrimination flag F1 is set in a case where refrigerant leakage has occurred in the utilization unit 30a, the refrigerant leakage discrimination flag F2 is set in a case where refrigerant leakage has occurred in the utilization unit 30b, and the refrigerant leakage discrimination flag F3 is set in a case where refrigerant leakage has occurred in the utilization unit 30c.

(3-3) Mode Control Unit 63

[0073] The mode control unit 63 is a functional component that switches the control mode. The mode control unit 63 switches the control mode to the normal operating mode in a case where none of the refrigerant leakage discrimination flags F1, F2, and F3 is set. Specifically, the mode control unit 63 cancels the control mode discrimination flag F4 in a case where none of the refrigerant leakage discrimination flags F1, F2, and F3 is set.

[0074] On the other hand, the mode control unit 63 switches the control mode to the refrigerant leakage control mode when any of the refrigerant leakage discrimination flags F1, F2, and F3 is set. Specifically, the mode control unit 63 raises the control mode discrimination flag F4 when any of the refrigerant leakage discrimination flags F1, F2, and F3 is set.

(3-4) Actuator Control Unit 64

[0075] The actuator control unit 64 controls the operation of each of the actuators (e.g., the compressor 11, the on/off valves 36, etc.) included in the refrigeration apparatus 100 (the heat source unit 10 and the utilization units 30) in accordance with the situation in line with the control program. The actuator control unit 64 discriminates the control mode to which the controller 60 has transitioned by referencing the control mode discrimination flag F4 and controls the operation of each of the actuators on the basis of the control mode.

[0076] For example, in the normal operating mode, the actuator control unit 64 controls in real time the rotational speed of the compressor 11, the rotational speeds of the heat source-side fan 19 and the utilization-side fans 35, and the opening degrees of the heat source-side expansion valve 15 and the injection valve 16 in accordance with the set temperature and the detection values of the various types of sensors.

[0077] Furthermore, in the refrigerant leakage control mode, the actuator control unit 64 controls the operation of each of the actuators in such a way that predetermined operations are performed. Specifically, the operations performed in the refrigerant leakage control mode include a refrigerant recovery operation, a residual refrigerant quantity determination operation, and a fallback operation.

[0078] The refrigerant recovery operation is an operation that recovers, to the heat source unit 10 (particularly the heat source-side heat exchanger 12 and the receiver 13), the refrigerant inside the utilization unit 30 in which refrigerant leakage has occurred (hereinafter called "the refrigerant-leaking utilization unit 30") and the utilization units 30 in which refrigerant leakage has not occurred (hereinafter called "the operable utilization units 30"). The residual refrigerant quantity determination operation is an operation for causing the refrigerant to circulate in the refrigerant circuit RC after the completion of the refrigerant recovery operation to determine the quantity of refrigerant (residual refrigerant quantity) remaining (i.e., not leaking) in the refrigerant circuit RC. The fallback operation is an operation that causes the compressor 11 to operate in accordance with the residual refrigerant quantity to cause the refrigeration cycle to continue in the operable utilization units 30.

[0079] When the control mode discrimination flag F4 is raised (i.e., when the controller 60 transitions to the refrigerant leakage control mode), the actuator control unit 64 references the refrigerant leakage discrimination flags F1, F2, and F3 to identify the refrigerant-leaking utilization unit 30. Then, the actuator control unit 64 controls, to the closed state,

the on/off valve 36 corresponding to the refrigerant-leaking utilization unit 30 (the utilization unit 30 in which the refrigerant leakage has been detected). As a result, as regards the utilization unit 30 in which the refrigerant leakage is occurring, the flow of inflowing refrigerant is cut off so that the refrigerant is no longer supplied. For this reason, further refrigerant leakage is restrained.

[0080] Furthermore, the actuator control unit 64 also controls, to the closed state, the on/off valves 36 corresponding to each of the operable utilization units 30 (the utilization units 30 in which refrigerant leakage has not been detected). Then, the actuator control unit 64 causes the compressor 11 to be driven at a predetermined rotational speed for the refrigerant recovery operation. Because of this, the refrigerant recovery operation is started and the refrigerant inside each of the utilization units 30 is recovered to the heat source unit 10. It will be noted that in the present embodiment the rotational speed of the compressor 11 in the refrigerant recovery operation is set to the maximum rotational speed so that the refrigerant recovery is completed in the shortest amount of time.

[0081] The actuator control unit 64 ends the refrigerant recovery operation when a state is reached in which it is assumed that the refrigerant recovery has been completed (specifically, a state in which the suction pressure LP is less than a predetermined threshold value ΔTh) after the start of the refrigerant recovery operation. It will be noted that the threshold value ΔTh is set to a value that is not enough to fall below atmospheric pressure on the basis of the quantity of refrigerant contained inside the refrigerant circuit RC and the quantity of refrigerant in circulation determined from the characteristics of the compressor 11. In the present embodiment, the threshold value ΔTh is set to 0.1 MPa.

[0082] Next, the actuator control unit 64 switches, to the open state, the on/off valves 36 corresponding to the operable utilization units 30 (the utilization units 30 that are not leaking refrigerant). Thereafter, the actuator control unit 64 causes the compressor 11 to operate at a predetermined rotational speed for the residual refrigerant quantity determination operation. Because of this, the residual refrigerant quantity determination operation is started. Specifically, the refrigerant is sent from the heat source unit 10 to the operable utilization units 30, and the refrigerant circulates in the refrigerant circuit RC.

[0083] It will be noted that in the present embodiment the actuator control unit 64 causes the compressor 11 to stop temporarily before causing the residual refrigerant quantity determination operation to start after the refrigerant recovery operation. This is to prevent damage to joint sections of refrigerant pipes and devices caused by an abrupt change in the pressure inside the refrigerant circuit RC in a case where the actuator control unit 64 has switched the on/off valves 36 from the closed state to the open state in a state in which the compressor 11 is operating.

[0084] Furthermore, in the residual refrigerant quantity determination operation, the actuator control unit 64 causes the on/off valve 36 corresponding to the refrigerant-leaking utilization unit 30 to maintain its closed state without switching to the open state. Because of this, the refrigerant is not supplied to the refrigerant-leaking utilization unit 30, so further refrigerant leakage from the refrigerant-leaking utilization unit 30 is restrained.

[0085] In the residual refrigerant quantity determination operation, the actuator control unit 64 determines the residual refrigerant quantity by comparing the detection value (the suction pressure LP) of the suction pressure sensor 20 with a predetermined pressure standard value SP at a predetermined timing. In the present embodiment, the actuator control unit 64 is configured to determine the residual refrigerant quantity upon the elapse of a predetermined amount of time t1 after the start of the residual refrigerant quantity determination operation. The predetermined amount of time t1 is appropriately set in accordance with the design specifications and installation environment, and, for example, is set to three minutes.

[0086] Here, the pressure standard value SP is decided in accordance with the detection values of the receiver outlet temperature sensor 22 and the heat source-side air temperature sensor 23, the quantity of refrigerant in circulation determined from the characteristics of the compressor 11, the Cv value of the heat source-side expansion valve 15, and the pipe lengths of the various types of refrigerant pipes, and a pressure standard value table (not shown in the drawings) in which pressure standard values SP by situation are defined is stored in the storage component 61. The actuator control unit 64 decides the pressure standard value SP on the basis of the pressure standard value table. Additionally, the actuator control unit 64 determines the extent of the deficiency (gas deficiency) in the residual refrigerant quantity by comparing the suction pressure LP with the decided pressure standard value SP.

[0087] Thereafter, the actuator control unit 64 causes the compressor 11 to operate at a rotational speed according to the determination result (a rotational speed for the fallback operation). Because of this, the fallback operation is started. As a result, a refrigeration cycle using the residual refrigerant is performed between the heat source unit 10 and the operable utilization units 30. For this reason, refrigeration of refrigerated products (particularly food products requiring temperature management) in the interior spaces where the operable utilization units 30 are installed is continued, so that deterioration is restrained. Furthermore, at this time, the on/off valve 36 of the refrigerant-leaking utilization unit 30 is maintained in the closed state without being switched to the open state, so it is also possible to perform repair work on the refrigerant-leaking utilization unit 30 while the operable utilization units 30 perform the fallback operation.

[0088] Furthermore, in the fallback operation, the compressor 11 is operated at a predetermined rotational speed that has been appropriately determined in accordance with the residual refrigerant quantity. Because of this, a failure of the compressor 11 is restrained. It will be noted that a fallback operation table (not shown in the drawings) in which rotational

speeds of the compressor 11 in the fallback operation are defined is stored in the storage component 61, and the actuator control unit 64 decides the rotational speed of the compressor 11 in the fallback operation by referencing the fallback operation table.

(3-5) Display Control Unit 65

[0089] The display control unit 65 is a functional component that controls the operation of the remote controllers 50 serving as display devices. The display control unit 65 causes the remote controllers 50 to output predetermined information in order to display information pertaining to the operating state and situation to the manager. For example, during the refrigeration operation in the normal mode, the display control unit 65 causes the remote controllers 50 to display various types of information such as the set temperature. Furthermore, in the refrigerant leakage control mode, the display control unit 65 causes the remote controllers 50 to display information (notification information) specifically indicating that refrigerant leakage is occurring and the refrigerant-leaking utilization unit 30. Furthermore, in the refrigerant recovery operation in the refrigerant leakage control mode, the display control unit 65 causes the remote controllers 50 to display notification information indicating that the refrigerant recovery operation is being performed. Furthermore, in the fallback operation in the refrigerant leakage control mode, the display control unit 65 causes the remote controllers 50 to display notification information indicating that the fallback operation is being performed in the operable utilization units 30 and information urging that a service technician be notified.

(4) Flow of Processes Executed by Controller 60

[0090] An example of a flow of processes executed by the controller 60 will be described with reference to FIG. 3. FIG. 3 is a flowchart showing an example of a flow of processes executed by the controller 60.

[0091] When the controller 60 is powered on, the controller 60 performs processes in the flow shown in steps S101 to S117 in FIG. 3. In FIG. 3, processes pertaining to the normal operating mode are shown in steps S102 to S104, and processes pertaining to the refrigerant leakage control mode are shown in steps S105 to S116. More specifically, FIG. 3 shows the refrigeration operation being performed in step S104, the refrigerant recovery operation being performed in steps S106 to S110, the residual refrigerant quantity determination operation being performed in steps S112 to S114, and the fallback operation being performed in step S115.

[0092] It will be noted that the flow of processes shown in FIG. 3 is an example and can be appropriately changed. For example, the order of the steps may be changed to the extent that there are no incompatibilities, and some steps may be executed in parallel with other steps.

[0093] In step S101, in a case where the controller 60 is receiving the refrigerant leakage signal from any of the refrigerant leakage sensors 40 (i.e., a case where it is assumed that refrigerant leakage is occurring in any of the utilization units 30), the controller 60 proceeds to step S105. On the other hand, in a case where the controller 60 is not receiving the refrigerant leakage signal from any of the refrigerant leakage sensors 40 (i.e., a case where it is assumed that refrigerant leakage is not occurring in any of the utilization units 30), the controller 60 proceeds to step S102.

[0094] In step S102, the controller 60 transitions to the normal operating mode. Thereafter, the controller 60 proceeds to step S103.

[0095] In step S103, in a case where a command to operate (an instruction to start operating) has not been input, the controller 60 returns to step S101. On the other hand, in a case where a command to operate has been input, the controller 60 proceeds to step S104.

[0096] In step S104, the controller 60 controls in real time the states of each of the actuators and causes the refrigeration operation to be performed in accordance with the set temperature that has been set and the detection values of the various types of sensors (20 to 23). Furthermore, the controller 60 causes the remote controllers 50 to display various types of information such as the set temperature. Thereafter, the controller 60 returns to step S101.

[0097] In step S105, the controller 60 transitions to the refrigerant leakage control mode in accordance with having received the refrigerant leakage signal. Thereafter, the controller 60 proceeds to step S106.

[0098] In step S106, the controller 60 identifies the refrigerant-leaking utilization unit 30 in accordance with the statuses of the refrigerant leakage discrimination flags F1, F2, and F3. Then, the controller 60 controls to the closed state the on/off valve 36 of the refrigerant-leaking utilization unit 30 that it has identified. Because of this, the inflow of the refrigerant to the refrigerant-leaking utilization unit 30 stops. Furthermore, the controller 60 causes the remote controllers 50 to display information specifically indicating that refrigerant leakage is occurring and the refrigerant-leaking utilization unit 30. Thereafter, the controller 60 proceeds to step S107.

[0099] In step S107, the controller 60 controls to the closed state the on/off valves 36 of the operable utilization units 30. Thereafter, the controller 60 proceeds to step S108.

[0100] In step S108, the controller 60 causes the compressor 11 to operate at the rotational speed for the refrigerant recovery operation (maximum rotational speed). Because of this, the refrigerant recovery operation is started and the

refrigerant inside the refrigerant-leaking utilization unit 30 and the operable utilization units 30 is recovered to the heat source unit 10. Thereafter, the controller 60 proceeds to step S109.

[0101] In step S109, the controller 60 determines whether or not the suction pressure LP is less than the threshold value ΔTh. In a case where the result of the determination is that the suction pressure LP is equal to or greater than the threshold value ΔTh, the controller 60 repeats the determination in step S109. On the other hand, in a case where the suction pressure LP is less than the threshold value ΔTh, the controller 60 proceeds to step S110.

[0102] In step S110, the controller 60 stops the compressor 11 and causes the refrigerant recovery operation to end due to the suction pressure LP having become less than the threshold value ΔTh and a state having been reached in which it is assumed that the refrigerant recovery to the heat source unit 10 has been completed. Thereafter, the controller 60 proceeds to step S111.

[0103] In step S111, in a case where a command to operate (an instruction to start operating) has not been input in relation to the operable utilization units 30, the controller 60 stands by in step Sill. On the other hand, in a case where a command to operate has been input, the controller 60 proceeds to step S112.

[0104] In step S112, the controller 60 controls to the open state the on/off valves 36 of the operable utilization units 30. Thereafter, the controller 60 proceeds to step S113.

[0105] In step S113, the controller 60 causes the compressor 11 to operate at the rotational speed for the residual refrigerant quantity determination operation. Because of this, the residual refrigerant quantity determination operation is started, and the refrigerant circulates between the heat source unit 10 and the operable utilization units 30. Thereafter, the controller 60 proceeds to step S114.

[0106] In step S114, the controller 60 performs the residual refrigerant quantity determination. Specifically, the controller 60 decides the pressure standard value SP on the basis of the pressure standard value table and determines the extent of the deficiency (gas shortage) in the residual refrigerant quantity by comparing the suction pressure LP with the pressure standard value SP it has decided. Thereafter, the controller 60 proceeds to step S115.

[0107] In step S115, the controller 60 causes the compressor 11 to operate at the rotational speed according to the result of the residual refrigerant quantity determination (the rotational speed for the fallback operation). Because of this, the fallback operation is started and a refrigeration cycle using the residual refrigerant is performed between the heat source unit 10 and the operable utilization units 30. Furthermore, the controller 60 causes the remote controllers 50 to display this information. Thereafter, the controller 60 proceeds to step S116.

[0108] In step S116, in a case where a command to stop operating (an instruction to stop operating) has not been input in relation to the operable utilization units 30, the controller 60 returns to step S115. On the other hand, in a case where a command to stop operating has been input in relation to the operable utilization units 30, the controller 60 proceeds to step S117.

[0109] In step S117, the controller 60 stops the compressor 11 and causes the fallback operation to end. Thereafter, the controller 60 returns to step Sill.

(5) Changes in States of On/Off Valves 36 and Compressor 11

[0110] Changes in states according to the situation of the on/off valves 36 and the compressor 11 will be described below. FIG. 4 is a timing chart showing an example of changes in the states of the on/off valves 36 and the compressor 11 at the time of operation. FIG. 4 shows each part being controlled in the normal operating mode in period A and being controlled in the refrigerant leakage control mode in periods B to F.

[0111] In period A, the controller 60 performs control in the normal operating mode, and the on/off valves 36 of each of the utilization units 30 are controlled to the open state. Furthermore, the compressor 11 is controlled to a state in which it operates at the predetermined rotational speed for the refrigeration operation (a rotational speed according to the set temperature and the load), and the refrigeration operation is performed.

[0112] In period B, the controller 60 transitions to the refrigerant leakage control mode in response to having received the refrigerant leakage signal from the refrigerant leakage sensor 40a (i.e., in response to refrigerant leakage having occurred in the utilization unit 30a). As a result, the on/off valve 36 of the utilization unit (refrigerant-leaking utilization unit) 30a is controlled to the closed state. Because of this, the flow of refrigerant flowing into the utilization unit 30a is cut off so that the refrigerant is no longer supplied, and further refrigerant leakage is restrained.

[0113] Furthermore, each of the on/off valves 36 of the utilization units (operable utilization units) 30b and 30c is also controlled to the closed state, the compressor 11 is controlled to a state in which it operates at the predetermined rotational speed for the refrigerant recovery operation (here, the maximum rotational speed), and the refrigerant recovery operation is performed.

[0114] In period C, in response to the suction pressure LP having become less than the threshold value ΔTh (i.e., in response to a situation having been reached where it is assumed that the refrigerant recovery has been completed) after the start of the refrigerant recovery operation, the compressor 11 is controlled to a stopped state and the refrigerant recovery operation ends.

[0115] In period D, each of the on/off valves 36 of the utilization units (operable utilization units) 30b and 30c is controlled to the open state. In this way, each of the on/off valves 36 is controlled to the open state in a state in which the compressor 11 is stopped, so damage to refrigerant pipes and devices caused by an abrupt pressure fluctuation inside the refrigerant circuit RC is restrained. It will be noted that the on/off valve 36 of the utilization unit (refrigerant-leaking utilization unit) 30a remains controlled to the closed state.

[0116] In period E, in a state in which each of the on/off valves 36 of the utilization units (operable utilization units) 30b and 30c is controlled to the open state, the compressor 11 is controlled to a state in which it operates at the predetermined rotational speed for the residual refrigerant quantity determination operation, and the residual refrigerant quantity determination operation is performed. That is, the refrigerant circulates between the heat source unit 10 and the operable utilization units 30.

[0117] In period F, in a state in which each of the on/off valves 36 of the utilization units (operable utilization units) 30b and 30c is controlled to the open state, the compressor 11 is controlled to a state in which it operates at the predetermined rotational speed for the fallback operation, and the fallback operation is performed. As a result, the refrigeration cycle is performed between the heat source unit 10 and the operable utilization units 30, refrigeration of the refrigerated products in the interior spaces where the operable utilization units 30 are installed is continued, so that deterioration of the products is restrained.

(6) Characteristics of Refrigeration Apparatus 100

(6-1)

[0118] In the refrigeration apparatus 100 pertaining to the above embodiment, in a case where the refrigerant leakage sensors 40 have detected refrigerant leakage in any of the utilization units 30, the controller 60 transitions to the refrigerant leakage control mode, controls to the closed state the on/off valve 36 disposed on the inlet side of the utilization-side heat exchanger 32 of the utilization unit 30 in which the refrigerant leakage has been detected, and causes the compressor 11 to operate at the predetermined rotational speed. Due to this, the supply of the refrigerant to the refrigerant-leaking utilization unit 30 is stopped. As a result, even in a case where refrigerant leakage has occurred in any of the utilization units 30, an increase in the quantity of leaking refrigerant is restrained.

[0119] Furthermore, the compressor 11 is configured so as to be operated in a state in which the on/off valve 36 disposed on the inlet side of the utilization-side heat exchanger 32 of the refrigerant-leaking utilization unit 30 is closed. For this reason, the refrigerant remaining inside the refrigerant-leaking utilization unit 30 is recovered to the heat source unit 10, so that an increase in the quantity of leaking refrigerant is restrained.

[0120] Thus, the concentration of leaking refrigerant is restrained from becoming greater in the interior space where the refrigerant-leaking utilization unit 30 is installed, and so security is excellent.

(6-2)

[0121] In the refrigeration apparatus 100 pertaining to the above embodiment, in the refrigerant leakage control mode, the controller 60 controls, to a predetermined opening degree for the refrigerant recovery operation, the on/off valves 36 disposed on the inlet sides of the utilization-side heat exchangers 32 of the operable utilization units 30 in which the refrigerant leakage has not been detected.

[0122] Due to this, the refrigerant inside each of the utilization units 30 including the refrigerant-leaking utilization unit 30 is recovered to the heat source unit 10. As a result, a situation where the refrigerant flows into the refrigerant-leaking utilization unit 30 from the operable utilization units 30 so that the quantity of leaking refrigerant increases is restrained, and so security is excellent.

(6-3)

[0123] In the refrigeration apparatus 100 pertaining to the above embodiment, the check valves 37 that cut off the flow of the refrigerant from the outlet sides to the inlet sides are disposed on the refrigerant outlet sides of the utilization-side heat exchangers 32 of the utilization units 30. Additionally, when it is assumed that the recovery of the refrigerant from each of the utilization-side heat exchangers 32 to the heat source unit 10 has been completed in the refrigerant leakage control mode, the controller 60 causes the fallback operation of the compressor 11 to be performed and controls, to a predetermined opening degree for the fallback operation, the on/off valves 36 disposed on the inlet sides of the utilization-side heat exchangers 32 of the operable utilization units 30.

[0124] Due to this, the compressor 11 is fallback-operated and the refrigeration cycle is performed in the operable utilization units 30 even in a case where refrigerant leakage has occurred in any of the utilization units 30. Thus, deterioration of the products requiring temperature management is restrained in the interior spaces where the operable

utilization units 30 are disposed.

(6-4)

[0125] The refrigeration apparatus 100 pertaining to the above embodiment is equipped with the remote controllers 50 whose operation is controlled by the controller 60 and which output information, and in the refrigerant leakage control mode, the controller 60 causes the remote controllers 50 to output the predetermined notification information.

[0126] Due to this, in a case where refrigerant leakage has occurred in the utilization units 30, the notification information identifying the fact that refrigerant leakage has occurred and the utilization unit 30 in which the refrigerant leakage is occurring is output. As a result, in a case where refrigerant leakage has occurred in any of the utilization units 30, the manager easily becomes aware of this and is urged to take action, so security is even more excellent.

(7) Modifications

[0127] The above embodiment can be appropriately modified as described in the following modifications. It will be noted that each modification may also be combined with another modification and applied to the extent that incompatibilities do not arise.

(7-1) Modification A

[0128] In the above embodiment, the on/off valves 36 were disposed, as the "inlet valves" that cut off the flow of the refrigerant flowing into the utilization units 30, on the refrigerant inlet sides of the utilization-side heat exchangers 32 in the utilization units 30. However, the disposition (position) of the on/off valves 36 is not invariably limited to this and can be appropriately changed in accordance with the design specifications and installation environment.

[0129] For example, the on/off valves 36 may also be disposed as shown in FIG. 5. FIG. 5 shows the general configuration of a refrigeration apparatus 100a having a refrigerant circuit RC1 where the disposition (position) of the on/off valves 36 is different from what it is in the refrigerant circuit RC.

[0130] In the refrigerant circuit RC1, the on/off valves 36 are disposed outside the utilization units 30 rather than inside the utilization units 30. More specifically, in the refrigerant circuit RC1, the on/off valves 36 are disposed in the sections of the utilization-side liquid refrigerant pipes P5 that extend outside the utilization units 30 (that is to say, disposed between the utilization units 30 and the liquid refrigerant communication pipe L1). That is, in the refrigeration apparatus 100, the on/off valves 36 were included among the constituent elements of the utilization units 30, but the on/off valves 36 in the refrigeration apparatus 100a are disposed as elements independent of the utilization units 30 in the refrigerant circuit RC1.

[0131] Even in the refrigeration apparatus 100a having the refrigerant circuit RC1 instead of the refrigerant circuit RC, the on/off valves 36 are disposed on the refrigerant inlet sides of the utilization-side heat exchangers 32 and can cut off the flow of the refrigerant flowing into the utilization units 30. For this reason, the same effects as those of the refrigeration apparatus 100 can be achieved.

(7-2) Modification B

[0132] In the above embodiment, the on/off valves 36 were disposed, as the "inlet valves" that cut off the flow of the refrigerant flowing into the utilization units 30, on the refrigerant inlet sides of the utilization-side heat exchangers 32 in the utilization units 30. However, the on/off valves 36 can also be appropriately omitted in accordance with the design specifications and installation environment.

[0133] For example, the on/off valves 36 may also be omitted from the refrigerant circuit RC, being disposed as in a refrigerant circuit RC2 shown in FIG. 6. FIG. 6 shows the general configuration of a refrigeration apparatus 100b having a refrigerant circuit RC2 where the on/off valves 36 are omitted.

[0134] In the refrigerant circuit RC2, utilization-side electronic expansion valves 31a are disposed instead of the thermostatic utilization-side expansion valves 31. The utilization-side electronic expansion valves 31a are electrically powered valves capable of opening degree adjustment in which their opening degrees change as a result of a predetermined drive voltage being supplied. The controller 60 appropriately adjusts the opening degrees of the utilization-side electronic expansion valves 31a, so that the same effects as those of the refrigeration apparatus 100 can be achieved.

[0135] That is, by replacing the closed state of each of the on/off valves 36 in the timing chart in FIG. 4 with a minimum opening degree (totally closed state) of the utilization-side electronic expansion valves 31a, the utilization-side electronic expansion valves 31a can function as the "inlet valves" in the same way as the on/off valves 36 to cut off the flow of the refrigerant flowing into the refrigerant-leaking utilization unit 30. Furthermore, the refrigeration apparatus 100b can also, like the refrigeration apparatus 100, perform the refrigeration operation, the refrigerant recovery operation, the residual

refrigerant quantity determination operation, and the fallback operation.

[0136] In the refrigeration apparatus 100b, it is not invariably necessary for the controller 60 to cause the compressor 11 to stop before switching the utilization-side electronic expansion valves 31a of the operable utilization units 30 from the minimum opening degree to the open state after the end of the refrigerant recovery operation. This is because, since the utilization-side electronic expansion valves 31a are electrically powered valves whose opening degrees can be adjusted, even without causing the compressor 11 to stop it is possible to prevent an abrupt pressure fluctuation inside the refrigerant circuit RC2 by gradually increasing the opening degrees, so that damage to refrigerant pipes and devices is restrained.

[0137] Furthermore, in the refrigeration apparatus 100, the on/off valves of the operable utilization units 30 were controlled to the closed state in the refrigerant recovery operation, but in the refrigeration apparatus 100b, the utilization-side electronic expansion valves 31a of the operable utilization units 30 do not invariably need to be controlled to the minimum opening degree in the refrigerant recovery operation. That is, it suffices for the opening degree of the utilization-side electronic expansion valves 31a to be set to an opening degree (e.g., a minute opening degree) at which the refrigerant can be recovered from the utilization units 30 to the heat source unit 10.

(7-3) Modification C

[0138] In the above embodiment, the check valves 37 were disposed, as the "outlet valves" that prevent the inflow of the refrigerant from the outlet sides to the inlet sides, in the refrigerant outlet sides of the utilization-side heat exchangers 32. However, instead of the check valves 37, electromagnetic valves or electrically powered valves may also be disposed. The electromagnetic valves or the electrically powered valves are controlled to the closed state or the minimum opening degree (totally closed state) in the refrigerant recovery operation, the residual refrigerant quantity determination operation, and the fallback operation, so that further refrigerant leakage in the refrigerant-leaking utilization unit 30 can be restrained and the fallback operation can be performed in the operable utilization units 30. That is, in this case, the electromagnetic valves or the electrically powered valves disposed instead of the check valves 37 function as the "outlet valves".

(7-4) Modification D

[0139] In the above embodiment, the controller 60 caused the compressor 11 to stop before switching the on/off valves 36 of the operable utilization units 30 from the closed state to the open state after the end of the refrigerant recovery operation. In this regard, according to the standpoint of preventing damage to refrigerant pipes and devices caused by an abrupt pressure fluctuation inside the refrigerant circuit RC, it is preferred that the controller 60 cause the compressor 11 to stop temporarily at this timing. However, in a situation where security is ensured even without causing the compressor 11 to stop, it is not invariably necessary for the controller 60 to cause the compressor 11 to stop at this timing. For example, in a case where there is no concern that there will be damage to refrigerant pipes and devices by setting low the rotational speed of the compressor 11 at this timing, it is alright if the controller 60 does not cause the compressor 11 to stop.

(7-5) Modification E

[0140] In the above embodiment, the controller 60 performed the residual refrigerant quantity determination operation after the end of the refrigerant recovery operation. In this regard, when performing the fallback operation in the operable utilization units 30 in a case where refrigerant leakage has occurred in any of the utilization units 30, it is preferred from the standpoint of security that the controller 60 cause the compressor 11 to operate at a rotational speed according to the quantity of refrigerant remaining in the refrigerant circuit RC. However, in the case of a situation where security is ensured even without the controller 60 performing the residual refrigerant quantity determination, it is not invariably necessary for the controller 60 to perform the residual refrigerant quantity determination operation at this timing, and the residual refrigerant quantity determination operation can also be appropriately omitted.

[0141] Furthermore, the controller 60 may also be configured in such a way that, rather than performing the residual refrigerant quantity determination operation independently, the residual refrigerant quantity determination operation is performed during the fallback operation.

(7-6) Modification F

[0142] In the above embodiment, the controller 60 that controls the operation of the refrigeration apparatus 100 was configured as a result of the heat-source-unit control unit 25 and the utilization-unit control units 38 being interconnected via the communication line cb1. However, the configuration of the controller 60 is not invariably limited to this and can be appropriately changed in accordance with the design specifications and installation environment. For example, some

or all of the elements (the storage component 61, the communication component 62, the mode control unit 63, the actuator control unit 64, and the display control unit 65) included in the controller 60 do not invariably need to be disposed in either of the heat source unit 10 and the utilization units 30, and may also be disposed in a separate device or may also be disposed independently in a remote location connected by a communication network. That is, the configuration of the controller 60 is not particularly limited so long as the elements (the storage component 61, the communication component 62, the mode control unit 63, the actuator control unit 64, and the display control unit 65) included in the controller 60 can be constructed.

(7-7) Modification G

[0143] In the above embodiment, the refrigerant recovery operation was configured to end based on the assumption that the refrigerant recovery has been completed when the detection value (suction pressure LP) of the suction pressure sensor 20 becomes less than the predetermined threshold value ΔTh (see step S109 and step S110 in FIG. 3). However, the basis for ending the refrigerant recovery operation can also be appropriately changed in accordance with the design specifications and installation environment.

[0144] For example, the refrigerant recovery operation may also be configured to end based on the assumption that the refrigerant recovery has been completed when the detection value (the discharge pressure HP) of the discharge pressure sensor 21 becomes less than a predetermined value.

[0145] Furthermore, for example, the refrigerant recovery operation may also be configured to end based on the assumption that the refrigerant recovery has been completed when a predetermined amount of time set beforehand has elapsed after the start of the refrigerant recovery operation.

(7-8) Modification H

[0146] In the above embodiment, the threshold value ΔTh was set to a value that is not enough to fall below atmospheric pressure on the basis of the quantity of refrigerant contained inside the refrigerant circuit RC and the quantity of refrigerant in circulation determined from the characteristics of the compressor 11, and was set to 0.1 MPa. However, the threshold value ΔTh is not invariably limited to 0.1 MPa, and it suffices for an appropriate value to be set in accordance with the design specifications and installation environment.

(7-9) Modification I

[0147] In the above embodiment, in the residual refrigerant quantity determination operation, the controller 60 determined the residual refrigerant quantity by comparing the detection value (the suction pressure LP) of the suction pressure sensor 20 with the predetermined pressure standard value SP. However, the method by which the controller 60 determines the residual refrigerant quantity is not invariably limited to this and can be appropriately changed. For example, the controller 60 may also be configured to determine the residual refrigerant quantity by comparing the detection value (the discharge pressure HP) of the discharge pressure sensor 21 with the predetermined pressure standard value SP.

(7-10) Modification J

[0148] In the above embodiment, the rotational speed of the compressor 11 in the refrigerant recovery operation was set to the maximum rotational speed so that the refrigerant recovery is completed in the shortest amount of time. However, the rotational speed of the compressor 11 in the refrigerant recovery operation is not invariably limited to this and can be appropriately changed in accordance with the design specifications and installation environment.

(7-11) Modification K

[0149] In the above embodiment, the fallback operation was performed after the residual refrigerant quantity determination operation, and in the fallback operation the compressor 11 was configured to operate at a rotational speed commensurate with the residual refrigerant quantity. In this regard, for example, in a case where plural compressors 11 are disposed in the refrigerant circuit RC, capacity may also be saved by limiting the number of the compressors 11 that the controller 60 causes to operate in the fallback operation.

[0150] Furthermore, for example, a tank charged with refrigerant for replenishment may also be connected beforehand to the refrigerant circuit RC, and the refrigerant circuit RC may be configured in such a way that it becomes appropriately replenished with a quantity of refrigerant corresponding to the deficiency before the fallback operation or during the fallback operation.

(7-12) Modification L

[0151] In the above embodiment, the controller 60 was configured to determine the residual refrigerant quantity upon the elapse of the predetermined amount of time t1 after the start of the residual refrigerant quantity determination operation, and the predetermined amount of time t1 was set to three minutes. However, the predetermined amount of time t1 is not invariably limited to three minutes and can be appropriately changed. For example, the predetermined amount of time t1 may also be set to one minute or may also be set to five minutes. Furthermore, rather than the controller 60 determining the residual refrigerant quantity upon the elapse of the predetermined amount of time t1 after the start of the residual refrigerant quantity determination operation, the controller 60 may also be changed in such a way that the residual refrigerant quantity is determined on the basis of another event.

(7-13) Modification M

[0152] In the above embodiment, the refrigerant leakage sensors 40 were disposed inside the utilization units 30. However, the refrigerant leakage sensors 40 do not invariably need to be disposed inside the utilization units 30 provided that the refrigerant leakage sensors 40 are disposed in such a way that they can detect refrigerant leakage inside the corresponding utilization units 30. For example, the refrigerant leakage sensors 40 may also be disposed in the spaces (interior spaces) where the corresponding utilization units 30 are installed.

(7-14) Modification N

[0153] In the above embodiment, the refrigerant leakage sensors 40 were disposed to detect refrigerant leakage in each of the utilization units 30. However, in a case where it is possible to detect refrigerant leakage in each of the utilization units 30 without relying on the refrigerant leakage sensors 40, the refrigerant leakage sensors 40 are not invariably necessary in the refrigeration apparatus 100. For example, in a case where sensors such as refrigerant pressure sensors and/or refrigerant temperature sensors are disposed inside each of the utilization units 30 and it is possible to individually detect refrigerant leakage in each of the utilization units 30 on the basis of changes in the detection values of the sensors, the refrigerant leakage sensors 40 may also be omitted.

(7-15) Modification O

[0154] In the above embodiment, the controller 60 caused the remote controllers 50 serving as the "information output units" to output predetermined information in accordance with the operating situation. In particular, the controller 60 caused the remote controllers 50 to output predetermined notification information in the refrigerant recovery operation, the residual refrigerant quantity determination operation, and the fallback operation. In this regard, in a case where refrigerant leakage has occurred, the controller 60 may also cause devices other than the remote controllers 50 to function as the "information output units" so long as they can notify the manager.

[0155] For example, speakers capable of outputting audio may be disposed, and the controller 60 may cause the speakers to output a predetermined warning sound or audio message to thereby cause the speakers to output the notification information and function as the "information output units". Furthermore, light sources such as LED lamps may be disposed, and the controller 60 may cause the light sources to blink or light up to thereby cause the light sources to output the notification information and function as the "information output units". Furthermore, the controller 60 may also cause a device such as a central management device installed in the facility to which the refrigeration apparatus 100 is applied or a remote off-site location to output the notification information and function as the "information output units".

(7-16) Modification P

[0156] In the above embodiment, the present invention was applied to the refrigeration apparatus 100 that refrigerates interior spaces of refrigerated storage rooms or showcases in a store. However, the present invention is not limited to this and is also applicable to other refrigeration apparatuses having a refrigerant circuit having plural utilization units. For example, the present invention may also be applied to a refrigeration apparatus that refrigerates the insides of shipping containers. Furthermore, for example, the present invention may also be applied to an air conditioning system (air conditioner) that realizes air conditioning by cooling the inside of a building.

[0157] Furthermore, for example, by disposing a four-port switching valve in the refrigerant circuit RC in FIG. 1, the utilization-side heat exchangers 32 may be caused to function as refrigerant radiators or condensers, so that the utilization units 30 are configured to perform a heat applying operation or a heating operation in the spaces where the utilization units 30 are installed.

(7-17) Modification Q

[0158] In the above embodiment, the refrigeration apparatus 100 had one heat source unit 10 and three utilization units 30. However, the number of the heat source units 10 disposed in the refrigeration apparatus 100 is not particularly limited and may also be two or more. Furthermore, the number of the utilization units 30 that the refrigeration apparatus 100 has is not particularly limited and may also be two or may also be four or more.

[0159] Furthermore, the number of the compressors 11 disposed in the refrigerant circuit RC was one, but the number of the compressors 11 is also not particularly limited, and two or more compressors 11 may also be disposed in accordance with the design specifications and installation environment.

[0160] Furthermore, in the above embodiment, a case was described where the utilization unit 30a was the refrigerant-leaking utilization unit and the utilization units 30b and 30c were the operable utilization units. However, the same effects as in the above embodiment are achieved even when a utilization unit other than the utilization unit 30a is the refrigerant-leaking utilization unit.

(7-18) Modification R

[0161] In the above embodiment, R32 was used as the refrigerant circulating through the refrigerant circuit RC. However, the refrigerant used in the refrigerant circuit RC is not particularly limited. For example, in the refrigerant circuit RC, HFO1234yf, HFO1234ze (E), or a mixed refrigerant including these refrigerants may also be used instead of R32. Furthermore, in the refrigerant circuit RC, an HFC refrigerant such as R407C or R410A may also be used. Furthermore, in the refrigerant circuit RC, a flammable refrigerant such as propane or a toxic refrigerant such as ammonia may also be used.

(7-19) Modification S

[0162] In the above embodiment, the controller 60 performed the refrigerant recovery operation and controlled the on/off valves 36 of the operable utilization units 30 to the closed state (step S107 in FIG. 3). However, this control is not invariably necessary and can be omitted. Even in this case, the action and effects described in (6-1) above can be realized. That is, even in a case where the refrigerant recovery operation is performed in a state in which the on/off valves 36 of the operable utilization units 30 are controlled to the open state, so long as the on/off valve 36 of the refrigerant-leaking utilization unit 30 is controlled to the closed state, the inflow of the refrigerant to the refrigerant-leaking utilization unit 30 is stopped and the refrigerant in the refrigerant-leaking utilization unit 30 is recovered to the heat source unit 10. Thus, an increase in the quantity of leaking refrigerant is restrained.

(7-20) Modification T

[0163] In the above embodiment, the operations performed in the refrigerant leakage control mode included the refrigerant recovery operation, the residual refrigerant quantity determination operation, and the fallback operation. However, the operations performed in the refrigerant leakage control mode may also include other operations instead of any of these operations or in addition to these operations.

[0164] For example, the controller 60 may also be configured in such a way that, in the refrigerant leakage control mode, instead of the refrigerant recovery operation, the residual refrigerant quantity determination operation, and the fallback operation, a continuity operation is performed in which the controller 60 causes the compressor 11 to operate continuously without the controller 60 particularly changing the rotational speed of the compressor 11 from what it is in the normal operating mode. In this continuity operation, the compressor 11 is operated at a random rotational speed according to the refrigerating load and so forth as in the normal operating mode.

[0165] In this case also, the action and effects described in (6-1) above can be realized. That is, in the continuity operation also, so long as the on/off valve 36 of the refrigerant-leaking utilization unit 30 is controlled to the closed state, the inflow of the refrigerant to the refrigerant-leaking utilization unit 30 is stopped so that an increase in the quantity of leaking refrigerant is restrained. Furthermore, when the operation of the compressor 11 is continued in a state in which the on/off valves 36 of the operable utilization units 30 are controlled to the open state, the refrigeration cycle is performed in the operable utilization units 30, and deterioration of the products requiring temperature management is restrained in the interior spaces where the operable utilization units 30 are installed.

INDUSTRIAL APPLICABILITY

[0166] The present invention is applicable to a refrigeration apparatus.

REFERENCE SIGNS LIST

[0167]

10:	Heat Source Unit
11:	Compressor
12:	Heat Source-side Heat Exchanger
13:	Receiver
14:	Sub-cooler
15:	Heat Source-side Expansion Valve
16:	Injection Valve
17:	Liquid-side Shut-off Valve
18:	Gas-side Shut-off Valve
19:	Heat Source-side Fan
20:	Suction Pressure Sensor
21:	Discharge Pressure Sensor
22:	Receiver Outlet Temperature Sensor
23:	Heat Source-side Air Temperature Sensor
25:	Heat-Source-Unit Control Unit
30 (30a, 30b, 30c):	Utilization Units
31:	Utilization-side Expansion Valve
31a:	Utilization-side Electronic Expansion Valve (Inlet Valve)
32:	Utilization-side Heat Exchanger
35:	Utilization-side Fan
36:	On/Off valve (Inlet Valve)
37:	Check Valve (Outlet Valve)
38:	Utilization-Unit Control Unit
40 (40a, 40b, 40c):	Refrigerant Leakage Sensors
50 (50a, 50b, 50c):	Remote Controllers (Information Output Units)
60:	Controller (Control Unit)
61:	Storage Component
62:	Communication Component
63:	Mode Control Unit
64:	Actuator Control Unit
65:	Display Control Unit
100, 100a, 100b:	refrigeration apparatuses
F1, F2, F3:	Refrigerant Leakage Discrimination Flags
F4:	Control Mode Discrimination Flag
G1:	Gas Refrigerant Communication Pipe
L1:	Liquid Refrigerant Communication Pipe
M11:	Compressor Motor
M19:	Heat Source-side Fan Motor
M35:	Utilization-side Fan Motor
P1:	First Heat Source-side Gas Refrigerant Pipe
P2:	Heat Source-side Liquid Refrigerant Pipe
P3:	Second Heat Source-side Gas Refrigerant Pipe
P4:	Injection Pipe
P5:	Utilization-side Liquid Refrigerant Pipe
P6:	Utilization-side Gas Refrigerant Pipe
RC, RC1, RC2:	Refrigerant Circuits
cb1, cb2:	Communication Lines

CITATION LIST

<Patent Literature>

[0168] Patent Document 1: Japanese Laid-open Patent Publication No. 2013-24540

Claims

1. A refrigeration apparatus (100, 100a, 100b) comprising:

   a refrigerant circuit (RC, RC1, RC2) configured and arranged to include a heat source unit (10) which has a compressor (11), and a plurality of utilization units (30), each of which has a utilization-side heat exchanger (32) and which are disposed in parallel to each other;
   a plurality of inlet valves (36, 31a) configured and arranged to cut off a flow of supplied refrigerant in a closed state; and
   a control unit (60) configured and arranged to transition to a predetermined control mode in accordance with the situation and configured and arranged to control the operation of the compressor and each of the inlet valves in accordance with the control mode,
   wherein
   each of the inlet valves is disposed on a refrigerant inlet side of any of the utilization-side heat exchangers, and the control unit is electrically connected to refrigerant leakage sensors (40) configured and arranged to detect refrigerant leakage inside each of the utilization units, the control unit is configured and arranged to transition to a refrigerant leakage control mode in a case where the refrigerant leakage sensors have detected refrigerant leakage in any of the utilization units, and, the control unit is configured and arranged to, in the refrigerant leakage control mode, control to the closed state the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has been detected and cause the compressor to operate at a predetermined rotational speed.

2. The refrigeration apparatus (100, 100a, 100b) according to claim 1, wherein in the refrigerant leakage control mode, the control unit is configured and arranged to control, to a predetermined opening degree for a refrigerant recovery operation, the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has not been detected.

3. The refrigeration apparatus (100, 100a, 100b) according to claim 1 or 2, further comprising a plurality of outlet valves (37) configured and arranged to cut off, on refrigerant outlet sides of the utilization-side heat exchangers, a flow of the refrigerant from the outlet sides to the inlet sides, wherein
   each of the outlet valves is disposed on the outlet side of any of the utilization-side heat exchangers, and
   the control unit is configured and arranged to, when it is assumed that recovery of the refrigerant from each of the utilization-side heat exchangers to the heat source unit has been completed in the refrigerant leakage control mode cause a fallback operation of the compressor to be performed and configured and arranged to control, to a predetermined opening degree for the fallback operation, the inlet valve disposed on the inlet side of the utilization-side heat exchanger of the utilization unit in which the refrigerant leakage has not been detected.

4. The refrigeration apparatus (100, 100a, 100b) according to any one of claims 1 to 3, further comprising an information output unit (50) configured and arranged to be controlled by the control unit and configured and arranged to output information, wherein
   the control unit is configured and arranged to, in the refrigerant leakage control mode, cause the information output unit to output predetermined notification information.

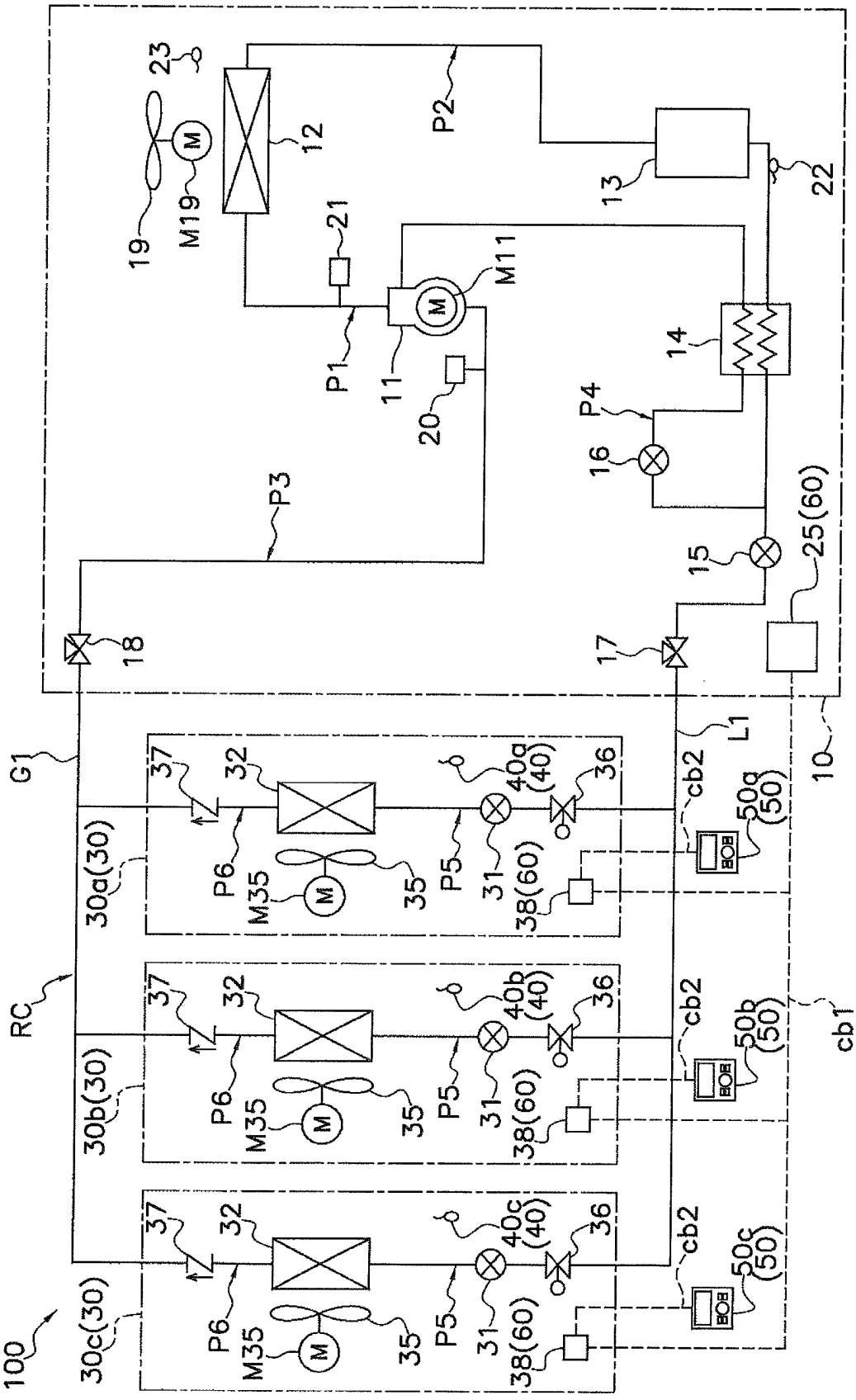

100
RC
G1
L1
10
cb1
cb2
12
13
14
15
16
17
18
19
20
21
22
23
25(60)
11
M11
M19
P1
P2
P3
P4
30a(30)
30b(30)
30c(30)
31
32
35
36
37
38(60)
40a(40)
40b(40)
40c(40)
50a(50)
50b(50)
50c(50)
M35
P5
P6

FIG. 1

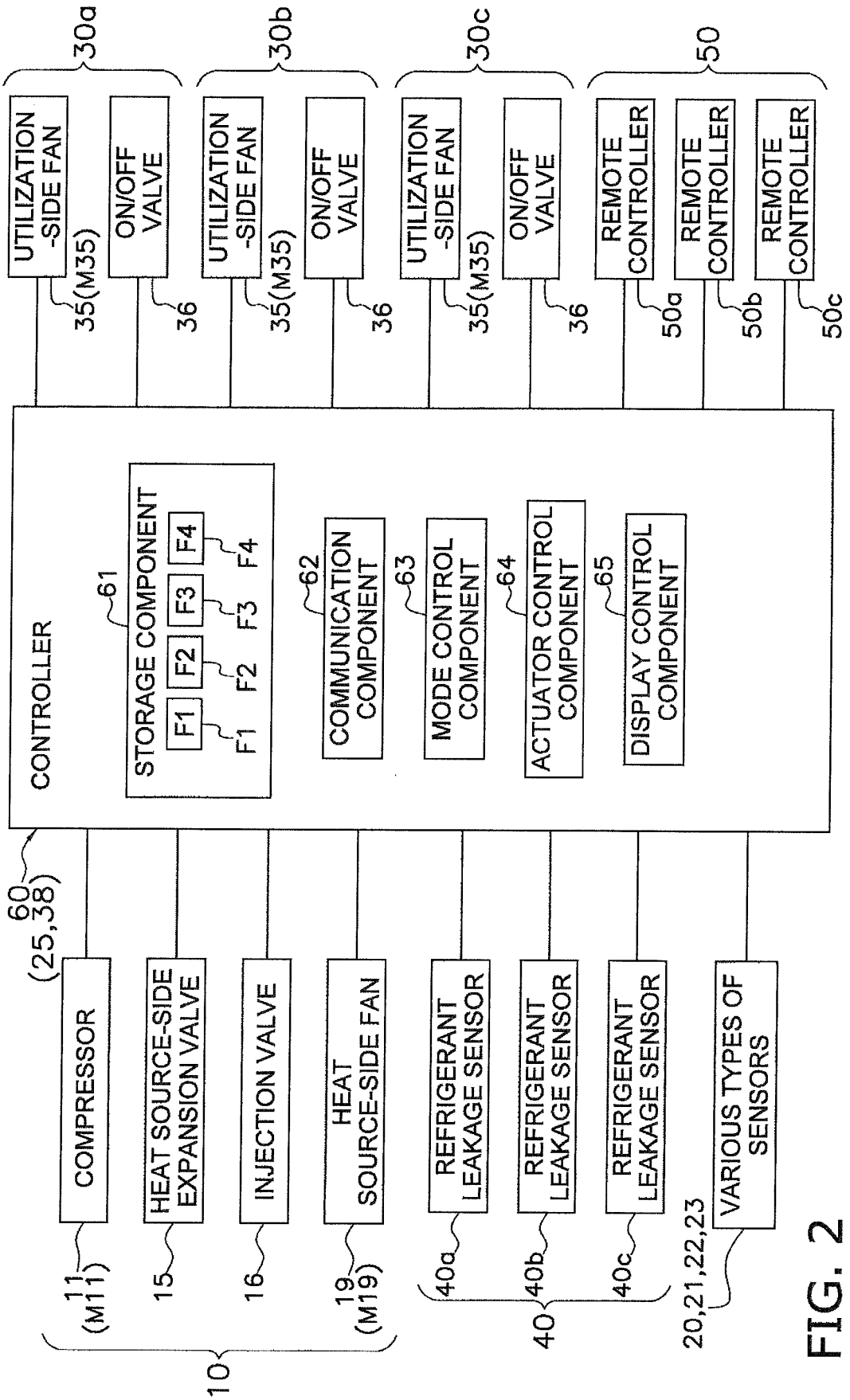
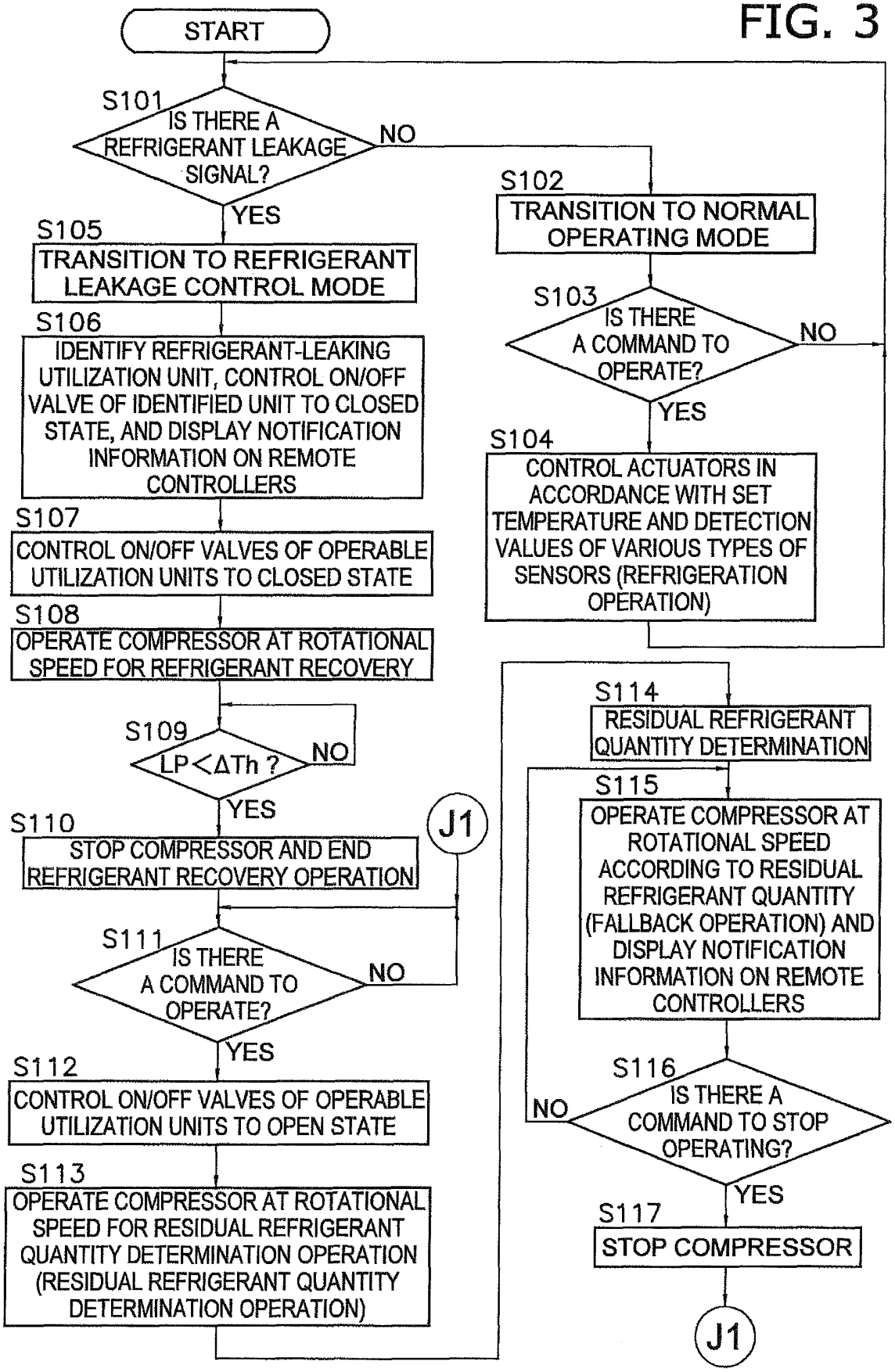

30a
30b
30c
50
UTILIZATION -SIDE FAN
ON/OFF VALVE
REMOTE CONTROLLER
35(M35)
36
50a
50b
50c
CONTROLLER
STORAGE COMPONENT
F1
F2
F3
F4
61
62
63
64
65
COMMUNICATION COMPONENT
MODE CONTROL COMPONENT
ACTUATOR CONTROL COMPONENT
DISPLAY CONTROL COMPONENT
60
(25,38)
COMPRESSOR
HEAT SOURCE-SIDE EXPANSION VALVE
INJECTION VALVE
HEAT SOURCE-SIDE FAN
REFRIGERANT LEAKAGE SENSOR
VARIOUS TYPES OF SENSORS
11
(M11)
15
16
19
(M19)
40a
40b
40c
40
20,21,22,23
10

FIG. 2

FIG. 3


START
S101
IS THERE A REFRIGERANT LEAKAGE SIGNAL?
NO
YES
S102
TRANSITION TO NORMAL OPERATING MODE
S103
IS THERE A COMMAND TO OPERATE?
NO
YES
S104
CONTROL ACTUATORS IN ACCORDANCE WITH SET TEMPERATURE AND DETECTION VALUES OF VARIOUS TYPES OF SENSORS (REFRIGERATION OPERATION)
S105
TRANSITION TO REFRIGERANT LEAKAGE CONTROL MODE
S106
IDENTIFY REFRIGERANT-LEAKING UTILIZATION UNIT, CONTROL ON/OFF VALVE OF IDENTIFIED UNIT TO CLOSED STATE, AND DISPLAY NOTIFICATION INFORMATION ON REMOTE CONTROLLERS
S107
CONTROL ON/OFF VALVES OF OPERABLE UTILIZATION UNITS TO CLOSED STATE
S108
OPERATE COMPRESSOR AT ROTATIONAL SPEED FOR REFRIGERANT RECOVERY
S109
LP<ΔTh ?
NO
YES
S110
STOP COMPRESSOR AND END REFRIGERANT RECOVERY OPERATION
J1
S111
IS THERE A COMMAND TO OPERATE?
NO
YES
S112
CONTROL ON/OFF VALVES OF OPERABLE UTILIZATION UNITS TO OPEN STATE
S113
OPERATE COMPRESSOR AT ROTATIONAL SPEED FOR RESIDUAL REFRIGERANT QUANTITY DETERMINATION OPERATION (RESIDUAL REFRIGERANT QUANTITY DETERMINATION OPERATION)
S114
RESIDUAL REFRIGERANT QUANTITY DETERMINATION
S115
OPERATE COMPRESSOR AT ROTATIONAL SPEED ACCORDING TO RESIDUAL REFRIGERANT QUANTITY (FALLBACK OPERATION) AND DISPLAY NOTIFICATION INFORMATION ON REMOTE CONTROLLERS
S116
IS THERE A COMMAND TO STOP OPERATING?
NO
YES
S117
STOP COMPRESSOR
J1

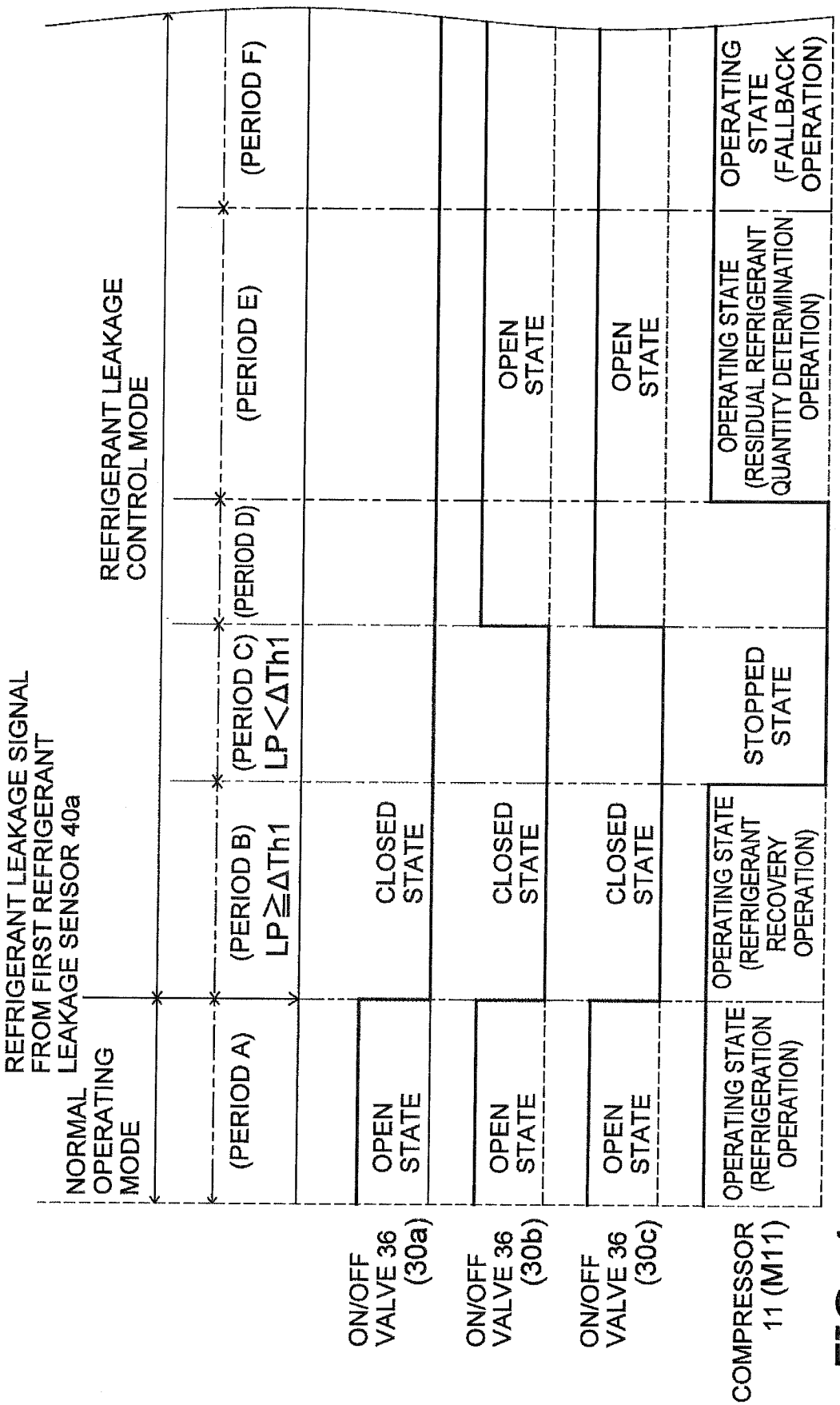

NORMAL OPERATING MODE
REFRIGERANT LEAKAGE SIGNAL FROM FIRST REFRIGERANT LEAKAGE SENSOR 40a
REFRIGERANT LEAKAGE CONTROL MODE
(PERIOD A)
(PERIOD B)
LP≧ΔTh1
(PERIOD C)
LP<ΔTh1
(PERIOD D)
(PERIOD E)
(PERIOD F)
ON/OFF VALVE 36 (30a)
OPEN STATE
CLOSED STATE
ON/OFF VALVE 36 (30b)
OPEN STATE
CLOSED STATE
ON/OFF VALVE 36 (30c)
OPEN STATE
CLOSED STATE
COMPRESSOR 11 (M11)
OPERATING STATE (REFRIGERATION OPERATION)
OPERATING STATE (REFRIGERANT RECOVERY OPERATION)
STOPPED STATE
OPERATING STATE (RESIDUAL REFRIGERANT QUANTITY DETERMINATION OPERATION)
OPERATING STATE (FALLBACK OPERATION)

FIG. 4

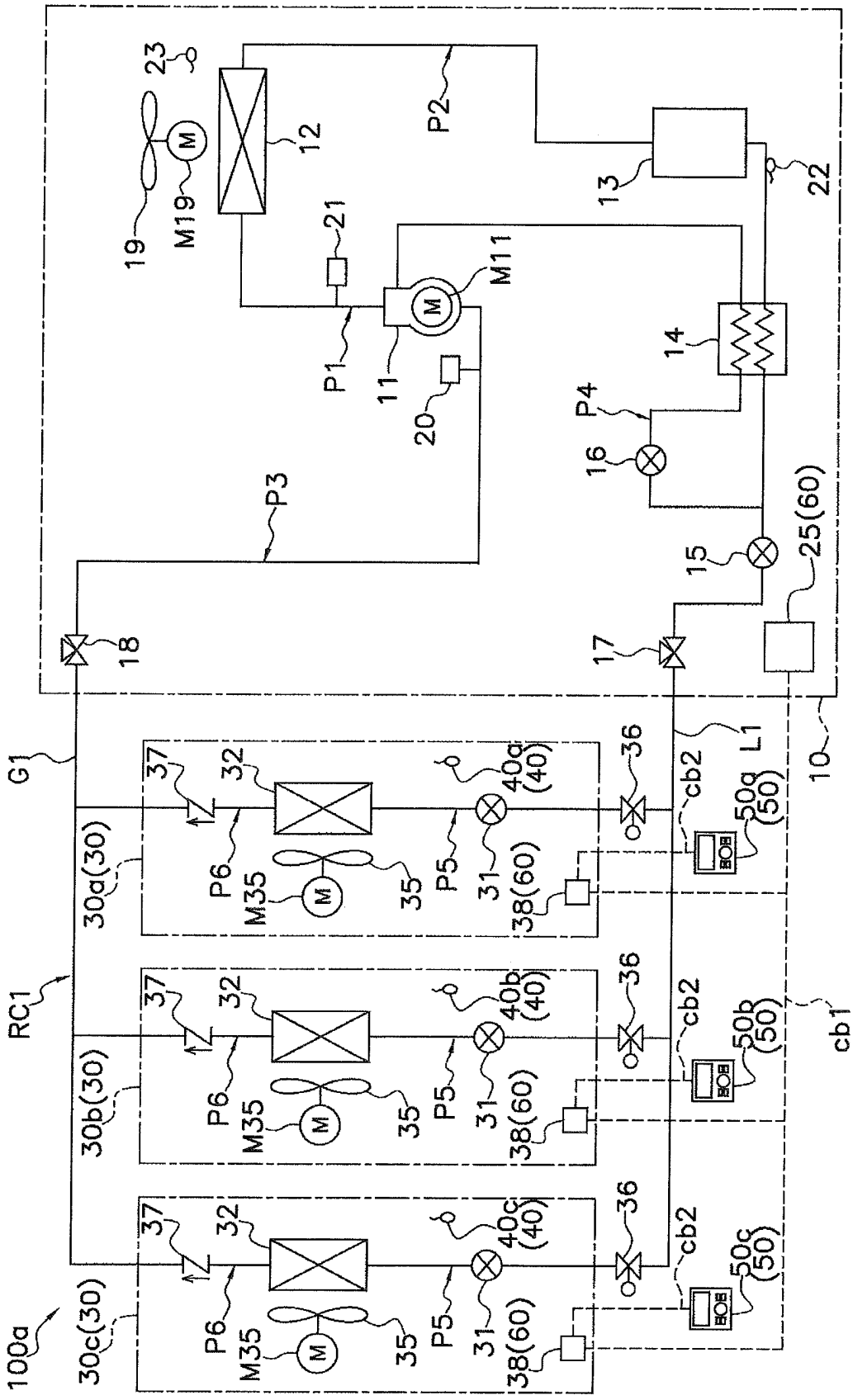

100a
RC1
G1
L1
10
cb1
cb2
11
12
13
14
15
16
17
18
19
20
21
22
23
25(60)
30a(30)
30b(30)
30c(30)
31
32
35
36
37
38(60)
40a (40)
40b (40)
40c (40)
50a (50)
50b (50)
50c (50)
M11
M19
M35
P1
P2
P3
P4
P5
P6

FIG. 5

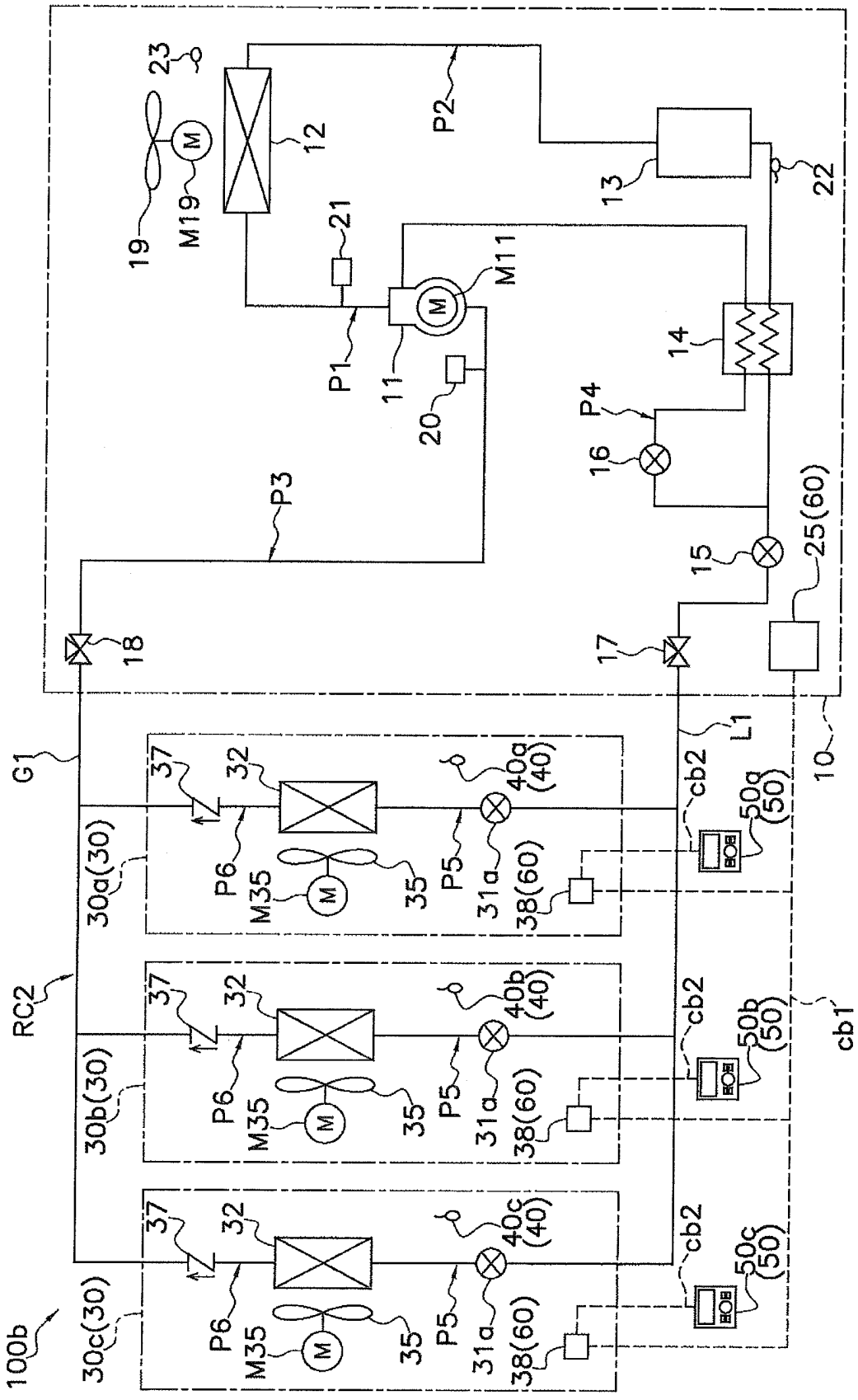

100b
RC2
G1
L1
cb1
cb2
10
11
12
13
14
15
16
17
18
19
20
21
22
23
25(60)
30a(30)
30b(30)
30c(30)
31a
32
35
37
38(60)
40a(40)
40b(40)
40c(40)
50a(50)
50b(50)
50c(50)
M11
M19
M35
P1
P2
P3
P4
P5
P6

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/074519

A. CLASSIFICATION OF SUBJECT MATTER
F25B49/02(2006.01)i, *F24F11/02*(2006.01)i, *F25B1/00*(2006.01)i, *F25B5/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B49/02, F24F11/02, F25B1/00, F25B5/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2016
Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 05-118720 A (Hitachi, Ltd.), 14 May 1993 (14.05.1993), paragraphs [0023] to [0025]; fig. 6 to 7 (Family: none)	1-4
Y	JP 2013-140002 A (Daikin Industries, Ltd.), 18 July 2013 (18.07.2013), paragraphs [0070] to [0072] & WO 2013/084510 A1	1-4
Y	JP 2005-241050 A (Mitsubishi Electric Building Techno-Service Co., Ltd.), 08 September 2005 (08.09.2005), paragraphs [0024] to [0029]; fig. 1 to 2 (Family: none)	4

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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Date of the actual completion of the international search	Date of mailing of the international search report
07 November 2016 (07.11.16)	15 November 2016 (15.11.16)
Name and mailing address of the ISA/ Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Authorized officer Telephone No.

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