



(12) **EUROPEAN PATENT APPLICATION**  
published in accordance with Art. 153(4) EPC

(43) Date of publication:  
**02.10.2019 Bulletin 2019/40**

(51) Int Cl.:  
**F25B 1/00 (2006.01) F25B 43/02 (2006.01)**

(21) Application number: **17872915.8**

(86) International application number:  
**PCT/JP2017/041919**

(22) Date of filing: **22.11.2017**

(87) International publication number:  
**WO 2018/097154 (31.05.2018 Gazette 2018/22)**

(84) Designated Contracting States:  
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**  
Designated Extension States:  
**BA ME**  
Designated Validation States:  
**MA MD**

(71) Applicant: **Daikin Industries, Ltd.**  
**Osaka-shi, Osaka 530-8323 (JP)**

(72) Inventor: **KONDOU, Azuma**  
**Osaka 530-8323 (JP)**

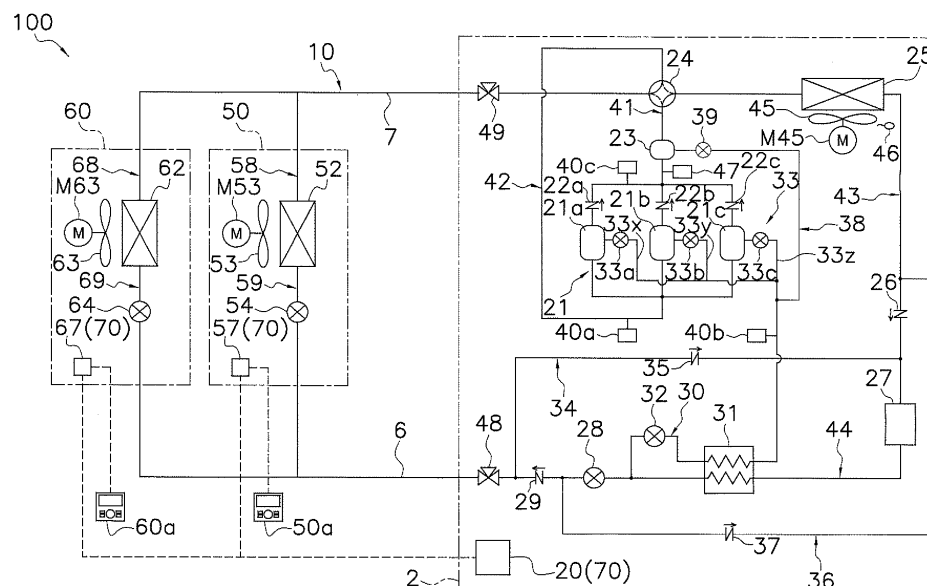
(74) Representative: **Hoffmann Eitle**  
**Patent- und Rechtsanwälte PartmbB**  
**Arabellastraße 30**  
**81925 München (DE)**

(30) Priority: **24.11.2016 JP 2016227658**

(54) **REFRIGERATION DEVICE**

(57) Provided is a refrigeration apparatus that is capable of implementing a novel control method capable of suppressing occurrence of a situation in which a refrigerating machine oil from an oil separator is unsatisfactorily returned to a compressor and a discharge gas refrigerant is mostly returned to the compressor. An oil return valve (39) is disposed on an oil return pipe (38) connecting an oil separator (23) disposed on a discharge

side of a compressor (21) to an injection pipe (30) for supplying a refrigerant to the compressor (21). A controller (70) controls the oil return valve (39) to reduce a flow rate when a temperature of the refrigerant discharged from the compressor (21) or a pressure of the refrigerant flowing through the injection pipe (30) satisfies a predetermined condition.



**FIG. 1**

## Description

### TECHNICAL FIELD

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

### BACKGROUND ART

[0002] A refrigeration apparatus that has been proposed in the related art includes an oil separator and an oil return pipe for a compressor in order to prevent exhaustion of a refrigerating machine oil as a lubricant in the compressor.

[0003] For example, Patent Literature 1 (JP 2011a-208860 A) discloses a refrigeration apparatus that includes an oil separator disposed on a discharge side of a compressor and configured to separate a refrigerating machine oil from a refrigerant, and an oil return circuit configured to return the refrigerating machine oil separated by the oil separator to an upstream side of a gas-liquid separator disposed on a suction side of the compressor. The refrigeration apparatus also includes an electronic expansion valve whose throttle opening degree is controllable, the electronic expansion valve being disposed at some midpoint to the oil return circuit. The opening degree of the electronic expansion valve is controlled in accordance with an operating frequency of the compressor and a difference in pressure between the suction side and discharge side of the compressor. The refrigerating machine oil is thus returned in appropriate amounts to the compressor.

### SUMMARY OF THE INVENTION

#### <Technical Problem>

[0004] However, Patent Literature 1 discloses only the refrigeration apparatus configured to control the opening degree of the electronic expansion valve for the oil return circuit in accordance with the operating frequency of the compressor and the difference in pressure between the suction side and discharge side of the compressor, but gives no considerations on other control methods.

[0005] In addition, if the oil separator does not separate the refrigerating machine oil so much, the refrigerating machine oil flows in considerably small amounts through the oil return circuit. Consequently, only a discharge gas refrigerant from the compressor may substantially flow through the oil return circuit. If only the discharge gas refrigerant flows through the oil return circuit, such a situation may lower the coefficient of performance of the refrigeration apparatus.

[0006] In view of the respects described above, the present invention provides a refrigeration apparatus that is capable of implementing a novel control method capable of suppressing occurrence of a situation in which a refrigerating machine oil from an oil separator is unsat-

isfactorily returned to a compressor and a discharge gas refrigerant is mostly returned to the compressor.

#### <Solutions to Problem>

[0007] According to a first aspect, a refrigeration apparatus includes a compressor, an oil separator, a refrigerant supply pipe, an oil return pipe, a flow rate adjusting mechanism, and a control unit. The oil separator is disposed on a discharge side of the compressor. The refrigerant supply pipe leads supply of a refrigerant to the compressor. The oil return pipe connects the oil separator to the refrigerant supply pipe. The flow rate adjusting mechanism is disposed on the oil return pipe. The control unit is configured to control the flow rate adjusting mechanism to reduce a flow rate when a temperature of the refrigerant discharged from the compressor or a pressure of the refrigerant flowing through the refrigerant supply pipe satisfies a predetermined condition.

[0008] The refrigerant supply pipe may be a pipe for supplying the refrigerant to a suction side of the compressor or may be a pipe for supplying the refrigerant to a middle of a compression process in the compressor.

[0009] Examples of the predetermined condition may include, but not limited to, a case where a discharge temperature rise rate at the compressor is more than a predetermined value (i.e., a case where a discharge temperature rise speed is more than a predetermined rise speed) and a case where a refrigerant pressure drop rate at the refrigerant supply pipe is more than a predetermined value (i.e., a case where a refrigerant pressure drop speed at the refrigerant supply pipe is more than a predetermined drop speed).

[0010] In the refrigeration apparatus, the control unit causes the flow rate adjusting mechanism to reduce the flow rate of a fluid (the refrigerant and/or a refrigerating machine oil) passing through the flow rate adjusting mechanism, when the temperature of the refrigerant discharged from the compressor or the pressure of the refrigerant flowing through the refrigerant supply pipe satisfies the predetermined condition.

[0011] In this case, the fluid flowing through the oil return pipe includes a small amount of refrigerating machine oil, and the fluid flowing through the oil return pipe includes a large amount of discharge gas refrigerant. If the discharge gas refrigerant is mostly returned to the compressor, the temperature of the refrigerant discharged from the compressor rises by repetition of gas refrigerant compressing operation by the compressor.

[0012] In a situation in which the refrigerating machine oil passes in large amounts through the flow rate adjusting mechanism on the oil return pipe, the refrigerating machine oil remains in a liquid state without phase change before flowing into the flow rate adjusting mechanism and after flown out of the flow rate adjusting mechanism. Since the refrigerating machine oil is higher in viscosity than the discharge gas refrigerant, the flow velocity of the refrigerating machine oil is less prone to in-

crease at the time when the refrigerating machine oil passes through the flow rate adjusting mechanism. Consequently, in the situation in which the refrigerating machine oil passes in large amounts through the flow rate adjusting mechanism on the oil return pipe, the refrigerating machine oil passes with smaller resistance; therefore, the flow rate adjusting mechanism is less prone to cause considerable decompression.

**[0013]** In contrast to this, the discharge gas refrigerant is lower in viscosity than the refrigerating machine oil. Therefore, in a situation in which the refrigerating machine oil passes in small amounts through the flow rate adjusting mechanism on the oil return pipe and the discharge gas refrigerant passes in large amounts through the flow rate adjusting mechanism on the oil return pipe, the flow velocity of the discharge gas refrigerant is apt to increase at the time when the discharge gas refrigerant passes through the flow rate adjusting mechanism. Consequently, in the situation in which the discharge gas refrigerant passes in large amounts through the flow rate adjusting mechanism on the oil return pipe, the discharge gas refrigerant passes with higher resistance, so that the flow rate adjusting mechanism is apt to cause decompression. A change from the situation in which the refrigerating machine oil passes in large amounts through the flow rate adjusting mechanism on the oil return pipe to the situation in which the gas refrigerant passes in large amount through the flow rate adjusting mechanism on the oil return pipe causes a reduction in pressure of the refrigerant flowing through the refrigerant supply pipe to which the oil return pipe is connected.

**[0014]** Hence, detecting a discharge refrigerant temperature rise at the compressor or a refrigerant pressure drop at the refrigerant supply pipe enables a grasp of a situation in which the gas refrigerant rather than the refrigerating machine oil is mostly returned to the compressor.

**[0015]** Consequently, for example, in the case where the discharge temperature rise rate at the compressor is more than the predetermined value (i.e., in the case where the discharge temperature rise speed is more than the predetermined rise speed) or in the case where the refrigerant pressure drop rate at the refrigerant supply pipe is more than the predetermined value (i.e., in the case where the refrigerant pressure drop speed at the refrigerant supply pipe is more than the predetermined drop speed), reducing the flow rate of the fluid passing through the flow rate adjusting mechanism prevents return of the gas refrigerant rather than the refrigerating machine oil at the oil return pipe. This configuration therefore suppresses occurrence of a situation in which the refrigerating machine oil from the oil separator is unsatisfactorily returned to the compressor and the discharge gas refrigerant is mostly returned to the compressor.

**[0016]** According to a second aspect, in the refrigeration apparatus according to the first aspect, the control unit performs normal control to control the flow rate adjusting mechanism, based on an amount of oil loss in the

compressor, the amount of oil loss being obtained by multiplying a circulation amount of refrigerant in the compressor by a rate of oil loss in the compressor. When the predetermined condition is satisfied in the normal control, the control unit controls the flow rate adjusting mechanism to further reduce the flow rate from a state of the flow rate adjusting mechanism in the normal control.

**[0017]** The circulation amount of refrigerant may be expressed in terms of mass or may be expressed in terms of volume. Preferably, the circulation amount of refrigerant is expressed in terms of mass.

**[0018]** The rate of oil loss refers to an amount of refrigerating machine oil contained per unit circulation amount of the refrigerant discharged from the compressor. For example, the rate of oil loss may be calculated based on a driving frequency of the compressor as well as a high pressure, an intermediate pressure, and a low pressure in a refrigeration cycle. The rate of oil loss may also be calculated in additional consideration of the degree of superheating of the refrigerant to be sucked into the compressor. However, the calculation method is not limited thereto.

**[0019]** In the refrigeration apparatus, when the predetermined condition is satisfied in the normal control, the control unit causes the flow rate adjusting mechanism to further reduce the flow rate from the state of the flow rate adjusting mechanism in the normal control. As described above, the refrigeration apparatus enables the control to reduce the flow rate in addition to the normal control. Therefore, even in the situation in which the discharge gas refrigerant is mostly returned to the compressor because of continuation of the normal control, the reduction in flow rate by the flow rate adjusting mechanism suppresses occurrence of the situation in which the refrigerating machine oil from the oil separator is unsatisfactorily returned to the compressor and the discharge gas refrigerant is mostly returned to the compressor.

**[0020]** According to a third aspect, the refrigeration apparatus according to the first or second aspect further includes a heat source-side heat exchanger and an intermediate expansion valve. The heat source-side heat exchanger is configured to condense the refrigerant discharged from the compressor. The refrigerant supply pipe is an injection pipe through which a part of the refrigerant condensed by the heat source-side heat exchanger is guided to a middle of a compression process in the compressor. The intermediate expansion valve is disposed at a middle of the injection pipe.

**[0021]** In the refrigeration apparatus, the oil return pipe leads, for example, the refrigerating machine oil separated by the oil separator to be guided to the middle of the compression process in the compressor, via the injection pipe. As described above, a part of the high-temperature fluid discharged from the compressor toward the oil separator is guided to the middle of the compression process in the compressor, rather than the suction side of the compressor. This configuration therefore suppresses occurrence of a situation in which heat energy of a part of

the high-temperature fluid discharged from the compressor is used for raising a suction refrigerant temperature at the compressor.

[0022] According to a fourth aspect, in the refrigeration apparatus according to any of the first to third aspects, the control unit controls the flow rate adjusting mechanism to a state that blocks passage of the refrigerant through the flow rate adjusting mechanism upon activation of the compressor.

[0023] Causing the flow rate adjusting mechanism to block the passage of the refrigerant through the flow rate adjusting mechanism upon activation of the compressor may be effected in at least a part of a period in which the frequency of the compressor increases. Such control is not necessarily effected over the entire period in which the frequency of the compressor increases. For example, the control used herein involves a case where the flow rate adjusting mechanism permits the passage of the refrigerant at the time when the frequency of the compressor starts to increase, and then blocks the passage of the refrigerant at the time when the frequency of the compressor further increases.

[0024] In the refrigeration apparatus, the flow rate adjusting mechanism blocks the passage of the refrigerant when the frequency of the compressor, which has been stopped, increases upon activation of the compressor. This configuration therefore efficiently increases a difference between a pressure at the discharge side of the compressor and a pressure at the side, to which the refrigerant supply pipe is connected, of the compressor in such a manner that the flow rate adjusting mechanism blocks the passage of the refrigerant upon activation of the compressor.

[0025] According to a fifth aspect, in the refrigeration apparatus according to any of the first to fourth aspects, the control unit controls the flow rate adjusting mechanism to a state that permits passage of the refrigerant through the flow rate adjusting mechanism before activation of the compressor.

[0026] In the refrigeration apparatus, the flow rate adjusting mechanism permits the passage of the refrigerant before activation of the compressor. This configuration therefore achieves pressure equalization by reducing the difference between the pressure at the discharge side of the compressor and the pressure at the side, to which the refrigerant supply pipe is connected, of the compressor. This configuration also allows the refrigerating machine oil in the oil separator to be dissolved into the refrigerant in the compressor via the oil return pipe and the refrigerant supply pipe. This configuration thus enables more reliable activation of the compressor.

<Advantageous Effects of Invention>

[0027] The refrigeration apparatus according to the first aspect suppresses occurrence of the situation in which the refrigerating machine oil from the oil separator is unsatisfactorily returned to the compressor and the

discharge gas refrigerant is mostly returned to the compressor.

[0028] The refrigeration apparatus according to the second aspect suppresses occurrence of the situation in which the refrigerating machine oil from the oil separator is unsatisfactorily returned to the compressor and the discharge gas refrigerant is mostly returned to the compressor, by the reduction in flow rate by the flow rate adjusting mechanism, even in the situation in which the discharge gas refrigerant is mostly returned to the compressor because of continuation of the normal control.

[0029] The refrigeration apparatus according to the third aspect suppresses the situation in which heat energy of a part of the high-temperature fluid discharged from the compressor is used for raising the suction refrigerant temperature at the compressor.

[0030] The refrigeration apparatus according to the fourth aspect efficiently increases the difference between the pressure at the discharge side of the compressor and the pressure at the side, to which the refrigerant supply pipe is connected, of the compressor in such a manner that the flow rate adjusting mechanism blocks the passage of the refrigerant upon activation of the compressor.

[0031] The refrigeration apparatus according to the fifth aspect activates the compressor more reliably.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0032]

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

FIG. 2 is a schematic block diagram of a schematic configuration of a controller and components connected to the controller.

FIG. 3 is a flowchart of exemplary processing to be performed by the controller in performing normal control and hot gas bypass suppression control on an oil return valve.

FIG. 4 is a general configuration diagram of a refrigeration apparatus including a refrigerant circuit according to Modification A.

FIG. 5 is a general configuration diagram of a refrigeration apparatus including a refrigerant circuit according to Modification B.

FIG. 6 is a general configuration diagram of a refrigeration apparatus including a refrigerant circuit according to Modification C.

## DESCRIPTION OF EMBODIMENTS

[0033] A refrigeration apparatus 100 according to an embodiment of the present invention will be described below with reference to the drawings. It should be noted that the following embodiments are merely specific examples of the present invention, do not intend to limit the technical scope of the present invention, and may be

appropriately modified without departing from the gist of the present invention.

#### (1) Refrigeration Apparatus 100

**[0034]** FIG. 1 is a schematic configuration diagram of a refrigeration apparatus 100 according to an embodiment of the present invention. The refrigeration apparatus 100 employs a vapor compression refrigeration cycle to cool a usage-side space such as the interior of a cold storage warehouse or the interior of a showcase in a store.

**[0035]** The refrigeration apparatus 100 mainly includes: a heat source unit 2; a plurality of (two in this embodiment) usage units, that is, a first usage unit 50 and a second usage unit 60; a liquid-side-refrigerant connection pipe 6 and a gas-side-refrigerant connection pipe 7 each connecting the heat source unit 2 to the first usage unit 50 and the second usage unit 60; a plurality of remote controllers, that is, a first remote controller 50a and a second remote controller 60a each serving as an input device and a display device; and a controller 70 configured to control operation of the refrigeration apparatus 100.

**[0036]** In the refrigeration apparatus 100, the heat source unit 2 as well as the first usage unit 50 and the second usage unit 60 connected to the heat source unit 2 in parallel via the liquid-side-refrigerant connection pipe 6 and the gas-side-refrigerant connection pipe 7 constitute a refrigerant circuit 10. The refrigeration apparatus 100 performs a refrigeration cycle to compress, cool or condense, decompress, heat or evaporate, and then compress again a sealed-in refrigerant in the refrigerant circuit 10. In this embodiment, the refrigerant circuit 10 is filled with R32 as a refrigerant for a vapor compression refrigeration cycle; however, the refrigerant is not limited to R32.

##### (1-1) Heat Source Unit 2

**[0037]** The heat source unit 2, to which the first usage unit 50 and the second usage unit 60 are connected in parallel via the liquid-side-refrigerant connection pipe 6 and the gas-side-refrigerant connection pipe 7, constitutes a part of the refrigerant circuit 10. The heat source unit 2 mainly includes a compressor 21, an oil separator 23, a four-way switching valve 24, a heat source-side heat exchanger 25, a heat source-side fan 45, a receiver 27, a subcooler 31, a heat source-side expansion valve 28, an injection pipe 30, a subcooling expansion valve 32, an injection valve 33, an oil return pipe 38, an oil return valve 39, a first branch pipe 34, a second branch pipe 36, a liquid-side shutoff valve 48, and a gas-side shutoff valve 49.

**[0038]** The heat source unit 2 also includes a discharge-side pipe 41, a suction-side pipe 42, a first heat source liquid-side pipe 43, and a second heat source liquid-side pipe 44. The discharge-side pipe 41 connects

a discharge side of the compressor 21 to one of connection ports of the four-way switching valve 24, and the oil separator 23 is disposed at a middle of the discharge-side pipe 41. The suction-side pipe 42 connects a suction side of the compressor 21 to one of the connection ports of the four-way switching valve 24. The first heat source liquid-side pipe 43 connects a liquid side of the heat source-side heat exchanger 25 to the receiver 27. The second heat source liquid-side pipe 44 connects the liquid-side shutoff valve 48 to an end of the receiver 27, the end being opposite to an end connected to the heat source-side heat exchanger 25.

**[0039]** The compressor 21 is a device configured to change by compression a low-pressure refrigerant to a high-pressure refrigerant in the refrigeration cycle. The compressor 21 according to this embodiment includes a first compressor 21a, a second compressor 21b, and a third compressor 21c that are connected in parallel; however, the configuration of the compressor 21 is not limited thereto. In this embodiment, each of the first compressor 21a, the second compressor 21b, and the third compressor 21c is a fully hermetic high pressure dome-type scroll compressor. The first compressor 21a is a variable displacement compressor whose number of rotations is variable. The first compressor 21a includes an inverter. Each of the second compressor 21b and the third compressor 21c is a fixed displacement compressor whose number of rotations is fixed. Each of the second compressor 21b and the third compressor 21c does not include an inverter.

**[0040]** The first compressor 21a, the second compressor 21b, and the third compressor 21c have suction sides to which individual suction pipes are respectively connected. The individual suction pipes are merged into one at their most upstream sides. The suction-side pipe 42 connects the most upstream-side merged portion of the individual suction pipes to the four-way switching valve 24.

**[0041]** The first compressor 21a, the second compressor 21b, and the third compressor 21c also have discharge sides to which individual discharge pipes are respectively connected. The individual discharge pipes are merged into one at their most downstream sides. The discharge-side pipe 41 connects the most downstream-side merged portion of the individual discharge pipes to the four-way switching valve 24. A check valve 22a is disposed on the discharge side of the first compressor 21a to permit only a discharge flow. Likewise, a check valve 22b is disposed on the discharge side of the second compressor 21b to permit only a discharge flow, and a check valve 22c is disposed on the discharge side of the third compressor 21c to permit only a discharge flow.

**[0042]** The oil separator 23 is a container configured to mainly separate a refrigerating machine oil from the refrigerant discharged from the compressor 21, and is disposed at a middle of the discharge-side pipe 41. The oil separator 23 allows a collective inflow of fluids (including the refrigerant and the refrigerating machine oil) dis-

charged from the plurality of compressors, that is, the first compressor 21a, the second compressor 21b, and the third compressor 21c constituting the compressor 21, and mainly separates the refrigerating machine oil (into which a gas refrigerant is mixed to some extent depending on an operating condition) from the fluid. For this reason, the oil separator 23 according to this embodiment is larger in capacity than, for example, oil separators to be respectively disposed on the discharge sides of the first compressor 21a, second compressor 21b, and third compressor 21c in one-to-one correspondence.

**[0043]** The oil return pipe 38 extends from and branches off the oil separator 23 disposed at the middle of the discharge-side pipe 41. The oil return pipe 38 has a second end that is connected to a middle of the injection pipe 30 (to be described later) at a position between the subcooler 31 and first, second, and third injection shunt pipes 33x, 33y, and 33z. The oil return valve 39 is disposed at a middle of the oil return pipe 38. The oil return valve 39 includes an electric expansion valve whose valve opening degree is controllable.

**[0044]** The four-way switching valve 24 is connected to a downstream-side end of the discharge-side pipe 41. The four-way switching valve 24 switches a connection state, thereby switching between a cooling operation state in which the discharge side of the compressor 21 is connected to the heat source-side heat exchanger 25 and the gas-side shutoff valve 49 is connected to the suction side of the compressor 21, and a heating operation state in which the discharge side of the compressor 21 is connected to the gas-side shutoff valve 49 and the heat source-side heat exchanger 25 is connected to the suction side of the compressor 21.

**[0045]** The heat source-side heat exchanger 25 functions as a radiator for the high-pressure refrigerant in the refrigeration cycle, and also functions as an evaporator for the low-pressure refrigerant in the refrigeration cycle. The heat source-side heat exchanger 25 has a first end connected to a refrigerant pipe extending from the four-way switching valve 24, and a second end connected to the first heat source liquid-side pipe 43.

**[0046]** The heat source-side fan 45 sucks outside air (heat source-side air) into the heat source unit 2, causes the heat source-side air to exchange heat with the refrigerant in the heat source-side heat exchanger 25, and then forms an air flow for discharging the heat source-side air. The heat source-side fan 45 is driven to rotate by a heat source-side fan motor M45. The heat source-side fan 45 has an airflow volume controlled by adjusting the number of rotations of the heat source-side fan motor M45.

**[0047]** A first heat source liquid-side check valve 26 is disposed at a middle of the first heat source liquid-side pipe 43. The first heat source liquid-side check valve 26 permits only a flow of the refrigerant from the heat source-side heat exchanger 25 toward the receiver 27.

**[0048]** The receiver 27 is a container temporarily stores therein the refrigerant. The receiver 27 is disposed on

the first heat source liquid-side pipe 43 on a side opposite to the heat source-side heat exchanger 25. The first heat source liquid-side pipe 43 is connected to an upper gas-phase portion of the receiver 27.

**[0049]** The heat source-side expansion valve 28 is an electric expansion valve whose valve opening degree is controllable. The heat source-side expansion valve 28 is disposed on the second heat source liquid-side pipe 44. More specifically, the heat source-side expansion valve 28 is disposed downstream of the subcooler 31.

**[0050]** The subcooler 31 is a heat exchanger for further cooling the refrigerant temporarily stored in the receiver 27 before the refrigerant is supplied to the first and second usage units 50 and 60. The subcooler 31 is disposed on the second heat source liquid-side pipe 44 at a position between the receiver 27 and the heat source-side expansion valve 28.

**[0051]** The injection pipe 30 extends from the second heat source liquid-side pipe 44 so as to branch off a portion between the subcooler 31 and the heat source-side expansion valve 28. The injection pipe 30 is connected to a middle of a compression process in the compressor 21.

**[0052]** The subcooling expansion valve 32 is an electric expansion valve whose valve opening degree is controllable. The subcooling expansion valve 32 is disposed upstream of the subcooler 31 at a middle of the injection pipe 30. The subcooler 31 causes the refrigerant that flows out of the receiver 27 and flows through the second heat source liquid-side pipe 44 to exchange heat with the refrigerant that flows through the injection pipe 30 and is decompressed by the subcooling expansion valve 32. The refrigerant flowing through the second heat source liquid-side pipe 44 is thus subcooled, and then flows toward the heat source-side expansion valve 28. In the injection pipe 30, the refrigerant passes through the subcooler 31, and then flows toward the downstream side of the injection pipe 30.

**[0053]** In the injection pipe 30, a portion downstream of a merged portion with the oil return pipe 38 (i.e., a portion closer to the compressor 21 than the merged portion is) extends to the compressor 21 via the first, second, and third injection shunt pipes 33x, 33y, and 33z. Specifically, the portion downstream of the merged portion with the oil return pipe 38 (i.e., the portion closer to the compressor 21 than the merged portion is) in the injection pipe 30 is separated into the first injection shunt pipe 33x through which the refrigerant flows into the middle of the compression process in the first compressor 21a, the second injection shunt pipe 33y through which the refrigerant flows into the middle of the compression process in the second compressor 21b, and the third injection shunt pipe 33z through which the refrigerant flows into the middle of the compression process in the third compressor 21c.

**[0054]** The injection valve 33 is an electric expansion valve whose valve opening degree is controllable. The injection valve 33 includes first, second, and third injec-

tion valves 33a, 33b, and 33c respectively disposed at middles of the first, second, and third injection shunt pipes 33x, 33y, and 33z of the injection pipe 30. Specifically, the first injection valve 33a is disposed at the middle of the first injection shunt pipe 33x, the second injection valve 33b is disposed at the middle of the second injection shunt pipe 33y, and the third injection valve 33c is disposed at the middle of the third injection shunt pipe 33z.

**[0055]** A second heat source liquid-side check valve 29 is disposed on the second heat source liquid-side pipe 44 at a position between the heat source-side expansion valve 28 and the liquid-side shutoff valve 48. The second heat source liquid-side check valve 29 permits only a flow of the refrigerant from the heat source-side expansion valve 28 toward the liquid-side shutoff valve 48.

**[0056]** The first branch pipe 34 is a refrigerant pipe that branches off a portion between the second heat source liquid-side check valve 29 and the liquid-side shutoff valve 48 at a middle of the second heat source liquid-side pipe 44 and merges with a portion between the first heat source liquid-side check valve 26 and the receiver 27 at a middle of the first heat source liquid-side pipe 43. A first branch check valve 35 is disposed at a middle of the first branch pipe 34. The first branch check valve 35 permits only a flow of the refrigerant from the second heat source liquid-side pipe 44 toward the first heat source liquid-side pipe 43.

**[0057]** The second branch pipe 36 is a refrigerant pipe that branches off a portion between the heat source-side expansion valve 28 and the second heat source liquid-side check valve 29 at a middle of the second heat source liquid-side pipe 44 and merges with a portion between the heat source-side heat exchanger 25 and the first heat source liquid-side check valve 26 at a middle of the first heat source liquid-side pipe 43. A second branch check valve 37 is disposed at a middle of the second branch pipe 36. The second branch check valve 37 permits only a flow of the refrigerant from the second heat source liquid-side pipe 44 toward the first heat source liquid-side pipe 43.

**[0058]** The liquid-side shutoff valve 48 is a manual valve disposed at a joint between the second heat source liquid-side pipe 44 and the liquid-side-refrigerant connection pipe 6.

**[0059]** The gas-side shutoff valve 49 is a manual valve disposed at a joint between a pipe extending from the four-way switching valve 24 and the gas-side-refrigerant connection pipe 7.

**[0060]** The heat source unit 2 includes various sensors. Specifically, a low-pressure sensor 40a is disposed on the suction-side pipe 42. The low-pressure sensor 40a is configured to detect a suction pressure that is a pressure of the refrigerant at the suction side of the compressor 21. A high-pressure sensor 40c is disposed at a middle of the individual discharge pipe for the first compressor 21a. The high-pressure sensor 40c is configured to detect a discharge pressure that is a pressure of the refrigerant at the discharge side of the compressor 21.

An intermediate-pressure sensor 40b is disposed between a merged portion of the injection pipe 30 with the oil return pipe 38 and the subcooler 31 at a middle of the injection pipe 30. The intermediate-pressure sensor 40b is configured to detect an intermediate pressure in the refrigeration cycle. A heat source-side air temperature sensor 46 is disposed around the heat source-side heat exchanger 25 or the heat source-side fan 45. The heat source-side air temperature sensor 46 is configured to detect a temperature of heat source-side air to be sucked into the heat source unit 2. A discharge temperature sensor 47 is disposed at a middle of the discharge-side pipe 41. In this embodiment, the discharge temperature sensor 47 is disposed upstream of the oil separator 23 at a position where the discharge refrigerants from the first compressor 21a, second compressor 21b, and third compressor 21c are merged. The discharge temperature sensor 47 is configured to detect a temperature of the refrigerant discharged from the compressor 21.

**[0061]** The heat source unit 2 also includes a heat source unit control unit 20 configured to control operations of the respective components constituting the heat source unit 2. The heat source unit control unit 20 includes a microcomputer including, for example, a central processing unit (CPU) and a memory. The heat source unit control unit 20 is connected to usage unit control units 57 and 67 of each usage unit 50, 60 via communication lines to exchange, for example, a control signal with the usage unit control units 57 and 67.

#### (1-2) First Usage Unit 50

**[0062]** The first usage unit 50 is connected to the heat source unit 2 via the liquid-side-refrigerant connection pipe 6 and the gas-side-refrigerant connection pipe 7, and constitutes a part of the refrigerant circuit 10.

**[0063]** The first usage unit 50 includes a first usage-side expansion valve 54 and a first usage-side heat exchanger 52. The first usage unit 50 also includes: a first usage-side liquid refrigerant pipe 59 connecting a liquid-side end of the first usage-side heat exchanger 52 to the liquid-side-refrigerant connection pipe 6; and a first usage-side gas refrigerant pipe 58 connecting a gas-side end of the first usage-side heat exchanger 52 to the gas-side-refrigerant connection pipe 7.

**[0064]** The first usage-side expansion valve 54 is an electric expansion valve whose valve opening degree is controllable. The first usage-side expansion valve 54 is disposed at a middle of the first usage-side liquid refrigerant pipe 59.

**[0065]** The first usage-side heat exchanger 52 functions as an evaporator for the low-pressure refrigerant in a cooling operation in the refrigeration cycle to cool inside air (usage-side air), and also functions as a radiator for the refrigerant in a heating operation such as a defrosting operation.

**[0066]** The first usage unit 50 includes a first usage-side fan 53 for sucking usage-side air into the first usage

unit 50, causing the usage-side air to exchange heat with the refrigerant in the first usage-side heat exchanger 52, and then supplying the usage-side air to the usage-side space. The first usage-side fan 53 is configured to supply to the first usage-side heat exchanger 52 the usage-side air for heating the refrigerant flowing through the first usage-side heat exchanger 52. The first usage-side fan 53 is driven to rotate by a first usage-side fan motor M53.

**[0067]** The first usage unit 50 also includes a first usage unit control unit 57 configured to control operations of the respective components constituting the first usage unit 50. The first usage unit control unit 57 includes a micro-computer including, for example, a CPU and a memory. The first usage unit control unit 57 is connected to the heat source unit control unit 20 via the communication line to exchange, for example, a control signal with the heat source unit control unit 20.

#### (1-3) Second Usage Unit 60

**[0068]** The second usage unit 60 is similar in configuration to the first usage unit 50. The second usage unit 60 is also connected to the heat source unit 2 via the liquid-side-refrigerant connection pipe 6 and the gas-side-refrigerant connection pipe 7, and constitutes a part of the refrigerant circuit 10. The second usage unit 60 and the first usage unit 50 are connected in parallel.

**[0069]** The second usage unit 60 includes a second usage-side expansion valve 64 and a second usage-side heat exchanger 62. The second usage unit 60 also includes: a second usage-side liquid refrigerant pipe 69 connecting a liquid-side end of the second usage-side heat exchanger 62 to the liquid-side-refrigerant connection pipe 6; and a second usage-side gas refrigerant pipe 68 connecting a gas-side end of the second usage-side heat exchanger 62 to the gas-side-refrigerant connection pipe 7.

**[0070]** The second usage-side expansion valve 64 is an electric expansion valve whose valve opening degree is controllable. The second usage-side expansion valve 64 is disposed at a middle of the second usage-side liquid refrigerant pipe 69.

**[0071]** The second usage-side heat exchanger 62 functions as an evaporator for the low-pressure refrigerant in the cooling operation in the refrigeration cycle to cool inside air (usage-side air), and also functions as a radiator for the refrigerant in the heating operation such as the defrosting operation.

**[0072]** As in the first usage unit 50, the second usage unit 60 also includes a second usage-side fan 63 to be driven to rotate by a second usage-side fan motor M63.

**[0073]** The second usage unit 60 also includes a second usage unit control unit 67 configured to control operations of the respective components constituting the second usage unit 60. The second usage unit control unit 67 includes a microcomputer including, for example, a CPU and a memory. The second usage unit control unit 67 is connected to the heat source unit control unit 20

via the communication line to exchange, for example, a control signal with the heat source unit control unit 20.

#### (1-4) First Remote Controller 50a, Second Remote Controller 60a

**[0074]** The first remote controller 50a is an input device that causes a user of the first usage unit 50 to input various instructions for switching an operating state of the refrigeration apparatus 100. The first remote controller 50a also functions as a display device for displaying the operating state of the refrigeration apparatus 100 and predetermined notification information. The first remote controller 50a is connected to the first usage unit control unit 57 via a communication line to exchange signals with the first usage unit control unit 57.

**[0075]** As in the first remote controller 50a, the second remote controller 60a is an input device that causes a user of the second usage unit 60 to input various instructions for switching an operating state of the refrigeration apparatus 100, and a display device for displaying the operating state of the refrigeration apparatus 100 and predetermined notification information. The second remote controller 60a is connected to the second usage unit control unit 67 via a communication line to exchange signals with the second usage unit control unit 67.

#### (2) Details of Controller 70

**[0076]** In the refrigeration apparatus 100, the heat source unit control unit 20, the first usage unit control unit 57, and the second usage unit control unit 67 are connected via the communication lines to constitute the controller 70 for controlling operation of the refrigeration apparatus 100.

**[0077]** FIG. 2 is a schematic block diagram of a schematic configuration of the controller 70 and the components connected to the controller 70.

**[0078]** The controller 70 has a plurality of control modes, and controls the operation of the refrigeration apparatus 100 in accordance with a control mode in which the controller 70 is to be placed. Examples of the control modes of the controller 70 include: a cooling operating mode in which the controller 70 is placed in a normal situation; and a heating operating mode in which the controller 70 is placed in reverse cycle defrosting. The controller 70 selectively performs normal control on the oil return valve 39 and hot gas bypass suppression control on the oil return valve 39 in both the cooling operating mode and the heating operating mode. The controller 70 performs the normal control on the oil return valve 39 to return an appropriate amount of refrigerating machine oil to the compressor 21 in accordance with operating conditions of the refrigeration cycle. The controller 70 performs the hot gas bypass suppression control on the oil return valve 39 to suppress passage of a large amount of hot gas through the oil return valve 39 although the oil return valve 39 cannot allow passage of a satis-

factory amount of refrigerating machine oil.

**[0079]** The controller 70 is electrically connected to the actuators (i.e., the compressor 21, the four-way switching valve 24, the heat source-side expansion valve 28, the subcooling expansion valve 32, the injection valve 33, the oil return valve 39, and the heat source-side fan 45 (the heat source-side fan motor M45)) and the various sensors (i.e., the low-pressure sensor 40a, the intermediate-pressure sensor 40b, the high-pressure sensor 40c, the heat source-side air temperature sensor 46, the discharge temperature sensor 47, and the like) in the heat source unit 2. The controller 70 is also electrically connected to the actuators (i.e., the first usage-side fan 53 (the first usage-side fan motor M53) and the first usage-side expansion valve 54) in the first usage unit 50. The controller 70 is also electrically connected to the actuators (i.e., the second usage-side fan 63 (the second usage-side fan motor M63) and the second usage-side expansion valve 64) in the second usage unit 60. The controller 70 is also electrically connected to the first remote controller 50a and the second remote controller 60a.

**[0080]** The controller 70 mainly includes a storage unit 71, a communication unit 72, a mode control unit 73, an actuator control unit 74, and a display control unit 75. These units in the controller 70 are implemented in such a manner that the components in the heat source unit control unit 20 and/or each usage unit control unit 57, 67 integrally function.

#### (2-1) Storage Unit 71

**[0081]** The storage unit 71 includes, for example, a read only memory (ROM), a random access memory (RAM), and a flash memory. The storage unit 71 has a volatile storage region and a nonvolatile storage region. The storage unit 71 stores therein a control program that defines processing to be performed by each unit of the controller 70. Also in the storage unit 71, the respective units of the controller 70 appropriately store predetermined information (e.g., values detected by the respective sensors, commands input to the first remote controller 50a, commands input to the second remote controller 60a) in a predetermined storage region.

#### (2-2) Communication Unit 72

**[0082]** The communication unit 72 is a functional unit that plays a role as a communication interface for exchanging signals with the respective components connected to the controller 70. The communication unit 72 receives a request from the actuator control unit 74, and transmits a predetermined signal to a designated one of the actuators. The communication unit 72 also receives signals from the various sensors, the first remote controller 50a, and the second remote controller 60a, and stores the received signals in the predetermined storage region of the storage unit 71.

#### (2-3) Mode Control Unit 73

**[0083]** The mode control unit 73 is a functional unit that switches a control mode, for example. The mode control unit 73 places the controller 70 in the cooling operating mode when the refrigeration apparatus 100 that does not satisfy a predetermined defrosting condition is operated. The predetermined defrosting condition concerns frost forming on the first and second usage-side heat exchangers 52 and 62. When the predetermined defrosting condition is satisfied in the cooling operating mode, the mode control unit 73 switches the control mode to the heating operating mode. The mode control unit 73 basically performs the normal control on the oil return valve 39 in both the cooling operating mode and the heating operating mode. When a rise speed of a temperature of the refrigerant discharged from the compressor 21 (i.e., a temperature detected by the discharge temperature sensor 47) is more than a predetermined rise speed, the mode control unit 73 switches the normal control for the oil return valve 39 to the hot gas bypass suppression control for the oil return valve 39. (2-4) Actuator Control Unit 74

**[0084]** The actuator control unit 74 controls, based on the control program, the operations of the respective actuators (e.g., the compressor 21) in the refrigeration apparatus 100, in accordance with a situation.

**[0085]** In the cooling operating mode, the actuator control unit 74 connects the discharge side of the compressor 21 to the heat source-side heat exchanger 25 via the four-way switching valve 24, and also connects the suction side of the compressor 21 to the gas-side shutoff valve 49 via the four-way switching valve 24. In this connection state, the actuator control unit 74 brings the heat source-side expansion valve 28 into a fully open state. In addition, the actuator control unit 74 controls, for example, the number of rotations of the compressor 21, the number of rotations of the heat source-side fan 45, the opening degree of the subcooling expansion valve 32, the opening degree of the oil return valve 39, the valve opening degrees of the first, second, and third injection valves 33a, 33b, and 33c, the opening degrees of the usage-side expansion valves 54 and 64, and the numbers of rotations of the usage-side fans 53 and 63 in real time, in accordance with, for example, set temperatures and values detected by the various sensors. In the cooling operating mode, each of the first, second, and third injection valves 33a, 33b, and 33c is brought into a state other than the fully closed state.

**[0086]** In the heating operating mode, the actuator control unit 74 connects the discharge side of the compressor 21 to the gas-side shutoff valve 49 via the four-way switching valve 24, and also connects the suction side of the compressor 21 to the heat source-side heat exchanger 25 via the four-way switching valve 24. In this connection state, the actuator control unit 74 brings the subcooling expansion valve 32 into a fully closed state, brings the usage-side expansion valves 54 and 64 into the fully open state, and stops the usage-side fans 53

and 63. In addition, the actuator control unit 74 controls, for example, the number of rotations of the compressor 21, the number of rotations of the heat source-side fan 45, the opening degree of the heat source-side expansion valve 28, the opening degree of the oil return valve 39, and the valve opening degrees of the first, second, and third injection valves 33a, 33b, and 33c in real time, in accordance with, for example, values detected by the various sensors. Also in the heating operating mode, each of the first, second, and third injection valves 33a, 33b, and 33c is brought into a state other than the fully closed state.

**[0087]** In the cooling operating mode and the heating operating mode, the controller 70 selectively performs the normal control on the oil return valve 39 and the hot gas bypass suppression control on the oil return valve 39.

-- Normal control for oil return valve 39 --

**[0088]** In the normal control for the oil return valve 39 (i.e., control other than the hot gas bypass suppression control), the actuator control unit 74 controls the opening degree of the oil return valve 39 such that a passage and circulation amount becomes equal to an amount of oil loss in the compressor 21. In other words, the actuator control unit 74 controls the valve opening degree of the oil return valve 39 such that "an amount of oil loss in the compressor 21" becomes equal to "a passage and circulation amount in the oil return valve 39".

**[0089]** A relation of "an amount of oil loss in a compressor" = "a circulation amount of refrigerant in the compressor"  $\times$  "a rate of oil loss in the compressor" is satisfied. In a case where the plurality of compressors, that is, the first compressor 21a, the second compressor 21b, and the third compressor 21c, constituting the compressor 21 are respectively driven, "the amount of oil loss in the compressor" is calculated from "the circulation amount of refrigerant in the compressor" and "the rate of oil loss in the compressor" as to each of the compressors driven. By summing the results, "the amount of oil loss in the compressor 21" is calculated.

**[0090]** For example, "the circulation amount in the compressor" may be calculated based on, but not limited to, a piston displacement of the compressor, a driving frequency of the compressor, and a suction refrigerant density of the compressor. Alternatively, "the circulation amount in the compressor" may be calculated by dividing electric power input to the compressor 21 by a difference in enthalpy between the outlet and inlet of the compressor 21.

**[0091]** In addition, "the rate of oil loss in the compressor" may be calculated for each compressor driven, based on the driving frequency of the compressor, a high pressure, an intermediate pressure, and a low pressure in a refrigeration cycle, and the degree of superheating of a refrigerant to be sucked by the compressor if necessary.

**[0092]** In addition, "the passage and circulation

amount in the oil return valve 39" may be calculated using the valve opening degree of the oil return valve 39, the difference in pressure between the refrigerant before flowing into the oil return valve 39 and the refrigerant that has flown out of the oil return valve 39 (i.e., the high pressure - the intermediate pressure), and predetermined relation value table data stored in the storage unit 71 in advance. The predetermined relation value table data is obtained in advance, based on such a relation that a passage and circulation amount increases as the valve opening degree of the oil return valve 39 is larger and also increases as the difference in pressure between the refrigerant before flowing into the oil return valve 39 and the refrigerant that has flown out of the oil return valve 39 is larger.

**[0093]** As described above, the valve opening degree of the oil return valve 39 is substantially controlled in accordance with "the amount of oil loss in the compressor 21" and "the difference in pressure between the refrigerant before flowing into the oil return valve 39 and the refrigerant that has flown out of the oil return valve 39 (i.e., the high pressure - the intermediate pressure)".

-- Hot gas bypass suppression control for oil return valve 39 --

**[0094]** In the hot gas bypass suppression control for the oil return valve 39, the actuator control unit 74 lowers the opening degree of the oil return valve 39 below the valve opening degree of the oil return valve 39 subjected to the normal control in the preceding cooling operating mode or heating operating mode. For example, the actuator control unit 74 may lower the opening degree of the oil return valve 39 to a half of the valve opening degree of the oil return valve 39 subjected to the normal control in the preceding cooling operating mode or heating operating mode. Alternatively, the actuator control unit 74 may lower the opening degree of the oil return valve 39 so as to bring the oil return valve 39 into the fully closed state. However, the degree of lowering the opening degree of the oil return valve 39 is not limited thereto. Lowering the valve opening degree of the oil return valve 39 enables suppression of degradation in performance to be caused because hot gas is returned in large amounts to the suction side of the compressor 21 via the oil return pipe 38.

**[0095]** In lowering the opening degree of the oil return valve 39, the valve opening degrees of the first, second, and third injection valves 33a, 33b, and 33c are not particularly changed and are maintained at the same control state.

(2-5) Display Control Unit 75

**[0096]** The display control unit 75 is a functional unit that controls operations of the first remote controller 50a and second remote controller 60a each serving as the display device.

**[0097]** The display control unit 75 causes each of the first remote controller 50a and the second remote controller 60a to output predetermined information in order that information on an operating state or situation is displayed for an administrator.

**[0098]** For example, the display control unit 75 causes each of the first remote controller 50a and the second remote controller 60a to display thereon various kinds of information, such as set temperatures, during the cooling operation.

**[0099]** In the hot gas bypass suppression control, the display control unit 75 causes each of the first remote controller 50a and the second remote controller 60a to display thereon information indicating that the refrigeration apparatus 100 is in the hot gas bypass suppression control mode.

### (3) Flow of Refrigerant in Cooling Operating Mode

**[0100]** Next, a description will be given of the flow of the refrigerant in the refrigerant circuit 10 in the cooling operating mode.

**[0101]** During the operation, the refrigeration apparatus 100 performs the cooling operation (a refrigeration cycle operation) causing the refrigerant in the refrigerant circuit 10 to mainly circulate through the compressor 21, the heat source-side heat exchanger 25, the receiver 27, the subcooler 31, the heat source-side expansion valve 28, the usage-side expansion valves 54, 64, and the usage-side heat exchangers 52, 62 in this order.

**[0102]** When the cooling operation is started, the refrigerant is sucked into and compressed by the compressor 21, and then is discharged from the compressor 21, in the refrigerant circuit 10. In the cooling operation, the low pressure in the refrigeration cycle corresponds to the suction pressure to be detected by the low-pressure sensor 40a, the high pressure in the refrigeration cycle corresponds to the discharge pressure to be detected by the high-pressure sensor 40c, and the intermediate pressure in the refrigeration cycle corresponds to the discharge pressure to be detected by the intermediate-pressure sensor 40b.

**[0103]** The compressor 21 is subjected to capacity control according to a cooling load to be required for each of the first usage unit 50 and the second usage unit 60. Specifically, the operating frequency of the compressor 21 is controlled such that the suction pressure takes a target value set in accordance with the cooling load to be required for each of the first usage unit 50 and the second usage unit 60.

**[0104]** The gas refrigerant discharged from the compressor 21 flows into the heat source-side heat exchanger 25 through the gas-side end of the heat source-side heat exchanger 25, via the discharge-side pipe 41. The oil separator 23 disposed at the middle of the discharge-side pipe 41 separates the refrigerating machine oil from the refrigerant discharged from the compressor 21, and guides the refrigerating machine oil to the oil return pipe

38. In the cooling operating mode, the oil return valve 39 is subjected to the normal control or the hot gas bypass suppression control.

**[0105]** When the gas refrigerant flows into the heat source-side heat exchanger 25 through the gas-side end of the heat source-side heat exchanger 25, the heat source-side heat exchanger 25 causes the gas refrigerant to radiate heat by heat exchange with the heat source-side air supplied by the heat source-side fan 45, and then condenses the gas refrigerant to turn the gas refrigerant into the liquid refrigerant. The liquid refrigerant flows out of the heat source-side heat exchanger 25 through the liquid-side end of the heat source-side heat exchanger 25.

**[0106]** When the liquid refrigerant flows out of the heat source-side heat exchanger 25 through the liquid-side end of the heat source-side heat exchanger 25, then the liquid refrigerant passes through the first heat source liquid-side pipe 43 and the first heat source liquid-side check valve 26 without being shunted to the second branch pipe 36, and flows into the receiver 27 through the inlet of the receiver 27. When the liquid refrigerant flows into the receiver 27, the receiver 27 temporarily stores therein the liquid refrigerant in a saturated state. Thereafter, the liquid refrigerant flows out of the receiver 27 through the outlet of the receiver 27.

**[0107]** When the liquid refrigerant flows out of the receiver 27 through the outlet of the receiver 27, then the liquid refrigerant flows into the subcooler 31 through the second heat source liquid-side pipe 44.

**[0108]** When the liquid refrigerant flows into the subcooler 31, the subcooler 31 further cools the liquid refrigerant by heat exchange with the refrigerant flowing through the injection pipe 30, thereby bringing the liquid refrigerant into a subcooled state. The resultant liquid refrigerant flows out of the subcooler 31 through the outlet, coupled to the heat source-side expansion valve 28, of the subcooler 31. The controller 70 controls the valve opening degree of the subcooling expansion valve 32 such that the refrigerant flowing from the subcooler 31 toward the heat source-side expansion valve 28 has a predetermined positive degree of subcooling and a value detected by the intermediate-pressure sensor satisfies a predetermined intermediate pressure condition.

**[0109]** When the liquid refrigerant flows out of the subcooler 31 through the outlet, coupled to the heat source-side expansion valve 28, of the subcooler 31, then the liquid refrigerant flows into the heat source-side expansion valve 28 via a portion, between the subcooler 31 and the heat source-side expansion valve 28, of the second heat source liquid-side pipe 44. At this time, the liquid refrigerant, which has flown out of the subcooler 31 through the outlet, coupled to the heat source-side expansion valve 28, of the subcooler 31, partly flows toward the injection pipe 30 branching off the portion, between the subcooler 31 and the heat source-side expansion valve 28, of the second heat source liquid-side pipe 44.

**[0110]** The refrigerant flowing through the injection

pipe 30 is decompressed by the subcooling expansion valve 32 to have the intermediate pressure in the refrigeration cycle. The refrigerant decompressed by the subcooling expansion valve 32 flows through the injection pipe 30, and then flows into the subcooler 31 through the inlet, connected to the injection pipe 30, of the subcooler 31. When the refrigerant flows into the subcooler 31 through the inlet, connected to the injection pipe 30, of the subcooler 31, the subcooler 31 causes the refrigerant to exchange heat with the refrigerant flowing through the second heat source liquid-side pipe 44, and then heats the refrigerant to turn the refrigerant into the gas refrigerant. The refrigerant heated by the subcooler 31 flows toward the downstream side of the injection pipe 30, and is mixed with the refrigerating machine oil from the oil return pipe 38. The resultant refrigerant is then shunted to each of the first, second, and third injection shunt pipes 33x, 33y, and 33z, and the shunted refrigerants respectively flow into the middles of the compression processes in the first, second, and third compressors 21a, 21b, and 21c. The amounts of the refrigerants flowing through the first, second, and third injection shunt pipes 33x, 33y, and 33z are respectively adjusted by the valve opening degrees of the first, second, and third injection valves 33a, 33b, and 33c.

**[0111]** The heat source-side expansion valve 28 is brought into the fully open state in the cooling operating mode. The liquid refrigerant, which has flown into the heat source-side expansion valve 28 via the second heat source liquid-side pipe 44, therefore passes through the heat source-side expansion valve 28 without being decompressed, and flows into each of the first usage unit 50 and the second usage unit 60 that are currently operated, via the liquid-side shutoff valve 48 and the liquid-side-refrigerant connection pipe 6.

**[0112]** When the refrigerant flows into the first usage unit 50, then the refrigerant flows into the first usage-side expansion valve 54 via a part of the first usage-side liquid refrigerant pipe 59. When the refrigerant flows into the first usage-side expansion valve 54, then the refrigerant is decompressed by the first usage-side expansion valve 54 to have the low pressure in the refrigeration cycle. Thereafter, the refrigerant flows into the first usage-side heat exchanger 52 through the liquid-side end of the first usage-side heat exchanger 52 via the first usage-side liquid refrigerant pipe 59. When the refrigerant flows into the first usage-side heat exchanger 52 through the liquid-side end of the first usage-side heat exchanger 52, the first usage-side heat exchanger 52 evaporates the refrigerant by heat exchange with the usage-side air supplied by the first usage-side fan 53, thereby turning the refrigerant into the gas refrigerant. The resultant gas refrigerant flows out of the first usage-side heat exchanger 52 through the gas-side end of the first usage-side heat exchanger 52. When the gas refrigerant flows out of the first usage-side heat exchanger 52 through the gas-side end of the first usage-side heat exchanger 52, then the gas refrigerant flows to the gas-side-refrigerant connec-

tion pipe 7 via the first usage-side gas refrigerant pipe 58.

**[0113]** As in the first usage unit 50, when the refrigerant flows into the second usage unit 60, then the refrigerant flows into the second usage-side expansion valve 64 via a part of the second usage-side liquid refrigerant pipe 69. When the refrigerant flows into the second usage-side expansion valve 64, then the refrigerant is decompressed by the second usage-side expansion valve 64 to have the low pressure in the refrigeration cycle. Thereafter, the refrigerant flows into the second usage-side heat exchanger 62 through the liquid-side end of the second usage-side heat exchanger 62 via the second usage-side liquid refrigerant pipe 69. When the refrigerant flows into the second usage-side heat exchanger 62 through the liquid-side end of the second usage-side heat exchanger 62, the second usage-side heat exchanger 62 evaporates the refrigerant by heat exchange with the usage-side air supplied by the second usage-side fan 63, thereby turning the refrigerant into the gas refrigerant. The resultant gas refrigerant flows out of the second usage-side heat exchanger 62 through the gas-side end of the second usage-side heat exchanger 62. When the gas refrigerant flows out of the second usage-side heat exchanger 62 through the gas-side end of the second usage-side heat exchanger 62, then the gas refrigerant flows to the gas-side-refrigerant connection pipe 7 via the second usage-side gas refrigerant pipe 68.

**[0114]** The refrigerant, which has flown out of the first usage unit 50, and the refrigerant, which has flown out of the second usage unit 60, merge with each other at the gas-side-refrigerant connection pipe 7, and then are sucked into the compressor 21 again, via the gas-side shutoff valve 49, the four-way switching valve 24, and the suction-side pipe 42.

#### (4) Flow of Refrigerant in Heating Operating Mode

**[0115]** Next, a description will be given of the flow of the refrigerant in the refrigerant circuit 10 in the heating operating mode, which is performed, for example, for removing frost from the usage-side heat exchangers 52 and 62.

**[0116]** The heating operation is started when the controller 70 determines that a predetermined heating operation start condition is satisfied in the cooling operation (e.g., when the cooling operation is performed for a predetermined time or when a temperature of a heat exchanger to be subjected to defrosting is equal to or less than a predetermined temperature).

**[0117]** During the heating operation, the refrigeration apparatus 100 performs the heating operation (a refrigeration cycle operation) causing the refrigerant in the refrigerant circuit 10 to mainly circulate through the compressor 21, the usage-side heat exchangers 52 and 62, the usage-side expansion valves 54 and 64, the receiver 27, the heat source-side expansion valve 28, and the heat source-side heat exchanger 25 in this order.

**[0118]** When the heating operation is started, the re-

refrigerant is sucked into and compressed by the compressor 21, and then is discharged from the compressor 21, in the refrigerant circuit 10.

[0119] The compressor 21 is controlled at, for example, the maximum frequency; however, the control of the compressor 21 is not limited thereto.

[0120] The gas refrigerant discharged from the compressor 21 flows into each of the usage-side heat exchangers 52 and 62 through each of the gas-side ends of the usage-side heat exchangers 52 and 62, via the discharge-side pipe 41. As in the cooling operation, the oil return valve 39 is subjected to the normal control or the hot gas bypass suppression control.

[0121] When the gas refrigerants respectively flow into the usage-side heat exchangers 52 and 62 through the gas-side ends of the usage-side heat exchangers 52 and 62, then the gas refrigerants condense by radiating heat and melt frost on the usage-side heat exchangers 52 and 62. At this time, the usage-side fans 53 and 63 each come to a stop.

[0122] The refrigerants condensed by melting frost on the usage-side heat exchangers 52 and 62 respectively pass through the usage-side expansion valves 54 and 64 controlled in the fully open state, and then flow into the heat source unit 2 through the liquid side of the heat source unit 2 via the liquid-side-refrigerant connection pipe 6.

[0123] When the refrigerant passes through the liquid-side shutoff valve 48 of the heat source unit 2, then the refrigerant passes through the first branch check valve 35 on the first branch pipe 34, and flows into the receiver 27. However, the refrigerant does not flow toward the second heat source liquid-side pipe 44 since the second heat source liquid-side check valve 29 is disposed on the second heat source liquid-side pipe 44. When the refrigerant flows into the receiver 27, then the refrigerant flows through the second heat source liquid-side pipe 44, and passes through the subcooler 31. Thereafter, the refrigerant is decompressed by the heat source-side expansion valve 28 to have the low pressure in the refrigeration cycle, and then passes through the second branch check valve 37 on the second branch pipe 36. In the heating operation, since the subcooling expansion valve 32 is controlled in the fully closed state, the refrigerant does not flow toward the upstream side of the injection pipe 30. Also in the heating operation, since the opening degree of the oil return valve 39 is controlled, the refrigerating machine oil passes through the oil return pipe 38, and then is supplied to each of the first, second, and third compressors 21a, 21b, and 21c via the downstream portion of the injection pipe 30.

[0124] When the refrigerant passes through the second branch check valve 37 on the second branch pipe 36, then the refrigerant flows into the heat source-side heat exchanger 25 via the first heat source liquid-side pipe 43. When the refrigerant flows into the heat source-side heat exchanger 25 through the liquid-side end of the heat source-side heat exchanger 25, the heat source-

side heat exchanger 25 evaporates the refrigerant by heat exchange with the heat source-side air supplied by the heat source-side fan 45, thereby turning the refrigerant into the gas refrigerant. The gas refrigerant flows out of the heat source-side heat exchanger 25 through the gas-side end of the heat source-side heat exchanger 25.

[0125] When the gas refrigerant flows out of the heat source-side heat exchanger 25, then the gas refrigerant is sucked into the compressor 21 again via the four-way switching valve 24 and the suction-side pipe 42.

[0126] The heating operation terminates when the controller 70 determines that a predetermined heating operation termination condition is satisfied from the start of the heating operation (e.g., when a predetermined time is elapsed or when the temperature of the heat exchanger to be subjected to defrosting is equal to or more than the predetermined temperature). The normal cooling operation is then resumed.

(5) Processing by Controller 70 in Performing Normal Control and Hot Gas Bypass Suppression Control on Oil Return Valve 39

[0127] With reference to a flowchart of FIG. 3, next, a description will be given of exemplary processing to be performed by the controller 70 in performing the normal control and the hot gas bypass suppression control on the oil return valve 39.

[0128] In both the cooling operating mode and the heating operating mode, the normal control and the hot gas bypass suppression control are selectively performed on the oil return valve 39. Therefore, the following description involves a case where the compressor 21 that is stopping is activated in, for example, the cooling operating mode.

[0129] In step S11, the controller 70 controls the valve opening degree of the oil return valve 39 to temporarily bring the oil return valve 39 into the fully open state for a predetermined time before activation of the compressor 21 for starting the cooling operating mode from the state in which the compressor 21 stops. This configuration enables equalization of the pressure on the discharge side of the compressor 21 and the pressure on the side, to which the injection pipe 30 is connected, of the compressor 21, and also enables more reliable activation of the compressor 21.

[0130] In step S12, the controller 70 controls the valve opening degree of the oil return valve 39 to bring the oil return valve 39 into the fully closed state. This configuration easily brings about a difference in pressure between the refrigerant on the discharge side of the compressor 21 and the refrigerant on the side, to which the injection pipe 30 is connected, of the compressor 21 at the time when the compressor 21 is driven.

[0131] In step S13, the controller 70 activates the compressor 21, and increases the frequency of the compressor 21. Since the oil return valve 39 is brought into the fully closed state in step S11, the refrigerant discharged

from the compressor 21 and the refrigerating machine oil do not flow toward the joint to the injection pipe 30 in the compressor 21 via the oil return pipe 38. The difference in pressure is therefore secured with ease.

**[0132]** In step S14, the controller 70 determines whether the frequency of the compressor 21 increases to exceed the predetermined frequency. When the frequency is more than the predetermined frequency, the processing proceeds to step S15. When the frequency is less than the predetermined frequency, the processing returns to step S13 in which the controller 70 keeps the frequency increasing. When the frequency of the compressor 21 is more than the predetermined frequency, the controller 70 is maintained at the cooling operating mode described above.

**[0133]** In step S15, the controller 70 performs the normal control on the oil return valve 39 in order to return an appropriate amount of refrigerating machine oil from the oil separator 23 to the compressor 21 in accordance with an operating condition. Specifically, as described above, the controller 70 controls the valve opening degree of the oil return valve 39 such that "the amount of oil loss in the compressor 21" becomes equal to "the passage and circulation amount in the oil return valve 39".

**[0134]** In step S16, the controller 70 determines whether a rise speed of the temperature of the refrigerant discharged from the compressor 21 (i.e., the temperature detected by the discharge temperature sensor 47) is more than the predetermined rise speed. When the discharge refrigerant temperature rise speed at the compressor 21 is more than the predetermined rise speed, the hot gas passes in large amounts through the oil return valve 39, so that the hot gas flows in large amounts into the compressor 21 via the oil return pipe 38 and the injection pipe 30. It is therefore estimated that the discharge refrigerant temperature rapidly rises. In view of this, the processing proceeds to step S17 in order to reduce the amount of hot gas passing through the oil return valve 39. On the other hand, when the discharge refrigerant temperature rise speed is less than the predetermined rise speed, the processing returns to step S15 in which the controller 70 performs the normal control on the oil return valve 39 again.

**[0135]** In step S17, the controller 70 performs the hot gas bypass suppression control on the oil return valve 39 to reduce the amount of hot gas passing through the oil return valve 39. Specifically, in step S16, the controller 70 controls the valve opening degree of the oil return valve 39 so as to lower the opening degree of the oil return valve 39 below the valve opening degree at the time when it is determined that the discharge refrigerant temperature rise speed at the compressor 21 is more than the predetermined rise speed. More specifically, in step S16, the controller 70 controls the valve opening degree of the oil return valve 39 so as to lower the opening degree of the oil return valve 39 to, for example, a half of the valve opening degree at the time when it is determined that the discharge refrigerant temperature rise

speed at the compressor 21 is more than the predetermined rise speed.

**[0136]** In step S18, the controller 70 determines whether the state in which the discharge refrigerant temperature at the compressor 21 (i.e., the temperature detected by the discharge temperature sensor 47) is equal to or less than a predetermined temperature continues for a predetermined time with the oil return valve 39 subjected to the hot gas bypass suppression control. In other words, the controller 70 determines whether the discharge refrigerant temperature is maintained to be low by the hot gas bypass suppression control on the oil return valve 39. When the state in which the discharge refrigerant temperature is equal to or less than the predetermined temperature continues for the predetermined time, the controller 70 terminates the hot gas bypass suppression control of the oil return valve 39. The processing then returns to step S15. On the other hand, when the state in which the discharge refrigerant temperature is equal to or less than the predetermined temperature does not continue for the predetermined time, the processing proceeds to step S19.

**[0137]** In step S19, the controller 70 continuously performs the hot gas bypass suppression control with the valve opening degree of the oil return valve 39 further lowered. The processing then proceeds to step S18.

**[0138]** The controller 70 controls the oil return valve 39 in the cooling operating mode as described above until the cooling operating mode terminates. The normal control and the hot gas bypass suppression control for the oil return valve 39 are also performed in the heating operating mode.

**[0139]** When the operation of the refrigeration apparatus 100 is stopped after the termination of the cooling operating mode, the controller 70 controls the valve opening degree of the oil return valve 39 to bring the oil return valve 39 into the fully open state rather than the fully closed state. With this configuration, during the stop of the operation, the refrigerating machine oil in the oil separator 23 can be dissolved into the refrigerant in the compressor 21 via the oil return pipe 38 and the injection pipe 30. This configuration therefore enables the next activation of the compressor 21 more reliably.

## (6) Features of Refrigeration Apparatus 100

### (6-1)

**[0140]** In the refrigeration apparatus 100 according to this embodiment, the oil return valve 39 is subjected to the normal control in the cooling operating mode and the heating operating mode, so that the refrigerating machine oil can be returned to the compressor 21 in appropriate amounts according to the circulation amount of the refrigerant in the compressor 21 and the rate of oil loss in the compressor 21, that is, according to the situations of the refrigeration cycle, such as the frequency of the compressor 21 as well as the high pressure, intermediate

pressure, and low pressure in the refrigeration cycle. The reliability of the compressor 21 can be thus enhanced.

**[0141]** In the refrigeration apparatus 100 according to this embodiment, moreover, if the discharge refrigerant temperature at the compressor 21 rapidly rises (if the discharge refrigerant temperature rise speed is more than the predetermined rise speed) owing to, for example, a transitional change in operating condition, even in the normal control for the oil return valve 39, it is assumed that the high-temperature hot gas is supplied in large amounts to the compressor 21 since the hot gas refrigerant discharged from the compressor 21 passes in large amounts through the oil return valve 39, in addition to the refrigerating machine oil. Based on this assumption, the control for the oil return valve 39 is switched from the normal control to the hot gas bypass suppression control to lower the valve opening degree. This configuration thus reduces the amount of hot gas passing through the oil return valve 39. This configuration also can reduce such a factor of degradation in performance that the hot gas discharged from the compressor 21 is immediately sucked into the compressor 21, as small as possible.

**[0142]** In the refrigeration apparatus 100 according to this embodiment, moreover, one oil separator 23 is provided for the plurality of compressors, that is, the first compressor 21a, the second compressor 21b, and the third compressor 21c. The oil separator 23 of the refrigeration apparatus 100 according to this embodiment is therefore larger in capacity than oil separators to be provided for a plurality of compressors in one-to-one correspondence. If one oil separator 23 having a larger capacity is provided for the plurality of compressors as described above, the oil separator 23 retains not only the refrigerating machine oil, but also the hot gas refrigerant in large amounts. In addition, one oil return pipe 38 that extends from the oil separator 23 is provided without being branched in correspondence with the number of compressors. For this reason, the oil return pipe 38 is larger in inner diameter than an oil return pipe to be provided for each compressor. In the refrigeration apparatus 100 according to this embodiment, the oil separator 23 retains the hot gas in large amounts, so that the hot gas refrigerant easily passes in large amounts through the oil return pipe 38. With this configuration, however, even when the oil return valve 39 is subjected to the normal control, it easily occurs that the hot gas refrigerant passes in large amounts through the oil return pipe 38 owing to, for example, a transitional change in operating condition. Even with the configuration, in the refrigeration apparatus 100 according to this embodiment, the hot gas bypass suppression control for the oil return valve 39 suppresses degradation in performance of the refrigeration apparatus 100.

(6-2)

**[0143]** In the refrigeration apparatus 100 according to this embodiment, the oil return pipe 38 is disposed to

merge with the injection pipe 30 that is not connected to the suction side of the compressor 21, but is connected to the middle of the compression process in the compressor 21. This configuration thus can suppress a situation in which heat energy of a part of the high-temperature fluid (the refrigerant and the refrigerating machine oil) discharged from the compressor 21 is used for raising the suction refrigerant temperature at the compressor 21.

(6-3)

**[0144]** In the refrigeration apparatus 100 according to this embodiment, the oil return valve 39 is controlled to be closed in performing the control to increase the frequency of the compressor 21 upon activation of the compressor 21. This configuration therefore efficiently can increase the difference between the pressure at the discharge side of the compressor 21 and the pressure at the side, to which the injection pipe 30 is connected, of the compressor 21 upon activation of the compressor 21.

(6-4)

**[0145]** In the refrigeration apparatus 100 according to this embodiment, the oil return valve 39 is not controlled to be closed (the oil return valve 39 is brought into the fully open state in this embodiment) before activation of the compressor 21 which has been stopped. This configuration therefore achieves pressure equalization by reducing the difference between the pressure at the discharge side of the compressor 21 and the pressure at the side, to which the injection pipe 30 is connected, of the compressor 21. This configuration also allows the refrigerating machine oil in the oil separator 23 to be dissolved into the refrigerant in the compressor 21 via the oil return pipe 38 and the injection pipe 30. This configuration thus enables more reliable activation of the compressor 21.

(7) Modifications

**[0146]** The foregoing embodiment may be appropriately modified as described in the following modifications. It should be noted that these modifications are applicable in conjunction with other modifications insofar as there are no inconsistencies.

(7-1) Modification A

**[0147]** According to the foregoing embodiment, the oil return pipe 38 is connected to the middle of the injection pipe 30 at its opposite end to the end connected to the oil separator 23.

**[0148]** However, the oil return pipe is not necessarily connected as described above. As illustrated in FIG. 4, for example, in a refrigeration apparatus 200, an oil return pipe 38a may be connected to a middle of a suction-side pipe 42 at its opposite end to an end connected to an oil

separator 23.

**[0149]** In this case, a refrigerating machine oil separated by the oil separator 23 is supplied to a suction side of a compressor 21. Also in this case, it is considered that a discharge refrigerant temperature at the compressor 21 rises if a hot gas passes in large amounts through an oil return valve 39 on the oil return pipe 38a. Therefore, normal control and hot gas bypass suppression control can be performed on the oil return valve 39 on the oil return pipe 38a in a manner similar to that described in the foregoing embodiment.

#### (7-2) Modification B

**[0150]** According to the foregoing embodiment, the downstream side of the injection pipe 30 merges with the middle of the compression process in the compressor 21.

**[0151]** As illustrated in FIG. 5, alternatively, in a refrigeration apparatus 300, an injection pipe 30a may be connected at its downstream side to a suction side of a compressor 21. It should be noted that the injection pipe 30 in the foregoing embodiment is connected to the middle of the compression process in the compressor 21; therefore, the amount of refrigerant to be sucked into the compressor 21 is less prone to be reduced because of the refrigerant flowing through the injection pipe 30.

**[0152]** In this case, as in Modification A, a refrigerating machine oil separated by an oil separator 23 is supplied to the suction side of the compressor 21 via the downstream side of the injection pipe 30a. Also in this case, it is considered that a discharge refrigerant temperature at the compressor 21 rises if a hot gas passes in large amounts through an oil return valve 39. Therefore, normal control and hot gas bypass suppression control can be performed on the oil return valve 39 in a manner similar to that described in the foregoing embodiment.

#### (7-3) Modification C

**[0153]** According to Modification B, the refrigeration apparatus 300 includes the injection pipe 30a connected at its downstream end to the suction side of the compressor 21.

**[0154]** As illustrated in FIG. 6, alternatively, a refrigeration apparatus 400 may include an injection pipe 30a connected at its downstream side to a suction side of a compressor 21. As in Modification A, the refrigeration apparatus 400 may also include an oil return pipe 38a connected to a middle of a suction-side pipe 42 at its opposite end to an end connected to an oil separator 23.

#### (7-4) Modification D

**[0155]** According to the foregoing embodiment, the refrigeration apparatus 100 switches the control for the oil return valve 39 from the normal control to the hot gas bypass suppression control on the condition that the discharge refrigerant temperature rise speed at the com-

pressor 21 is more than the predetermined rise speed.

**[0156]** However, the condition to switch the control for the oil return valve 39 from the normal control to the hot gas bypass suppression control is not limited thereto. For example, it is considered that the intermediate pressure in the refrigeration cycle (i.e., the pressure detected by the intermediate-pressure sensor 40b) lowers if the amount of hot gas passing through the oil return valve 39 increases in the normal control for the oil return valve 39. Therefore, the control for the oil return valve 39 may be switched on a condition that an intermediate pressure drop speed is more than a predetermined pressure drop speed (i.e., the intermediate pressure lowers rapidly).

**[0157]** In the situation in which the refrigerating machine oil passes in large amounts through the oil return valve 39, the refrigerating machine oil is maintained at a liquid state before flowing into the oil return valve 39 and after flown out of the oil return valve 39. This refrigerating machine oil is higher in viscosity than the gas refrigerant and is lower in fluidity than the gas refrigerant. Therefore, the flow velocity of the refrigerating machine oil does not increase so much at the time when the refrigerating machine oil passes through the oil return valve 39. Consequently, in the situation in which the refrigerating machine oil passes in large amounts through the oil return valve 39, the refrigerating machine oil passes through the oil return valve 39 at a low flow velocity with lower resistance; therefore, the oil return valve 39 is less prone to cause considerable decompression.

**[0158]** In contrast to this, the discharge gas refrigerant is lower in viscosity than the refrigerating machine oil and is higher in fluidity than the refrigerating machine oil. Therefore, the flow velocity of the gas refrigerant is apt to increase at the time when the discharge gas refrigerant passes through the oil return valve 39. Consequently, in the situation in which the refrigerating machine oil passes in small amounts through the oil return valve 39 and the discharge gas refrigerant passes in large amounts through the oil return valve 39, the gas refrigerant passes through the oil return valve 39 at a high flow velocity with higher resistance, so that the oil return valve 39 is apt to cause considerable decompression.

**[0159]** A change from the situation in which the refrigerating machine oil passes in large amounts through the oil return valve 39 to the situation in which the gas refrigerant passes in large amount through the oil return valve 39 causes a reduction in pressure at the downstream side of the oil return valve 39, and therefore causes a reduction in pressure of the refrigerant flowing through the injection pipe 30 to which the oil return pipe 38 is connected.

**[0160]** As described above, hence, the control for the oil return valve 39 may be switched from the normal control to the hot gas bypass suppression control when the drop speed of the intermediate pressure detected by the intermediate-pressure sensor 40b on the injection pipe 30 is more than the predetermined pressure drop speed.

**[0161]** In each of the refrigeration apparatus 200 ac-

cording to Modification A and the refrigeration apparatus 400 according to Modification C, the oil return pipe 38a is connected to the suction-side pipe 42. The control for the oil return valve 39 may be switched from the normal control to the hot gas bypass suppression control on a condition that a drop speed of the low pressure (pressure detected by the low-pressure sensor 40a) in the refrigeration cycle is more than a predetermined pressure drop speed.

**[0162]** Alternatively, the control for the oil return valve 39 may be switched from the normal control to the hot gas bypass suppression control on conditions that the discharge refrigerant temperature rise speed at the compressor 21 is more than the predetermined rise speed and a drop speed of the intermediate pressure or low pressure in the refrigeration cycle is more than a predetermined pressure drop speed.

**[0163]** In a case where relational data on a discharge refrigerant temperature appropriate for the intermediate pressure in the refrigeration cycle is possessed in advance, the control for the oil return valve 39 may be switched from the normal control to the hot gas bypass suppression control on a condition that the discharge refrigerant temperature is more than the discharge refrigerant temperature appropriate for the intermediate pressure.

#### (7-5) Modification E

**[0164]** According to the foregoing embodiment and the respective modifications, the branch position of the injection pipe 30 is on the side closer to the heat source-side expansion valve 28 with respect to the subcooler 31.

**[0165]** Alternatively, the branch position of the injection pipe 30 may be on the side opposite to the heat source-side expansion valve 28 with respect to the subcooler 31.

#### (7-6) Modification F

**[0166]** According to the foregoing embodiment, the refrigeration apparatus 100 is configured to cool, for example, the interior of a cold storage warehouse or the interior of a showcase in a store.

**[0167]** However, the use of the refrigeration apparatus 100 is not limited thereto. For example, the refrigeration apparatus 100 may be configured to cool the interior of a container for transportation. Alternatively, the refrigeration apparatus 100 may be an air conditioning system (an air conditioner) that implements air conditioning by cooling the interior of a building.

### INDUSTRIAL APPLICABILITY

**[0168]** The present invention is applicable to a refrigeration apparatus.

### REFERENCE SIGNS LIST

#### [0169]

- |    |                                                               |
|----|---------------------------------------------------------------|
| 5  | 2: heat source unit                                           |
|    | 6: liquid-side-refrigerant connection pipe                    |
|    | 7: gas-side-refrigerant connection pipe                       |
|    | 10: refrigerant circuit                                       |
|    | 20: heat source unit control unit                             |
| 10 | 21: compressor                                                |
|    | 21a: first compressor                                         |
|    | 21b: second compressor                                        |
|    | 21c: third compressor                                         |
|    | 23: oil separator                                             |
| 15 | 25: heat source-side heat exchanger                           |
|    | 26: first heat source liquid-side check valve                 |
|    | 27: receiver                                                  |
|    | 28: heat source-side expansion valve                          |
|    | 29: second heat source liquid-side check valve                |
| 20 | 30: injection pipe (refrigerant supply pipe, injection pipe)  |
|    | 30a: injection pipe (refrigerant supply pipe)                 |
|    | 31: subcooler                                                 |
|    | 32: subcooling expansion valve (intermediate expansion valve) |
| 25 | 33: injection valve                                           |
|    | 33a: first injection valve                                    |
|    | 33b: second injection valve                                   |
|    | 33c: third injection valve                                    |
| 30 | 34: first bypass pipe                                         |
|    | 35: first bypass check valve                                  |
|    | 36: second branch pipe                                        |
|    | 37: second branch check valve                                 |
|    | 38: oil return pipe                                           |
| 35 | 38a: oil return pipe                                          |
|    | 39: oil return valve (flow rate adjusting mechanism)          |
|    | 40a: low-pressure sensor                                      |
|    | 40b: intermediate-pressure sensor                             |
|    | 40c: high-pressure sensor                                     |
| 40 | 41: discharge-side pipe                                       |
|    | 42: suction-side pipe (refrigerant supply pipe)               |
|    | 43: first heat source liquid-side pipe                        |
|    | 44: second heat source liquid-side pipe                       |
|    | 45: heat source-side fan                                      |
| 45 | 47: discharge temperature sensor                              |
|    | 50: first usage unit                                          |
|    | 52: first usage-side heat exchanger                           |
|    | 54: first usage-side expansion valve                          |
|    | 57: first usage unit control unit                             |
| 50 | 58: first usage-side gas refrigerant pipe                     |
|    | 59: first usage-side liquid refrigerant pipe                  |
|    | 60: second usage unit                                         |
|    | 62: second usage-side heat exchanger                          |
|    | 64: second usage-side expansion valve                         |
| 55 | 67: second usage unit control unit                            |
|    | 68: second usage-side gas refrigerant pipe                    |
|    | 69: second usage-side liquid refrigerant pipe                 |
|    | 70: controller (control unit)                                 |

100, 200, 300, 400: refrigeration apparatus

## CITATION LIST

### PATENT LITERATURE

[0170] Patent Literature 1: JP 2011-208860 A

### Claims

1. A refrigeration apparatus (100, 200, 300, 400) comprising:

a compressor (21);  
 an oil separator (23) disposed on a discharge side of the compressor;  
 a refrigerant supply pipe (30, 30a, 42) through which a refrigerant is supplied to the compressor;  
 an oil return pipe (38, 38a) connecting the oil separator (23) to the refrigerant supply pipe (30, 30a, 42);  
 a flow rate adjusting mechanism (39) disposed on the oil return pipe; and  
 a control unit (70) configured to control the flow rate adjusting mechanism (39) to reduce a flow rate when a temperature of the refrigerant discharged from the compressor or a pressure of the refrigerant flowing through the refrigerant supply pipe satisfies a predetermined condition.

2. The refrigeration apparatus according to claim 1, wherein

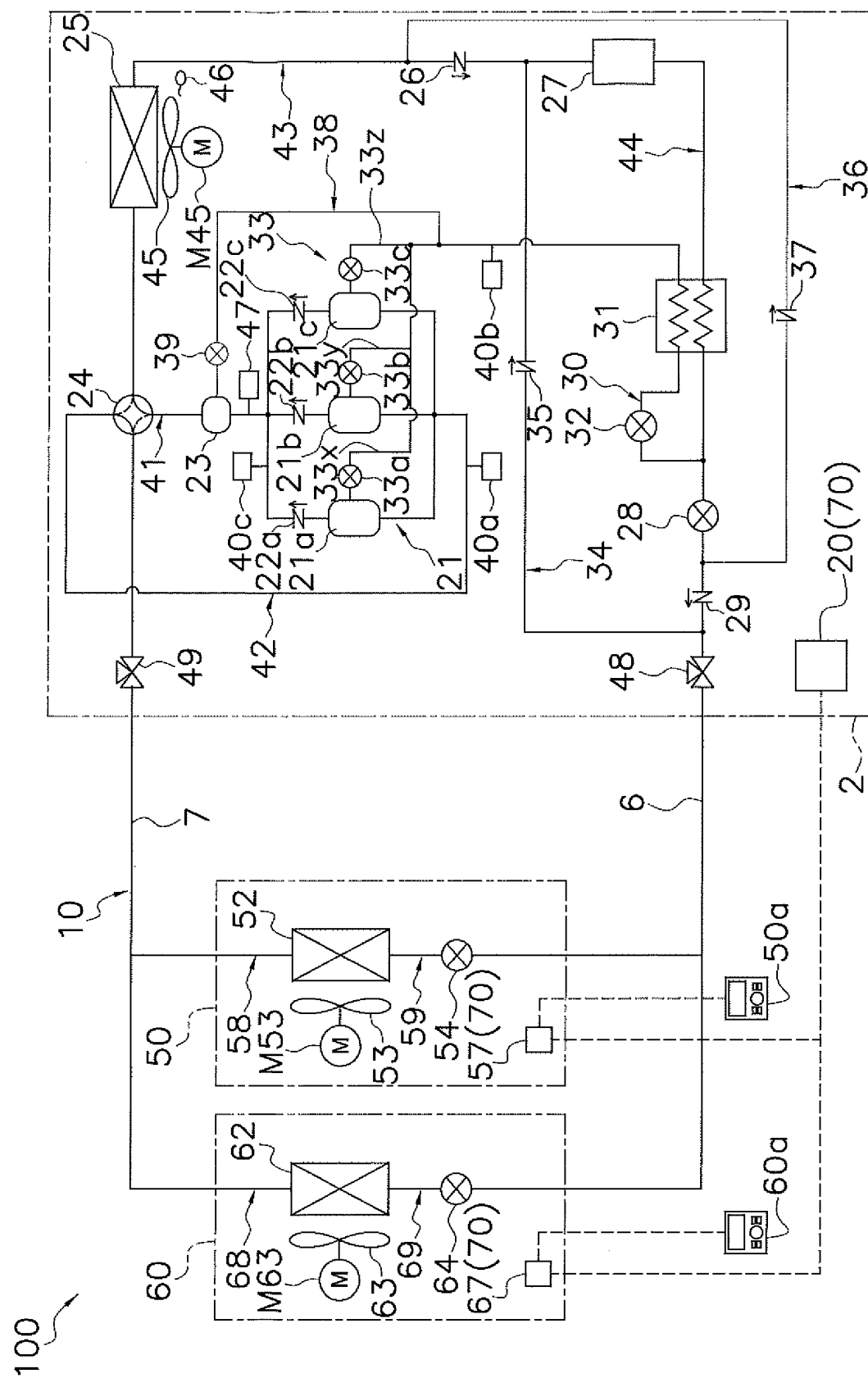
the control unit performs normal control to control the flow rate adjusting mechanism, based on an amount of oil loss in the compressor, the amount of oil loss being obtained by multiplying a circulation amount of the refrigerant by a rate of oil loss in the compressor, and  
 when the predetermined condition is satisfied in the normal control, the control unit controls the flow rate adjusting mechanism to further reduce the flow rate from a state of the flow rate adjusting mechanism in the normal control.

3. The refrigeration apparatus according to claim 1 or 2, further comprising:

a heat source-side heat exchanger (25) configured to condense the refrigerant discharged from the compressor,  
 wherein  
 the refrigerant supply pipe is an injection pipe (30) through which a part of the refrigerant condensed by the heat source-side heat exchanger is guided to a middle of a compression process

in the compressor,  
 the refrigeration apparatus further comprising:  
 an intermediate expansion valve (32) disposed at a middle of the injection pipe.

4. The refrigeration apparatus according to any one of claims 1 to 3, wherein  
 the control unit controls the flow rate adjusting mechanism to a state that blocks passage of the refrigerant through the flow rate adjusting mechanism upon activation of the compressor.
5. The refrigeration apparatus according to any one of claims 1 to 4, wherein  
 the control unit controls the flow rate adjusting mechanism to a state that permits passage of the refrigerant through the flow rate adjusting mechanism before activation of the compressor.



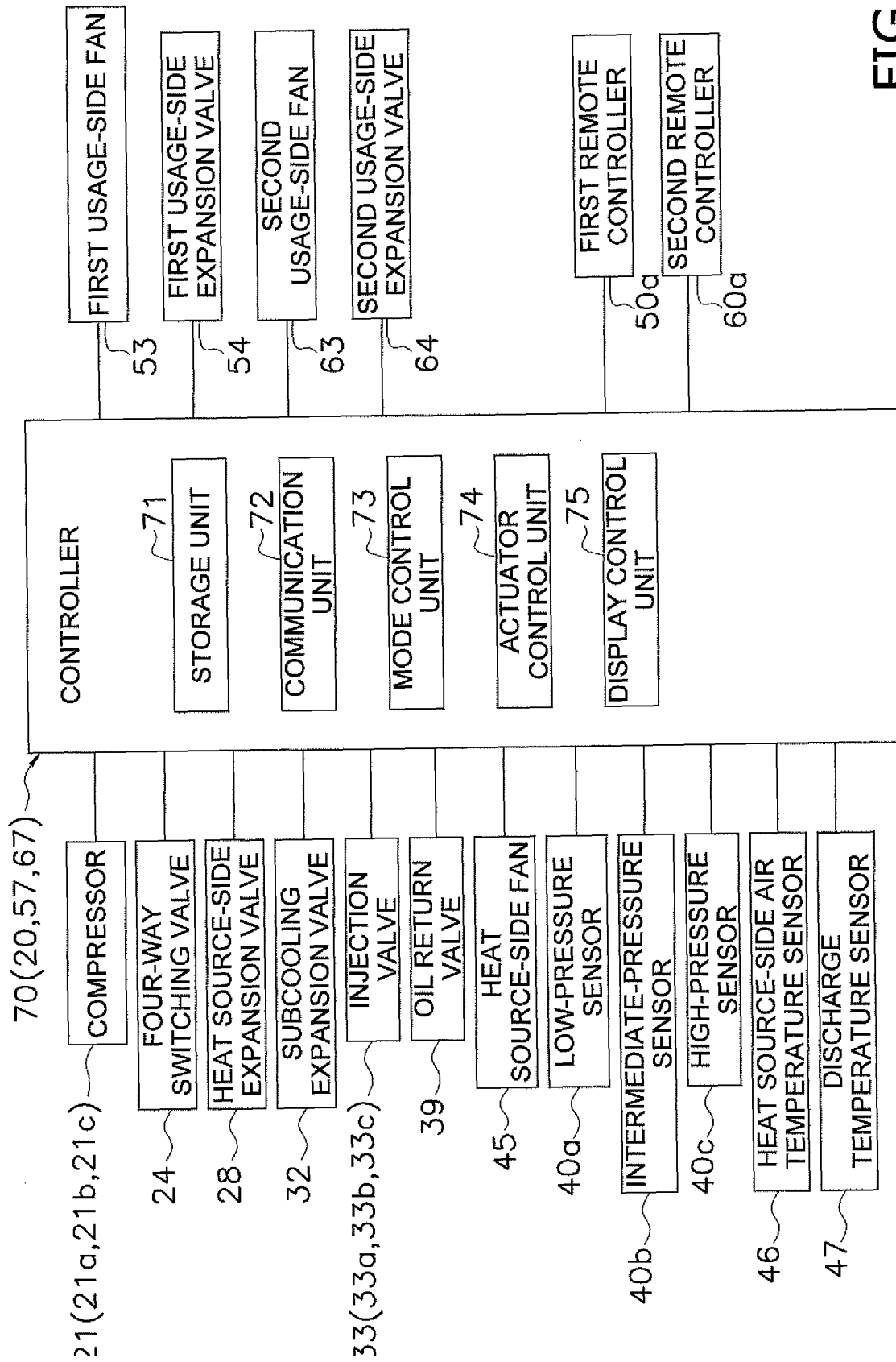


FIG. 2

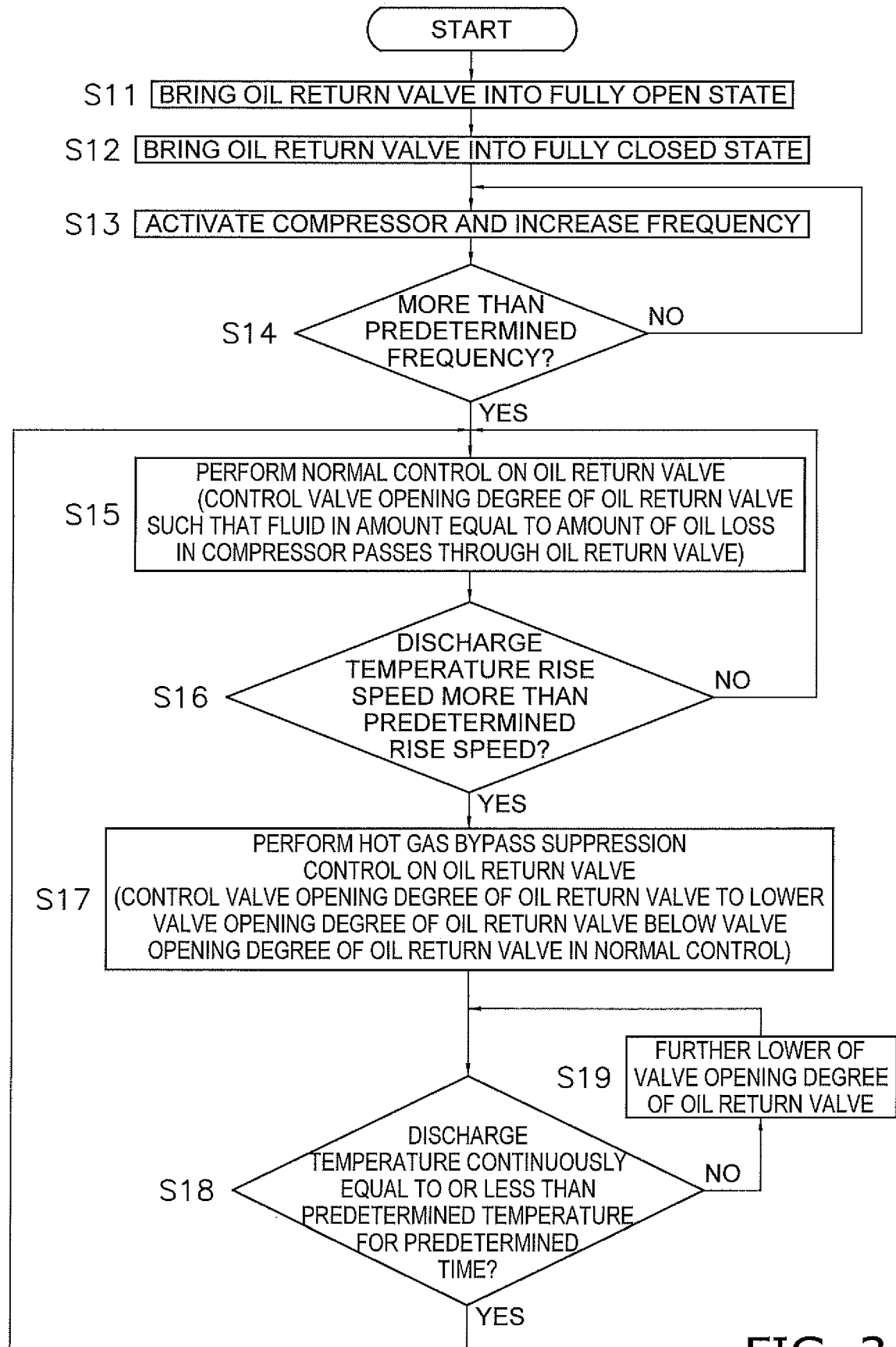


FIG. 3

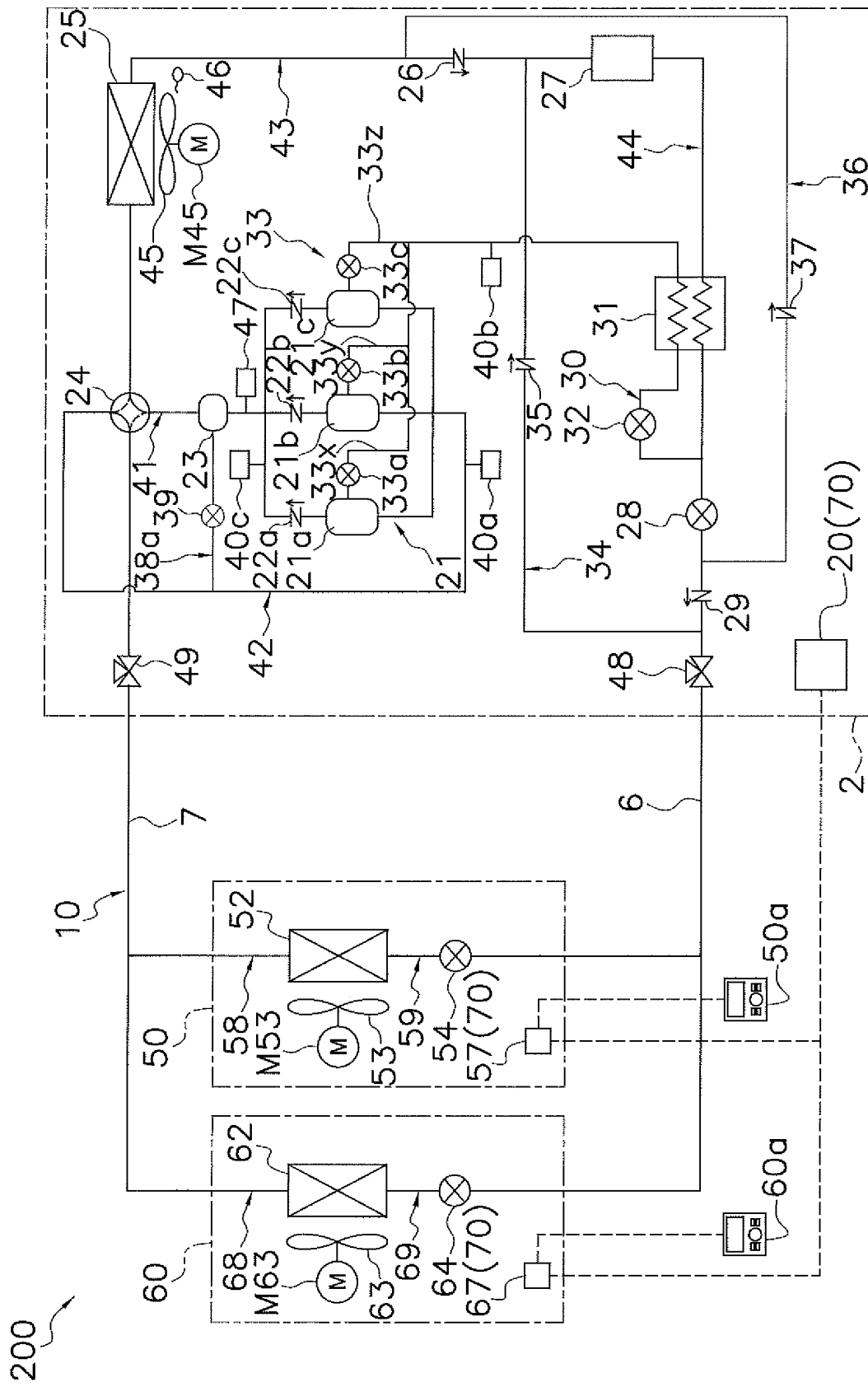


FIG. 4

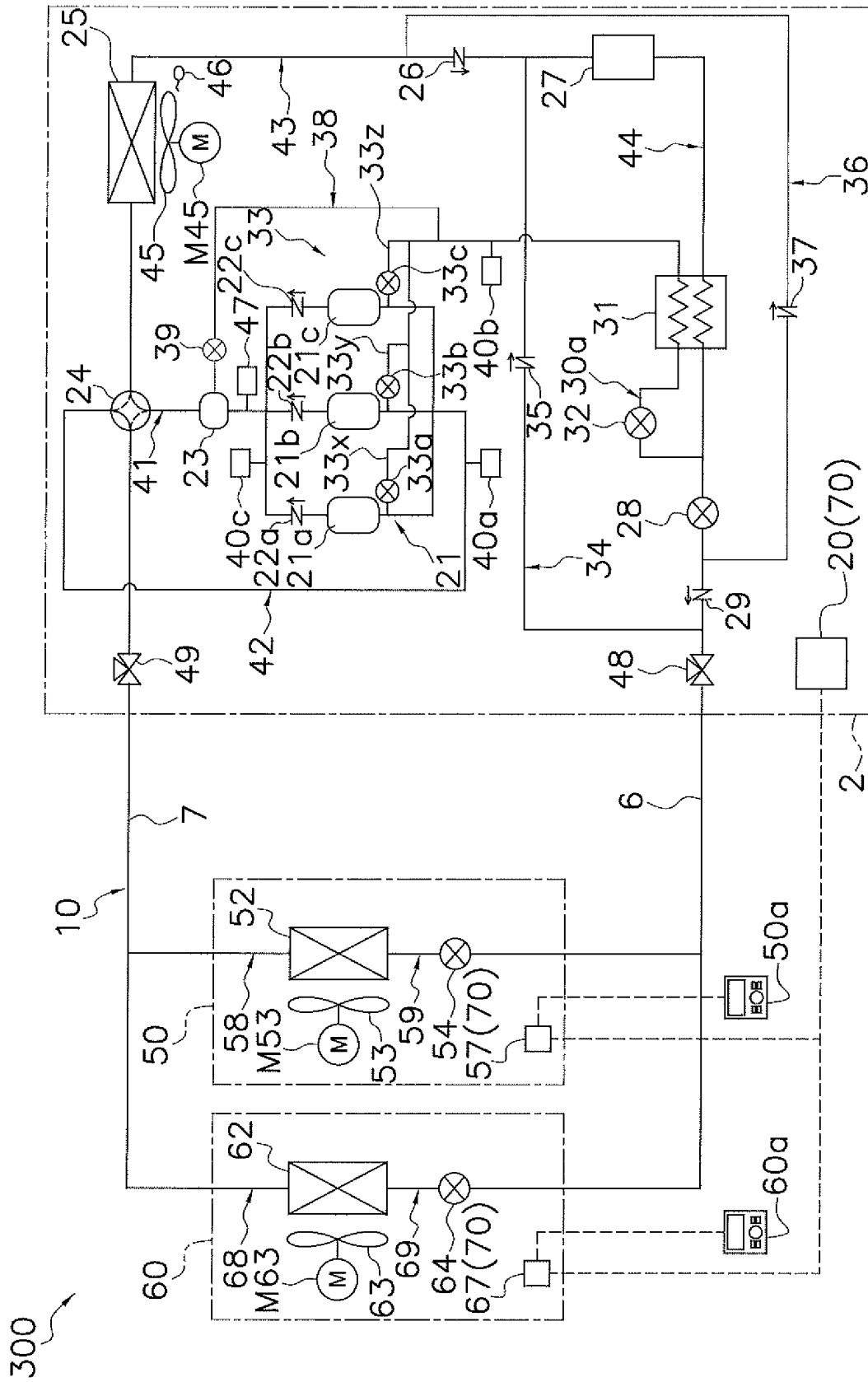
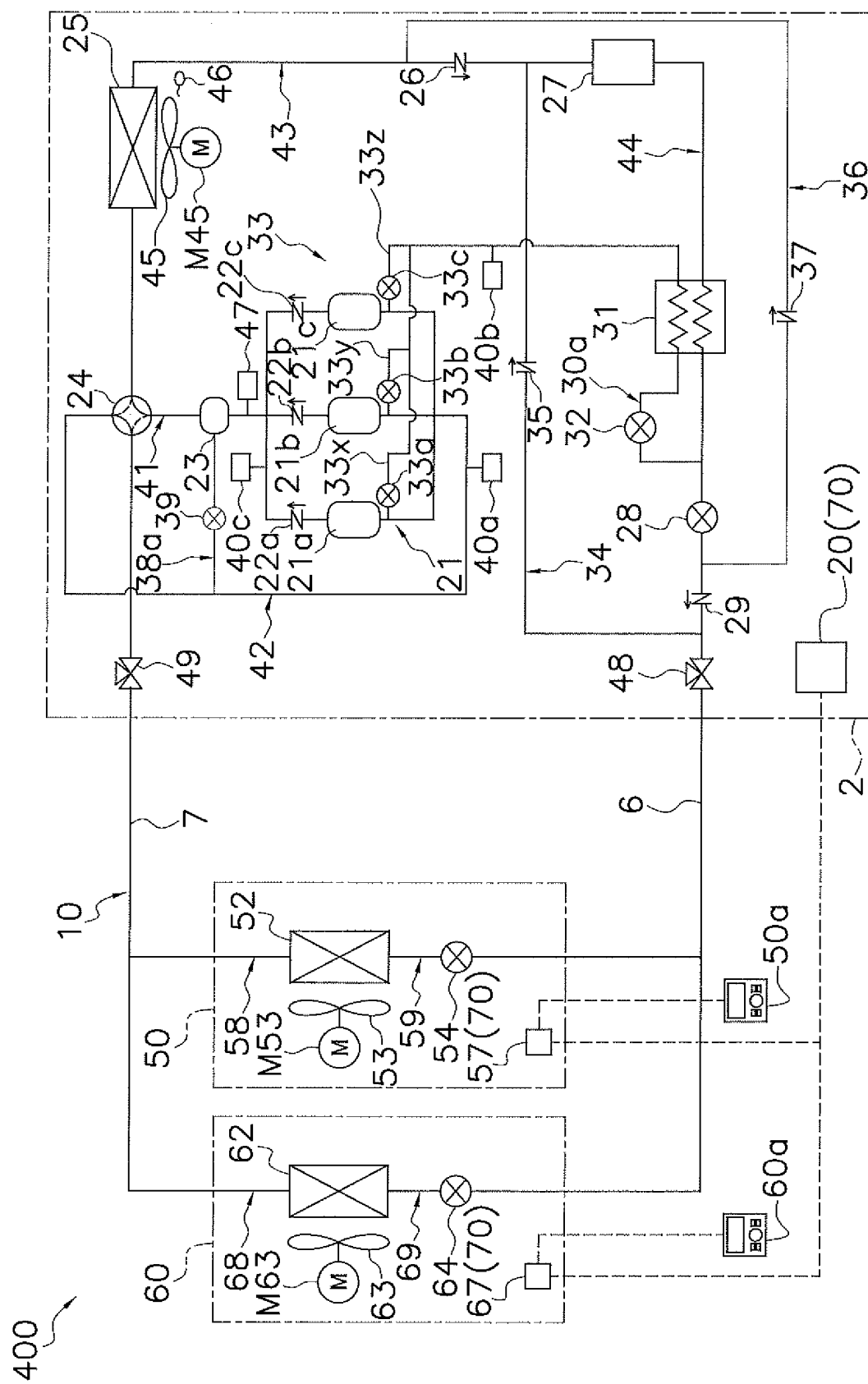


FIG. 5



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/041919

## A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F25B1/00 (2006.01) i, F25B43/02 (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)

Int.Cl. F25B1/00-1/10, F25B43/02

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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

DWPI (Derwent Innovation), Japio-GPG/FX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                        | Relevant to claim No. |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X<br>Y    | JP 6-74579 A (DAIKIN INDUSTRIES, LTD.) 15 March 1994, paragraphs [0013], [0030], fig. 1, 6-7 (Family: none)                               | 1<br>2-5              |
| X<br>Y    | JP 2006-170500 A (MITSUBISHI HEAVY INDUSTRIES, LTD.) 29 June 2006, paragraphs [0016]-[0021], [0026], [0028], fig. 1-2, 4-5 (Family: none) | 1<br>2-5              |
| Y         | JP 2016-176664 A (DAIKIN INDUSTRIES, LTD.) 26 October 2016, paragraphs [0021]-[0024] (Family: none)                                       | 2                     |



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

"T"

later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X"

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y"

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;"

document member of the same patent family

Date of the actual completion of the international search  
01 February 2018 (01.02.2018)Date of mailing of the international search report  
13 February 2018 (13.02.2018)Name and mailing address of the ISA/  
Japan Patent Office  
3-4-3, Kasumigaseki, Chiyoda-ku,  
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2017/041919

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                              | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | JP 2010-71614 A (HITACHI APPLIANCES, INC.) 02 April 2010, paragraphs [0036]–[0042], fig. 1 (Family: none)                       | 3                     |
| Y         | JP 2002-130146 A (KOBE STEEL, LTD.) 09 May 2002, paragraph [0020], fig. 4 (Family: none)                                        | 4                     |
| Y         | JP 2012-225630 A (MITSUBISHI ELECTRIC CORP.) 15 November 2012, paragraph [0045], fig. 8–9 (Family: none)                        | 5                     |
| Y         | WO 2016/121184 A1 (MITSUBISHI ELECTRIC CORP.) 04 August 2016, paragraph [0027], fig. 1 (Family: none)                           | 5                     |
| A         | JP 2011-117626 A (HITACHI APPLIANCES, INC.) 16 June 2011, abstract, fig. 1 (Family: none)                                       | 1–5                   |
| A         | JP 2015-148383 A (PANASONIC IP MANAGEMENT CO., LTD.) 20 August 2015, abstract, fig. 1 (Family: none)                            | 1–5                   |
| A         | CN 205580038 U (FUJIAN XINLONG ENVIRONMENTAL PROTECTION) 14 September 2016, abstract, fig. 1 (Family: none)                     | 1–5                   |
| A         | US 2015/0184910 A1 (LG ELECTRONICS INC.) 02 July 2015, abstract, fig. 1 & EP 2889556 A1 & KR 10-2015-0075490 A & CN 104748443 A | 1–5                   |

Form PCT/ISA/210 (continuation of second sheet) (January 2015)

**REFERENCES CITED IN THE DESCRIPTION**

*This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.*

**Patent documents cited in the description**

- JP 2011A208860 A [0003]
- JP 2011208860 A [0170]