



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

(43) Date of publication:  
**26.08.2015 Bulletin 2015/35**

(51) Int Cl.:  
**F25B 7/00 (2006.01) F25B 1/00 (2006.01)**

(21) Application number: **12884923.9**

(86) International application number:  
**PCT/JP2012/074214**

(22) Date of filing: **21.09.2012**

(87) International publication number:  
**WO 2014/045400 (27.03.2014 Gazette 2014/13)**

(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**

- **IKEDA, Takashi**  
Tokyo 100-8310 (JP)
- **HORIUCHI, Katsunori**  
Tokyo 102-0073 (JP)
- **HARAIGAWA, Hirofumi**  
Tokyo 102-0073 (JP)
- **TARUMI, Yuji**  
Tokyo 102-0073 (JP)
- **MIYAI, Junichi**  
Tokyo 102-0073 (JP)
- **SATO, Nobuki**  
Tokyo 102-0073 (JP)

(71) Applicant: **Mitsubishi Electric Corporation**  
Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner GbR**  
Patent- und Rechtsanwälte  
Theresienhöhe 11a  
80339 München (DE)

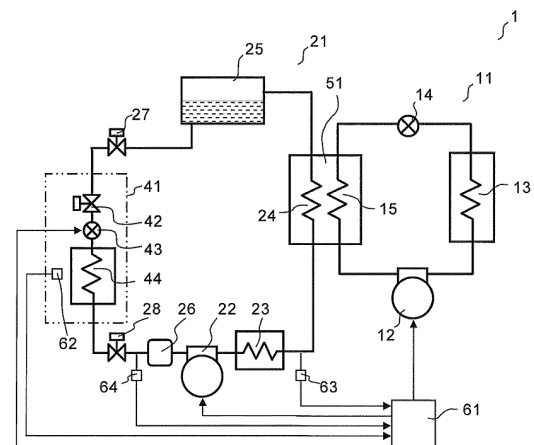
(72) Inventors:

- **KURACHI, Akinori**  
Tokyo 102-0073 (JP)
- **YAMASHITA, Tetsuya**  
Tokyo 100-8310 (JP)
- **SUGIMOTO, Takeshi**  
Tokyo 100-8310 (JP)

(54) **REFRIGERATION DEVICE AND METHOD FOR CONTROLLING SAME**

(57) A refrigeration apparatus 1 includes a high-temperature side cycle 11 in which a refrigerant circulates, the high-temperature side cycle 11 including a high-temperature side compressor 12, a high-temperature side condenser 13, a high-temperature side expansion valve 14, and a high-temperature side evaporator 15 sequentially connected by piping, a low-temperature side cycle 21 in which a refrigerant circulates, the low-temperature side cycle 21 including a low-temperature side compressor 22, a low-temperature side condenser 24, a receiver 25, a low-temperature side expansion valve 43, and a low-temperature side evaporator 44 sequentially connected by piping, and a cascade condenser 51 including the high-temperature side evaporator 15 and the low-temperature side condenser 24 and configured to heat exchange between the refrigerant flowing in the high-temperature side evaporator 15 and the refrigerant flowing in the low-temperature side condenser 24. The receiver 25 is located under the cascade condenser 51.

F I G. 1



## Description

### Technical Field

**[0001]** The present invention relates to a refrigeration apparatus including a plurality of refrigeration cycles (refrigerant circuits), and a control method of such a refrigeration apparatus.

### Background Art

**[0002]** Some of existing refrigeration apparatuses include a high-temperature side (or higher side, primary side) refrigeration cycle (hereinafter, high-temperature side cycle) and a low-temperature side (or lower side, secondary side) refrigeration cycle (hereinafter, low-temperature side cycle) (for example, see Patent Literature 1).

**[0003]** In such refrigeration apparatuses, an evaporator in the high-temperature side cycle and a condenser in the low-temperature side cycle constitute a cascade condenser.

**[0004]** A refrigerant in the high-temperature side cycle and a refrigerant in the low-temperature side cycle exchange heat in the cascade condenser.

**[0005]** The refrigerant in the low-temperature side cycle and an object to be cooled, such as air in a refrigerating room, exchange heat in the evaporator in the low-temperature side cycle.

### Citation List

### Patent Literature

**[0006]** Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2012-112615 (paragraphs [0013] to [0051], Fig. 1 to Fig. 7)

### Summary of Invention

### Technical Problem

**[0007]** In the refrigeration apparatus thus configured, when a refrigeration load in the low-temperature side cycle decreases the controller drives an expansion valve in the low-temperature side cycle so as to narrow the path, thereby reducing the refrigerant supply to a compressor in the low-temperature side cycle.

**[0008]** When the refrigeration load in the low-temperature side cycle decreases further after the refrigerant supply to the compressor in the low-temperature side cycle reaches the minimum level, the controller turns off the compressor in the low-temperature side cycle, in other words stops the circulation in the low-temperature side cycle, to thereby prevent the compressor in the low-temperature side cycle from sucking an excessive amount of the refrigerant, thus preventing a pressure drop in the low-temperature side cycle.

**[0009]** Such a control is called low-pressure cut-off control.

**[0010]** In addition, when a malfunction arises, for example, when the compressor in the low-temperature side cycle becomes inoperative, the circulation in the low-temperature side cycle is stopped, as in the low-pressure cut-off control.

**[0011]** Further, the circulation in the low-temperature side cycle may be stopped as in the low-pressure cut-off control, when the evaporator in the low-temperature side cycle is performing a defrosting operation.

**[0012]** In such a refrigeration apparatus, a refrigerant of a low critical temperature such as a CO<sub>2</sub> refrigerant is often employed as the refrigerant in the low-temperature side cycle.

**[0013]** When such a refrigeration apparatus is used in an environment where outside air has a higher temperature than the critical temperature of the refrigerant, the refrigerant in the low-temperature side cycle is heated by the outside air thus turning into gas phase when the circulation in the low-temperature side cycle is stopped as above, and therefore the pressure in the low-temperature side cycle increases.

**[0014]** Accordingly, in the conventional refrigeration apparatuses configured as above, the components constituting the low-temperature side cycle are required to have a rigid structure (for example, a sufficient wall thickness), in order to cope with the pressure increase in the low-temperature side cycle, which inevitably leads to an increase in cost as well as in weight.

**[0015]** The present invention has been accomplished in view of the foregoing problem, and provides a refrigeration apparatus that suppresses an increase in pressure in a low-temperature side cycle when circulation in the low-temperature side cycle is stopped, and a control method performed by the refrigeration apparatus.

### Solution to Problem

**[0016]** In an aspect, the present invention provides a refrigeration apparatus includes a first refrigerant circuit in which a refrigerant circulates, the first refrigerant circuit including a first compressor, a first condenser, a first throttle device, and a first evaporator sequentially connected by piping, a second refrigerant circuit in which a refrigerant circulates, the second refrigerant circuit including a second compressor, a second condenser, a receiver, a second throttle device, and a second evaporator sequentially connected by piping, and a cascade condenser including the first evaporator and the second condenser and configured to heat exchange between the refrigerant flowing in the first evaporator and the refrigerant flowing in the second condenser. The receiver is located under the cascade condenser.

### Advantageous Effects of Invention

**[0017]** In the refrigeration apparatus according to the

present invention, the receiver is located under the cascade condenser. Accordingly, when the circulation in the second refrigerant circuit is stopped, the refrigerant in the second refrigerant circuit, which has been condensed and liquefied by the refrigerant in the first refrigerant circuit, is rapidly collected in the receiver, and therefore an increase in pressure in the second refrigerant circuit can be suppressed.

#### Brief Description of Drawings

#### [0018]

[Fig. 1] Fig. 1 is a diagram showing a configuration of a refrigeration apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a perspective view showing the refrigeration apparatus according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 is a flowchart showing an operation of a controller in the refrigeration apparatus according to Embodiment 1 of the present invention.

[Fig. 4] Fig. 4 is a flowchart showing a variation of the operation of the controller in the refrigeration apparatus according to Embodiment 1 of the present invention.

[Fig. 5] Fig. 5 is a perspective view showing a variation of a cascade condenser in the refrigeration apparatus according to Embodiment 1 of the present invention.

[Fig. 6] Fig. 6 is a diagram showing a configuration of a refrigeration apparatus according to Embodiment 2 of the present invention.

[Fig. 7] Fig. 7 is a flowchart showing an operation of a controller in the refrigeration apparatus according to Embodiment 2 of the present invention.

[Fig. 8] Fig. 8 is a diagram showing a configuration of a refrigeration apparatus according to Embodiment 3 of the present invention.

[Fig. 9] Fig. 9 is a flowchart showing an operation of a controller in the refrigeration apparatus according to Embodiment 3 of the present invention.

[Fig. 10] Fig. 10 is a diagram showing a configuration of a refrigeration apparatus according to Embodiment 4 of the present invention.

[Fig. 11] Fig. 11 is a drawing showing an arrangement of components in the refrigeration apparatus according to Embodiment 4 of the present invention.

#### Description of Embodiments

[0019] A refrigeration apparatus according to the present invention will be described with reference to the drawings.

[0020] Although the description given hereunder refers to a refrigeration apparatus having two refrigeration cycles (binary refrigeration apparatus), the present invention encompasses refrigeration apparatuses having three or more refrigeration cycles (plural refrigeration ap-

paratus).

[0021] In the drawings, portions of minor importance may be simplified or excluded.

[0022] In addition, duplicate description will be simplified or skipped, as the case may be.

#### Embodiment 1

[0023] Hereunder, a refrigeration apparatus according to Embodiment 1 will be described.

[0024] The description given below refers to the case where circulation in a low-temperature side cycle is stopped under a low-pressure cut-off control, however the present invention also encompasses the case where the circulation in the low-temperature side cycle is stopped for another reason than the low-pressure cut-off control, such as a failure of a compressor in the low-temperature side cycle or defrosting operation of an evaporator in the low-temperature side cycle.

#### (Configuration of Refrigeration apparatus)

[0025] The configuration of the refrigeration apparatus according to Embodiment 1 will be described hereunder.

[0026] Fig. 1 is a diagram showing the configuration of the refrigeration apparatus according to Embodiment 1 of the present invention.

[0027] As shown in Fig. 1, the refrigeration apparatus 1 includes a high-temperature side cycle 11, a low-temperature side cycle 21, a cascade condenser 51, and a controller 61.

[0028] The high-temperature side cycle 11 corresponds to the "first refrigerant circuit" in the present invention.

[0029] The low-temperature side cycle 21 corresponds to the "second refrigerant circuit" in the present invention.

[0030] The high-temperature side cycle 11 includes a high-temperature side compressor 12, a high-temperature side condenser 13, a high-temperature side expansion valve 14, and a high-temperature side evaporator 15.

[0031] The high-temperature side compressor 12 corresponds to the "first compressor" in the present invention.

[0032] The high-temperature side condenser 13 corresponds to the "first condenser" in the present invention.

[0033] The high-temperature side expansion valve 14 corresponds to the "first throttle device" in the present invention.

[0034] The high-temperature side evaporator 15 corresponds to the "first evaporator" in the present invention.

[0035] The high-temperature side compressor 12, the high-temperature side condenser 13, the high-temperature side expansion valve 14, and the high-temperature side evaporator 15 are connected in series.

[0036] The low-temperature side cycle 21 includes a low-temperature side compressor 22, an intermediate cooler 23, a low-temperature side condenser 24, a re-

ceiver 25, a cooling unit 41, and an accumulator 26.

**[0037]** The low-temperature side compressor 22 corresponds to the "second compressor" in the present invention.

**[0038]** The low-temperature side condenser 24 corresponds to the "second condenser" in the present invention.

**[0039]** The low-temperature side compressor 22, the intermediate cooler 23, the low-temperature side condenser 24, the receiver 25, the cooling unit 41, and the accumulator 26 are connected in series.

**[0040]** A service valve 27 is provided between the outlet side of the receiver 25 and the inlet side of the cooling unit 41.

**[0041]** A service valve 28 is provided between the outlet side of the cooling unit 41 and the inlet side of the accumulator 26.

**[0042]** The cooling unit 41 can be separated from the refrigeration apparatus 1 by the service valves 27 and 28.

**[0043]** The service valves 27 and 28 may be excluded, and the cooling unit 41 may be inseparable.

**[0044]** Here, a non-illustrated sight glass for confirming the amount or condition of the refrigerant, and a non-illustrated drier for absorbing moisture in the pipe may be provided in the low-temperature side cycle 21.

**[0045]** The high-temperature side evaporator 15 and the low-temperature side condenser 24 constitute a cascade condenser 51.

**[0046]** The refrigerant in the high-temperature side cycle 11 and the refrigerant in the low-temperature side cycle 21 exchange heat with each other in the cascade condenser 51.

**[0047]** Fig. 2 is a perspective view showing the refrigeration apparatus according to Embodiment 1.

**[0048]** As shown in Fig. 2, the receiver 25 is located under the cascade condenser 51.

**[0049]** The receiver 25 and the low-temperature side condenser 24 are connected to each other via a pipe 29 having an outer diameter of, for example, 15.88 mm.

**[0050]** Fig. 2 illustrates the case where the cascade condenser 51 is composed of a pair of plate-type heat exchangers connected in series and disposed side by side.

**[0051]** In addition, Fig. 2 illustrates the case where the cooling unit 41 is separated.

**[0052]** The cooling unit 41 includes a low-temperature side first solenoid valve 42, a low-temperature side expansion valve 43, and a low-temperature side evaporator 44.

**[0053]** The low-temperature side expansion valve 43 corresponds to the "second throttle device" in the present invention.

**[0054]** The low-temperature side evaporator 44 corresponds to the "second evaporator" in the present invention.

**[0055]** The low-temperature side first solenoid valve 42, the low-temperature side expansion valve 43, and the low-temperature side evaporator 44 are connected

in series.

**[0056]** The low-temperature side evaporator 44 is located in a refrigerating room.

**[0057]** Examples of the refrigerating room include a freezing showcase installed in a super market or the like, and a freezing room of a unit cooler installed in a food processing plant.

**[0058]** A cooling unit utilized in an existing refrigerating room may be employed as the cooling unit 41.

**[0059]** As the refrigerant in the high-temperature side cycle 11, for example a HFC refrigerant (R410A, R404A, R32, R407C), a HFO refrigerant, or a HC refrigerant may be employed.

**[0060]** As the refrigerant in the low-temperature side cycle 21, for example a CO<sub>2</sub> refrigerant having a global warming potential (GWP) of 1 may be employed.

**[0061]** At least the high-temperature side compressor 12, the low-temperature side compressor 22, the low-temperature side expansion valve 43, the temperature sensor 62, the low-temperature side high pressure sensor 63, and the low-temperature side low pressure sensor 64 are connected to the controller 61.

**[0062]** The temperature sensor 62 detects the temperature of the object to be cooled, such as the air in the refrigerating room.

**[0063]** The low-temperature side high pressure sensor 63 is located, for example, between the outlet side of the intermediate cooler 23 and the inlet side of the low-temperature side condenser 24, and detects the pressure on the high-pressure side of the low-temperature side cycle 21.

**[0064]** The low-temperature side high pressure sensor 63 may be located at a desired position, provided that the position is between the outlet side of the low-temperature side compressor 22 and the inlet side of the low-temperature side expansion valve 43.

**[0065]** The low-temperature side low pressure sensor 64 is located, for example, between the service valve 28 and the inlet side of the accumulator 26, and detects the pressure on the low-pressure side of the low-temperature side cycle 21.

**[0066]** The low-temperature side low pressure sensor 64 may be located at a desired position, provided that the position is between the outlet side of the low-temperature side expansion valve 43 and the inlet side of the low-temperature side compressor 22.

#### (Operation of Refrigeration apparatus)

**[0067]** The operation of the refrigeration apparatus according to Embodiment 1 will be described hereunder.

**[0068]** First, the operation of the high-temperature side cycle 11 will be described.

**[0069]** High-temperature/high-pressure gas phase refrigerant discharged from the high-temperature side compressor 12 flows into the high-temperature side condenser 13.

**[0070]** The refrigerant which has entered the high-tem-

perature side condenser 13 is condensed and liquefied through heat exchange with outside air, and turns into high-pressure liquid phase refrigerant.

[0071] The high-pressure liquid phase refrigerant is depressurized in the high-temperature side expansion valve 14, thus to turn into low-temperature/low-pressure gas-liquid two-phase refrigerant.

[0072] The low-temperature/low-pressure gas-liquid two-phase refrigerant is heated in the cascade condenser 51 by the refrigerant in the low-temperature side cycle 21 (cools the refrigerant in the low-temperature side cycle 21) and evaporated, thus to turn into low-pressure gas phase refrigerant.

[0073] The low-pressure gas phase refrigerant flows into the high-temperature side compressor 12.

[0074] The operation of the low-temperature side cycle 21 will now be described.

[0075] High-temperature/high-pressure gas phase refrigerant discharged from the low-temperature side compressor 22 is cooled in the intermediate cooler 23 and flows into the cascade condenser 51.

[0076] The refrigerant which has entered the cascade condenser 51 is condensed and liquefied by the refrigerant in the high-temperature side cycle 11, and turns into high-pressure liquid phase refrigerant.

[0077] The high-pressure liquid phase refrigerant flows into the low-temperature side expansion valve 43 through the receiver 25, the service valve 27, and the low-temperature side first solenoid valve 42.

[0078] The high-pressure liquid phase refrigerant which has entered the low-temperature side expansion valve 43 is depressurized, thus to turn into low-temperature/low-pressure gas-liquid two-phase refrigerant.

[0079] The low-temperature/low-pressure gas-liquid two-phase refrigerant is heated in the low-temperature side evaporator 44 by the air in the refrigerating room (cools the air in the refrigerating room) and evaporated, thus to turn into low-pressure gas phase refrigerant.

[0080] The low-pressure gas phase refrigerant flows into the low-temperature side compressor 22 through the service valve 28 and the accumulator 26.

[0081] The operation of the controller 61 will be described hereunder.

[0082] The following is merely an example of the operation of the controller 61, and the present invention encompasses other operations of the controller 61.

[0083] Fig. 3 is a flowchart showing the operation of the controller in the refrigeration apparatus according to Embodiment 1.

[0084] At step 31, the controller 61 activates the high-temperature side compressor 12 and the low-temperature side compressor 22, and controls the opening degree of the low-temperature side expansion valve 43, so as to reduce the opening degree the closer the temperature detected by the temperature sensor 62 is to a target temperature.

[0085] At step 32, the controller 61 determines whether the pressure detected by the low-temperature side low

pressure sensor 64 is equal to or lower than a predetermined lower-limit pressure (hereinafter, first predetermined lower-limit pressure).

[0086] The first predetermined lower-limit pressure corresponds to the "third reference pressure" in the present invention.

[0087] In the case of No, the controller 61 returns to step 31.

[0088] In the case of Yes, the controller 61 proceeds to step 33.

[0089] At step 33, the controller 61 turns off the low-temperature side compressor 22, and turns on the high-temperature side compressor 12.

[0090] At step 34, the controller 61 determines whether the pressure detected by the low-temperature side low pressure sensor 64 is higher than another predetermined lower-limit pressure (hereinafter, second predetermined lower-limit pressure), and whether the pressure detected by the low-temperature side high pressure sensor 63 is equal to or lower than a predetermined upper-limit pressure (hereinafter, first predetermined upper-limit pressure).

[0091] The second predetermined lower-limit pressure corresponds to the "first reference pressure" in the present invention.

[0092] The first predetermined upper-limit pressure corresponds to the "second reference pressure" in the present invention.

[0093] In the case of No, the controller 61 returns to step 33.

[0094] In the case of Yes, the controller 61 proceeds to step 31.

[0095] The second predetermined lower-limit pressure of step 34 may be the same as or different from the first predetermined lower-limit pressure of step 32.

[0096] The first predetermined upper-limit pressure may be, for example, 6.9 MPa.

[0097] When the circulation in the low-temperature side cycle 21 is stopped for another reason than the low-pressure cut-off control, for example because of a failure of the low-temperature side compressor 22 or defrosting operation by the low-temperature side evaporator 44, the foregoing steps other than step 33 are skipped.

(Operation of Refrigeration apparatus)

[0098] The operation of the refrigeration apparatus according to Embodiment 1 will be described hereunder.

[0099] In the case where a refrigerant of a low critical temperature such as a CO<sub>2</sub> refrigerant is employed in the low-temperature side cycle 21, and the refrigeration apparatus 1 is installed in an environment where outside air temperature is higher than the critical temperature, the refrigerant in the low-temperature side cycle 21 is heated by the outside air and turns into gas phase when the circulation in the low-temperature side cycle 21 is stopped, and therefore the pressure in the low-temperature side cycle 21 increases.

**[0100]** Here, the critical temperature of the CO<sub>2</sub> refrigerant is approximately 31 degrees Celsius.

**[0101]** In the refrigeration apparatus according to Embodiment 1, the controller 61 turns on the high-temperature side compressor 12 when the circulation in the low-temperature side cycle 21 is stopped, to thereby activate the circulation in the high-temperature side cycle 11.

**[0102]** Accordingly, the gas phase refrigerant in the low-temperature side cycle 21 is condensed and liquefied in the cascade condenser 51 by the refrigerant in the high-temperature side cycle 11, and turns into liquid phase refrigerant.

**[0103]** The receiver 25 and the cascade condenser 51 have the same pressure, and therefore the liquid phase refrigerant drops onto the receiver 25 located under the cascade condenser 51 b through the pipe 29, because of the gravity.

**[0104]** Thus, in the refrigeration apparatus according to Embodiment 1, since the receiver 25 is located under the cascade condenser 51, the refrigerant in the low-temperature side cycle 21 condensed and liquefied by the refrigerant in the high-temperature side cycle 11 is promptly collected in the receiver 25 when the circulation in the low-temperature side cycle 21 is stopped, and therefore an increase in pressure in the low-temperature side cycle 21 can be suppressed.

**[0105]** Consequently, the cost as well as the weight of the components constituting the low-temperature side cycle 21 can be reduced.

(Variation)

**[0106]** In the refrigeration apparatus according to Embodiment 1, the controller 61 simply turns on the high-temperature side compressor 12 when the circulation in the low-temperature side cycle 21 is stopped.

**[0107]** Alternatively, the controller 61 may operate the high-temperature side compressor 12 while controlling at least one of the frequency thereof and the opening degree of the high-temperature side expansion valve 14, on the basis of the pressure detected by the low-temperature side high pressure sensor 63.

**[0108]** Fig. 4 is a flowchart showing a variation of the operation of the controller in the refrigeration apparatus according to Embodiment 1.

**[0109]** In the aforementioned case, the controller 61 works as shown in Fig. 4.

**[0110]** Steps 41, 42, and 44 are the same as steps 31, 32, and 34 in Fig. 3.

**[0111]** At step 43, the controller 61 turns off the low-temperature side compressor 22, and operates the high-temperature side compressor 12 at a higher frequency while reducing the opening degree of the high-temperature side expansion valve 14, the higher the pressure detected by the low-temperature side high pressure sensor 63 is.

**[0112]** At least one of the frequency of the high-temperature side compressor 12 and the opening degree of

the high-temperature side expansion valve 14 may be controlled either linearly or stepwise, on the basis of the pressure detected by the low-temperature side high pressure sensor 63.

**[0113]** The controller 61 may activate the high-temperature side compressor 12 only when the pressure detected by the low-temperature side high pressure sensor 63 is higher than a predetermined upper-limit pressure (hereinafter, second predetermined upper-limit pressure), at step 33 or step 43.

**[0114]** The second predetermined upper-limit pressure specified for the mentioned case may be the same as or different from the first predetermined upper-limit pressure of step 34 or step 44.

**[0115]** At step 33 or step 43, the controller 61 may activate the high-temperature side compressor 12 only when a predetermined time (hereinafter, first predetermined time) has elapsed after the circulation in the low-temperature side cycle 21 is stopped.

**[0116]** In such a case, the controller 61 may operate the high-temperature side compressor 12 either continuously or intermittently, when the first predetermined time has elapsed after the circulation in the low-temperature side cycle 21 is stopped.

**[0117]** Further, the controller 61 may monitor, based on the pressure detected by the low-temperature side high pressure sensor 63, whether the pressure in the low-temperature side cycle 21 has dropped, in other words whether the refrigerant is falling onto the receiver 25, at step 33 or step 43.

**[0118]** When the controller 61 determines that the refrigerant is not falling onto the receiver 25 in the mentioned case, the controller 61 outputs an alarm signal.

**[0119]** Alternatively, a non-illustrated temperature sensor may be provided in the receiver 25, and the controller 61 may determine whether the refrigerant is falling onto the receiver 25 on the basis of the temperature detected by the temperature sensor.

**[0120]** Although the cascade condenser 51 of the refrigeration apparatus according to Embodiment 1 includes a pair of plate-type heat exchangers connected in series and disposed side by side as shown in Fig. 2, the cascade condenser 51 may be configured in a different form.

**[0121]** The cascade condenser 51 may be a shell-and-tube heat exchanger, without limitation to the plate-type heat exchanger.

**[0122]** The cascade condenser 51 may be constituted of a single heat exchanger, or three or more heat exchangers disposed side by side.

**[0123]** The cascade condenser 51 may include a plurality of heat exchangers connected in parallel, or a plurality of heat exchangers aligned in a vertical direction.

**[0124]** Fig. 5 is a perspective view showing a variation of the cascade condenser in the refrigeration apparatus according to Embodiment 1.

**[0125]** In the case where a plurality of heat exchangers are aligned in the vertical direction as shown in Fig. 5,

the refrigerant in the low-temperature side cycle 21, which has been condensed and liquefied in the high-temperature side evaporator 15, can smoothly flow downward because of the gravity, thereby more effectively suppressing the increase in pressure in the low-temperature side cycle 21.

#### Embodiment 2

**[0126]** Hereunder, the refrigeration apparatus according to Embodiment 2 will be described.

**[0127]** The description of the same aspects as those of the refrigeration apparatus according to Embodiment 1 will be simplified or skipped, as the case may be.

#### (Configuration of Refrigeration apparatus)

**[0128]** The configuration of the refrigeration apparatus according to Embodiment 2 will be described hereunder.

**[0129]** Fig. 6 is a diagram showing the configuration of the refrigeration apparatus according to Embodiment 2.

**[0130]** As shown in Fig. 6, the refrigeration apparatus 2 includes the high-temperature side cycle 11, a low-temperature side cycle 30, the cascade condenser 51, and a controller 65.

**[0131]** The low-temperature side cycle 30 includes a low-temperature side compressor 22, the intermediate cooler 23, the low-temperature side condenser 24, the receiver 25, the cooling unit 41, and the accumulator 26.

**[0132]** A flow control valve 31 is provided between the outlet side of the low-temperature side condenser 24 and the inlet side of the receiver 25.

**[0133]** At least the high-temperature side compressor 12, the low-temperature side compressor 22, the flow control valve 31, the low-temperature side expansion valve 43, the temperature sensor 62, the low-temperature side high pressure sensor 63, and the low-temperature side low pressure sensor 64 are connected to the controller 65.

#### (Operation of Refrigeration apparatus)

**[0134]** The operation of the refrigeration apparatus according to Embodiment 2 will be described hereunder.

**[0135]** Fig. 7 is a flowchart showing the operation of the controller in the refrigeration apparatus according to Embodiment 2.

**[0136]** The controller 65 works as shown in Fig. 7.

**[0137]** Steps 71, 72, and 74 are the same as steps 31, 32, and 34 in Fig. 3.

**[0138]** At step 73, the controller 65 turns off the low-temperature side compressor 22 and turns on the high-temperature side compressor 12 while opening the flow control valve 31.

**[0139]** At step 73, the controller 65 may open the flow control valve 31 to a fixed opening degree.

**[0140]** Alternatively, the controller 65 may open the flow control valve 31 to the higher opening degree, the

higher the pressure detected by the low-temperature side high pressure sensor 63 is, at step 73.

**[0141]** In such a case, the opening degree of the flow control valve 31 may be adjusted either linearly or stepwise, on the basis of the pressure detected by the low-temperature side high pressure sensor 63.

**[0142]** At step 73, the controller 65 may open the flow control valve 31 to the fixed opening degree or to the opening degree based on the pressure detected by the low-temperature side high pressure sensor 63, only when the pressure detected by the low-temperature side high pressure sensor 63 is higher than a predetermined upper-limit pressure (hereinafter, third predetermined upper-limit pressure).

**[0143]** The third predetermined upper-limit pressure specified for the mentioned case may be the same as or different from the first predetermined upper-limit pressure of step 74.

**[0144]** At step 73, the controller 65 may open the flow control valve 31 only when a predetermined time (hereinafter, second predetermined time) has elapsed after the circulation in the low-temperature side cycle 30 is stopped.

**[0145]** In such a case, the controller 65 may open the flow control valve 31 either continuously or intermittently, when the second predetermined time has elapsed after the circulation in the low-temperature side cycle 30 is stopped.

#### (Advantageous Effects of Refrigeration apparatus)

**[0146]** The advantageous effects of the refrigeration apparatus according to Embodiment 2 will be described hereunder.

**[0147]** In the refrigeration apparatus according to Embodiment 2, the controller 65 activates the high-temperature side compressor 12 while opening the flow control valve 31, when the circulation of the refrigerant in the low-temperature side cycle 30 is stopped.

**[0148]** Accordingly, the refrigerant can more smoothly fall onto the receiver 25 from the low-temperature side condenser 24, and hence the refrigerant condensed and liquefied by the refrigerant in the high-temperature side cycle 11 is more rapidly collected into the receiver 25. Consequently, the increase in pressure in the low-temperature side cycle 30 can be more effectively suppressed.

#### (Variation)

**[0149]** Although the controller 65 controls the opening and closing of the flow control valve 31 in the refrigeration apparatus according to Embodiment 2, the flow control valve 31 may be manually opened and closed.

**[0150]** In the refrigeration apparatus according to Embodiment 2, the controller 65 simply turns on the high-temperature side compressor 12 when the circulation in the low-temperature side cycle 30 is stopped.

**[0151]** Alternatively, the controller 65 may operate the high-temperature side compressor 12 while controlling at least one of the frequency thereof and the opening degree of the high-temperature side expansion valve 14, on the basis of the pressure detected by the low-temperature side high pressure sensor 63, as shown in Fig. 4.

#### Embodiment 3

**[0152]** Hereunder, the refrigeration apparatus according to Embodiment 3 will be described.

**[0153]** The description of the same aspects as those of the refrigeration apparatus according to Embodiment 1 and Embodiment 2 will be simplified or skipped, as the case may be.

#### (Configuration of Refrigeration apparatus)

**[0154]** The configuration of the refrigeration apparatus according to Embodiment 3 will be described hereunder.

**[0155]** Fig. 8 is a diagram showing the configuration of the refrigeration apparatus according to Embodiment 3.

**[0156]** As shown in Fig. 8, the refrigeration apparatus 3 includes the high-temperature side cycle 11, a low-temperature side cycle 32, the cascade condenser 51, and a controller 66.

**[0157]** The low-temperature side cycle 32 includes the low-temperature side compressor 22, the intermediate cooler 23, the low-temperature side condenser 24, the receiver 25, the cooling unit 41, and the accumulator 26.

**[0158]** The top portion of the receiver 25 and the inlet side of the low-temperature side condenser 24 are connected to each other via a bypass pipe 33.

**[0159]** The bypass pipe 33 includes a low-temperature side second solenoid valve 34.

**[0160]** At least the high-temperature side compressor 12, the low-temperature side compressor 22, the low-temperature side second solenoid valve 34, the low-temperature side expansion valve 43, the temperature sensor 62, the low-temperature side high pressure sensor 63, and the low-temperature side low pressure sensor 64 are connected to the controller 66.

#### (Operation of Refrigeration apparatus)

**[0161]** The operation of the refrigeration apparatus according to Embodiment 3 will be described hereunder.

**[0162]** Fig. 9 is a flowchart showing the operation of the controller in the refrigeration apparatus according to Embodiment 3.

**[0163]** The controller 66 works as shown in Fig. 9.

**[0164]** Steps 91, 92, and 94 are the same as steps 31, 32, and 34 in Fig. 3.

**[0165]** At step 93, the controller 66 turns off the low-temperature side compressor 22 and turns on the high-temperature side compressor 12 while opening the low-temperature side second solenoid valve 34.

**[0166]** At step 93, the controller 66 may open the low-

temperature side second solenoid valve 34, only when the pressure detected by the low-temperature side high pressure sensor 63 is higher than a predetermined upper-limit pressure (hereinafter, fourth predetermined upper-limit pressure).

**[0167]** The fourth predetermined upper-limit pressure specified for the mentioned case may be the same as or different from the first predetermined upper-limit pressure of step 94.

**[0168]** At step 93, the controller 66 may open the low-temperature side second solenoid valve 34 only when a predetermined time (hereinafter, third predetermined time) has elapsed after the circulation in the low-temperature side cycle 32 is stopped.

**[0169]** In such a case, the controller 66 may open the low-temperature side second solenoid valve 34 either continuously or intermittently, when the third predetermined time has elapsed after the circulation in the low-temperature side cycle 32 is stopped.

#### (Advantageous Effects of Refrigeration apparatus)

**[0170]** The advantageous effects of the refrigeration apparatus according to Embodiment 3 will be described hereunder.

**[0171]** In the refrigeration apparatus according to Embodiment 3, the controller 66 activates the high-temperature side compressor 12 while opening the low-temperature side second solenoid valve 34, when the circulation of the refrigerant in the low-temperature side cycle 32 is stopped.

**[0172]** Accordingly, the refrigerant turned into gas phase is conducted to the low-temperature side condenser 24 through the bypass pipe 33, and hence the refrigerant condensed and liquefied by the refrigerant in the high-temperature side cycle 11 can more smoothly fall from the low-temperature side condenser 24 onto the receiver 25. Consequently, the increase in pressure in the low-temperature side cycle 32 can be more effectively suppressed.

#### (Variation)

**[0173]** Although the controller 66 controls the opening and closing of the low-temperature side second solenoid valve 34 in the refrigeration apparatus according to Embodiment 3, the valve may be provided in the bypass pipe 33 and manually opened and closed.

**[0174]** In the refrigeration apparatus according to Embodiment 3, the controller 66 simply turns on the high-temperature side compressor 12 when the circulation in the low-temperature side cycle 32 is stopped.

**[0175]** Alternatively, the controller 66 may operate the high-temperature side compressor 12 while controlling at least one of the frequency thereof and the opening degree of the high-temperature side expansion valve 14, on the basis of the pressure detected by the low-temperature side high pressure sensor 63, as shown in Fig. 4.

**[0176]** Further, the flow control valve 31 may be provided between the outlet side of the low-temperature side condenser 24 and the inlet side of the receiver 25, as in the refrigeration apparatus according to Embodiment 2.

#### Embodiment 4

**[0177]** Hereunder, the refrigeration apparatus according to Embodiment 4 will be described.

**[0178]** The description of the same aspects as those of the refrigeration apparatus according to Embodiment 1 to Embodiment 3 will be simplified or skipped, as the case may be.

#### (Configuration of Refrigeration apparatus)

**[0179]** The configuration of the refrigeration apparatus according to Embodiment 4 will be described hereunder.

**[0180]** Fig. 10 is a diagram showing the configuration of the refrigeration apparatus according to Embodiment 4.

**[0181]** As shown in Fig. 10, the refrigeration apparatus 4 includes a high-temperature side cycle 16, the low-temperature side cycle 21, the cascade condenser 51, and a controller 67.

**[0182]** The high-temperature side cycle 16 includes the high-temperature side compressor 12, the high-temperature side condenser 13, the high-temperature side expansion valve 14, and the high-temperature side evaporator 15.

**[0183]** A service valve 17 is provided between the outlet side of the high-temperature side expansion valve 14 and the inlet side of the high-temperature side evaporator 15.

**[0184]** A service valve 18 is provided between the outlet side of the high-temperature side evaporator 15 and the inlet side of the high-temperature side compressor 12.

**[0185]** The low-temperature side cycle 21 and the cascade condenser 51 can be separated from the refrigeration apparatus 4, by the service valves 17 and 18.

**[0186]** The controller 67 includes a high-temperature side controller 68 and a low-temperature side controller 69.

**[0187]** Fig. 11 is a drawing showing an arrangement of the components in the refrigeration apparatus according to Embodiment 4.

**[0188]** As shown in Fig. 11, the components of the refrigeration apparatus 4 are separately located in a high-temperature side casing 81 and a low-temperature side casing 82.

**[0189]** Here, Fig. 11 illustrates the case where the cooling unit 41 is separated.

**[0190]** The high-temperature side casing 81 includes the high-temperature side compressor 12, the high-temperature side condenser 13, the high-temperature side expansion valve 14, and the high-temperature side controller 68.

**[0191]** The low-temperature side casing 82 includes the low-temperature side compressor 22, the intermediate cooler 23, the receiver 25, the accumulator 26, the cascade condenser 51, and the low-temperature side controller 69.

**[0192]** The high-temperature side casing 81 and the low-temperature side casing 82 are mounted on a pedestal 83.

**[0193]** Forming the high-temperature side casing 81 and the low-temperature side casing 82 in the same shape enables the parts to be used in common, thereby contributing to reducing the cost of the refrigeration apparatus.

**[0194]** The service valves 17 and 18 are located in the high-temperature side casing 81.

**[0195]** Placing the service valves 17 and 18 on the farther side from the low-temperature side casing 82 improves the operability of the valves.

**[0196]** The service valves 27 and 28 are located in the high-temperature side casing 82.

**[0197]** Placing the service valves 27 and 28 on the farther side from the low-temperature side casing 81 improves the operability of the valves.

**[0198]** Placing the cascade condenser 51 on the nearer side to the high-temperature side casing 81 allows the pipe connecting between the high-temperature side evaporator 15 and the service valves 17, 18 to be shortened.

**[0199]** The high-temperature side controller 68 includes an operation switch 70.

**[0200]** At least the high-temperature side compressor 12, and an air-blowing device 84 that supplies outside air to the high-temperature side condenser 13 are connected to the high-temperature side controller 68.

**[0201]** The low-temperature side controller 69 includes an operation switch 71.

**[0202]** At least the low-temperature side compressor 22, the low-temperature side expansion valve 43, the temperature sensor 62, the low-temperature side high pressure sensor 63, the low-temperature side low pressure sensor 64, and an air-blowing device 85 that supplies outside air to the intermediate cooler 23 are connected to the low-temperature side controller 69.

#### (Advantageous Effects of Refrigeration apparatus)

**[0203]** The advantageous effects of the refrigeration apparatus according to Embodiment 4 will be described hereunder.

**[0204]** In the refrigeration apparatus according to Embodiment 4, the components are separately located in the high-temperature side casing 81 and the low-temperature side casing 82.

**[0205]** Such a configuration reduces the weight of each of the casings compared with the case where all the components are included in a single casing, thereby facilitating the transport and installment of the refrigeration apparatus 4.

**[0206]** Further, the cascade condenser 51 is located in the low-temperature side casing 82.

**[0207]** Accordingly, the low-temperature side casing 82 can be additionally connected on site to an existing refrigeration apparatus that includes a compressor, a condenser, and an expansion valve like the high-temperature side casing 81, and therefore the existing refrigeration apparatus can be easily converted into a plural refrigeration apparatus.

**[0208]** In the refrigeration apparatus according to Embodiment 4, further, the high-temperature side casing 81 and the low-temperature side casing 82 respectively include the high-temperature side controller 68 and the low-temperature side controller 69.

**[0209]** Accordingly, even when the circulation in the high-temperature side cycle 16 is stopped, for example because of a failure of the high-temperature side compressor 12 or maintenance work for the high-temperature side cycle 16, the operator can turn on the operation switch 71 provided in the low-temperature side casing 82 thereby cooling an object to be cooled, such as the air in the refrigerating room.

(Variation)

**[0210]** In the refrigeration apparatus according to Embodiment 4, the service valve 17 is provided between the outlet side of the high-temperature side expansion valve 14 and the inlet side of the high-temperature side evaporator 15. Alternatively, the service valve 17 may be provided between the outlet side of the high-temperature side condenser 13 and the inlet side of the high-temperature side expansion valve 14, and the high-temperature side expansion valve 14 may be located in the low-temperature side casing 82.

**[0211]** Although the cascade condenser 51 is located in the low-temperature side casing 82 in the refrigeration apparatus according to Embodiment 4, the service valves 17 and 18 may be provided in the low-temperature side cycle 21 and the cascade condenser 51 may be located in the high-temperature side casing 81.

**[0212]** Although the pipe of the high-temperature side casing 81 and the pipe of the low-temperature side casing 82 are connected via the service valves 17 and 18 in the refrigeration apparatus according to Embodiment 4, the pipes may be connected by a different method, for example by brazing, instead of via the service valves 17 and 18.

**[0213]** Although Embodiment 1 to Embodiment 4 have been described as above, the present invention is in no way limited to those Embodiments.

**[0214]** For example, two or more of Embodiments or variations thereof may be combined as desired.

Reference Signs List

**[0215]**

1, 2, 3, 4: refrigeration apparatus, 11, 16: high-temperature side cycle, 12: high-temperature side compressor, 13: high-temperature side condenser, 14: high-temperature side expansion valve, 15: high-temperature side evaporator, 17, 18, 27, 28: service valve, 21, 30, 32: low-temperature side cycle, 22: low-temperature side compressor, 23: intermediate cooler, 24: low-temperature side condenser, 25: receiver, 26: accumulator, 29: pipe, 31: flow control valve, 33: bypass pipe, 34: low-temperature side second solenoid valve, 41: cooling unit, 42: low-temperature side first solenoid valve, 43: low-temperature side expansion valve, 44: low-temperature side evaporator, 51: cascade condenser, 61, 65, 66, 67: controller, 62: temperature sensor, 63: low-temperature side high pressure sensor, 64: low-temperature side low pressure sensor, 68: high-temperature side controller, 69: low-temperature side controller, 70, 71: operation switch, 81: high-temperature side casing, 82: low-temperature side casing, 83: pedestal, 84, 85: air-blowing device.

## Claims

1. A refrigeration apparatus comprising:

a first refrigerant circuit in which a refrigerant circulates, the first refrigerant circuit including a first compressor, a first condenser, a first expansion device, and a first evaporator sequentially connected by piping;

a second refrigerant circuit in which a refrigerant circulates, the second refrigerant circuit including a second compressor, a second condenser, a receiver, a second expansion device, and a second evaporator sequentially connected by piping; and

a cascade condenser including the first evaporator and the second condenser and configured to heat exchange between the refrigerant flowing in the first evaporator and the refrigerant flowing in the second condenser, wherein the receiver is located under the cascade condenser.

2. The refrigeration apparatus of claim 1, further comprising a controller that controls operation of the first compressor and the second compressor, wherein the controller activates the first compressor when the second compressor is off.

3. The refrigeration apparatus of claim 2, wherein the controller controls at least one of frequency of the first compressor and an opening degree of the first expansion device on the basis of a pressure on a high-pressure side of the second refrigerant circuit, when the second compressor is off

and the first compressor is on.

4. The refrigeration apparatus of claim 2 or 3,  
wherein a flow control valve is provided to a pipe  
connecting between an outlet side of the second con- 5  
denser and the receiver, and  
the controller opens the flow control valve when the  
second compressor is off and the first compressor  
is on. 10
5. The refrigeration apparatus of any one of claims 2  
to 4,  
wherein a top portion of the receiver and an inlet side  
of the second condenser are connected to each other 15  
via a bypass pipe and a solenoid valve, and  
wherein the controller opens the solenoid valve when  
the second compressor is off and the first compres-  
sor is on.
6. The refrigeration apparatus of any one of claims 2 20  
to 5,  
wherein the controller activates the first compressor  
and the second compressor when a pressure on a  
low-pressure side of the second refrigerant circuit is  
higher than a first predetermined reference pressure 25  
and a pressure on the high-pressure side of the sec-  
ond refrigerant circuit is equal to or lower than a sec-  
ond predetermined reference pressure.
7. The refrigeration apparatus of any one of claims 2 30  
to 6,  
wherein the controller turns off the second compres-  
sor when the pressure on the low-pressure side of  
the second refrigerant circuit is equal to or lower than  
a third predetermined reference pressure. 35
8. A control method of a refrigeration apparatus includ-  
ing a first refrigerant circuit in which a refrigerant cir-  
culates, the first refrigerant circuit including a first 40  
compressor, a first condenser, a first expansion de-  
vice, and a first evaporator sequentially connected  
by piping; a second refrigerant circuit in which a re-  
frigerant circulates, the second refrigerant circuit in-  
cluding a second compressor, a second condenser, 45  
a receiver, a second expansion device, and a second  
evaporator sequentially connected by piping; and a  
cascade condenser including the first evaporator  
and the second condenser and configured to heat  
exchange between the refrigerant flowing in the first 50  
evaporator and the refrigerant flowing in the second  
condenser, the receiver being located under the cas-  
cade condenser, the method comprising:  
  
activating the first compressor when the second  
compressor is off. 55

FIG. 1

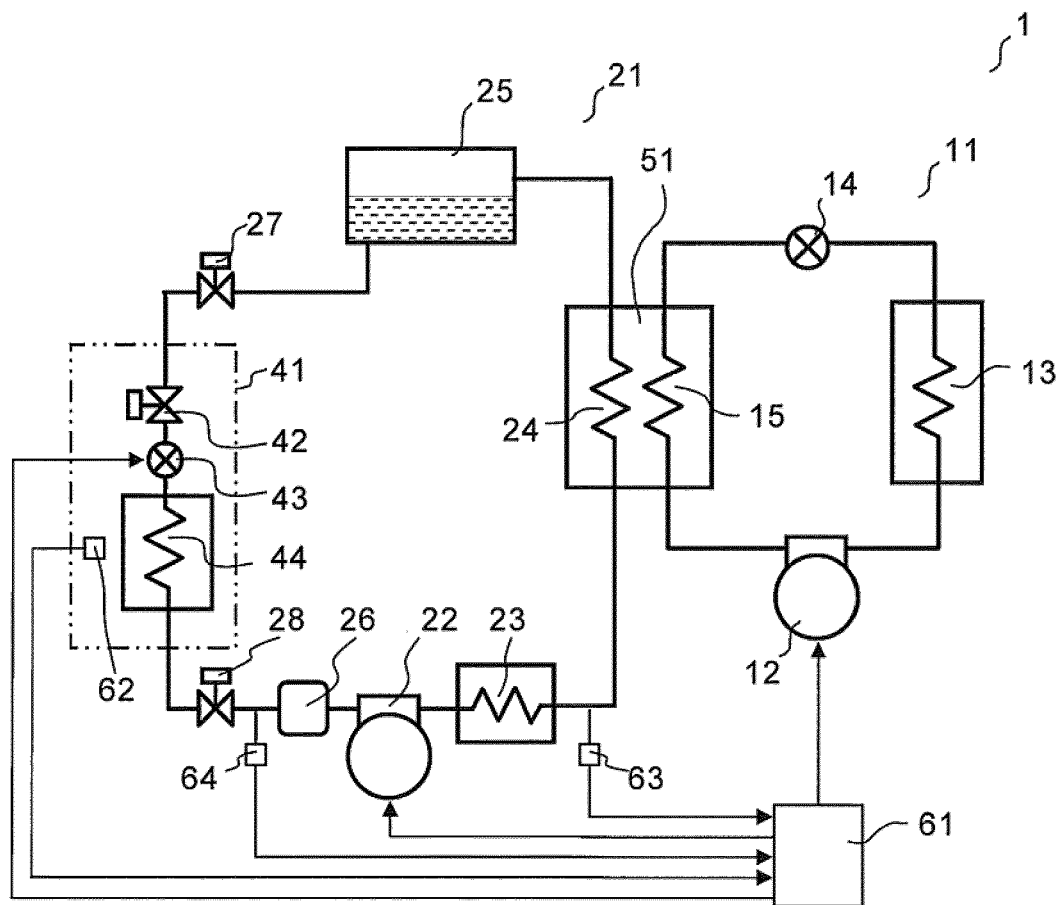


FIG. 2

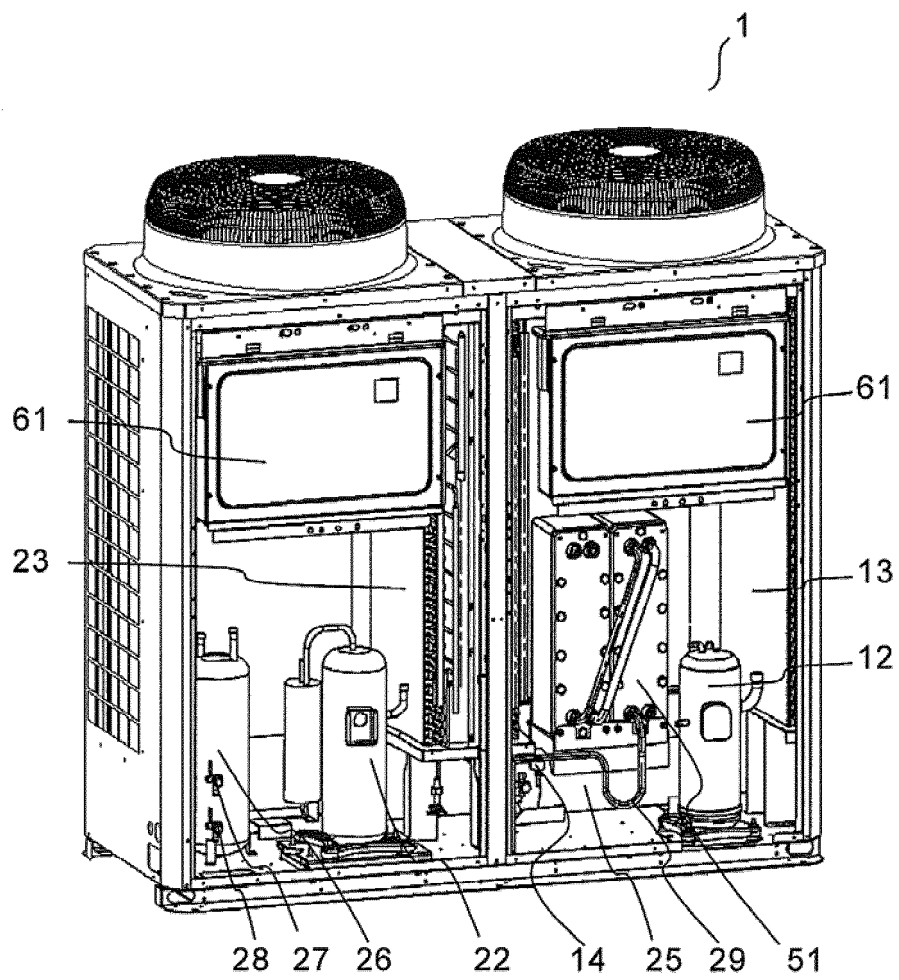


FIG. 3

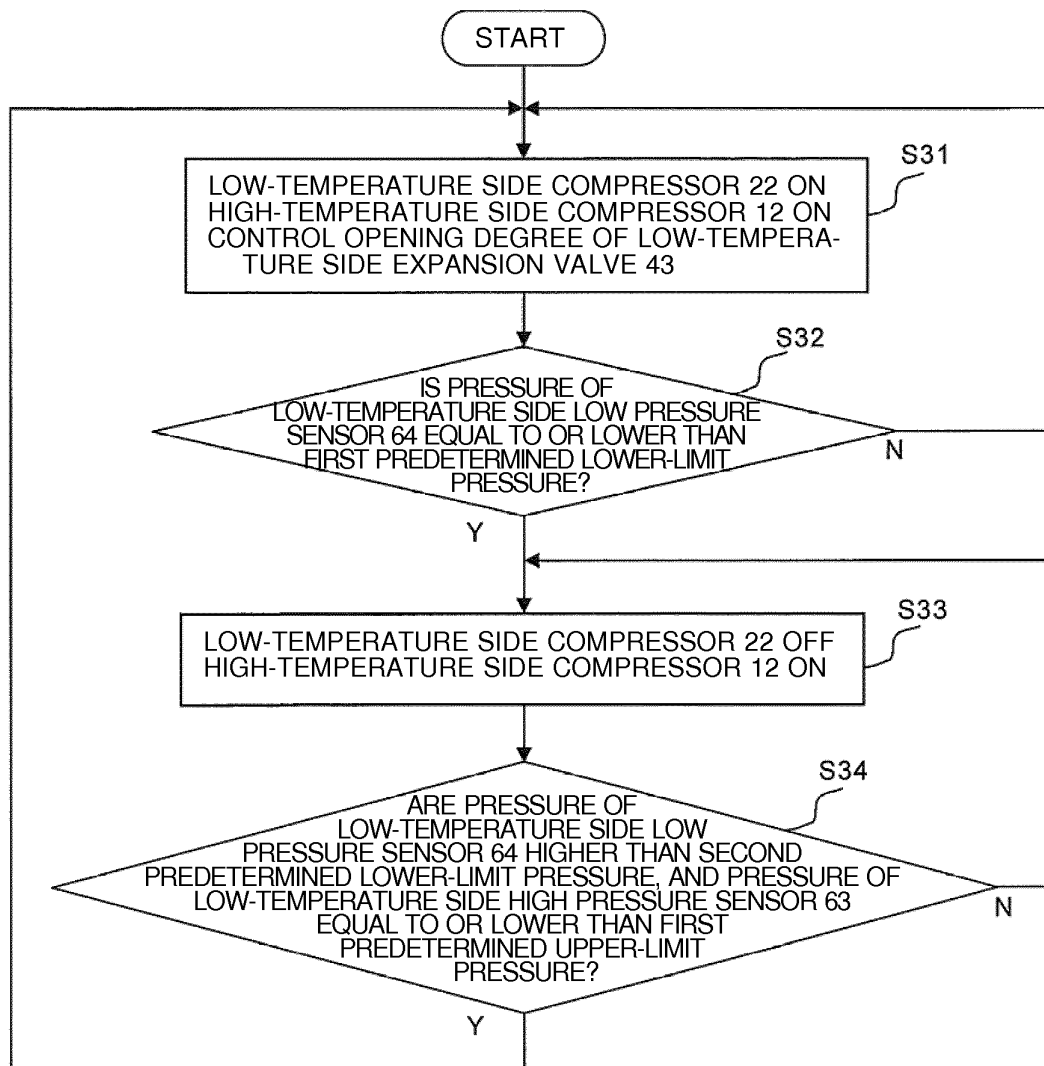


FIG. 4

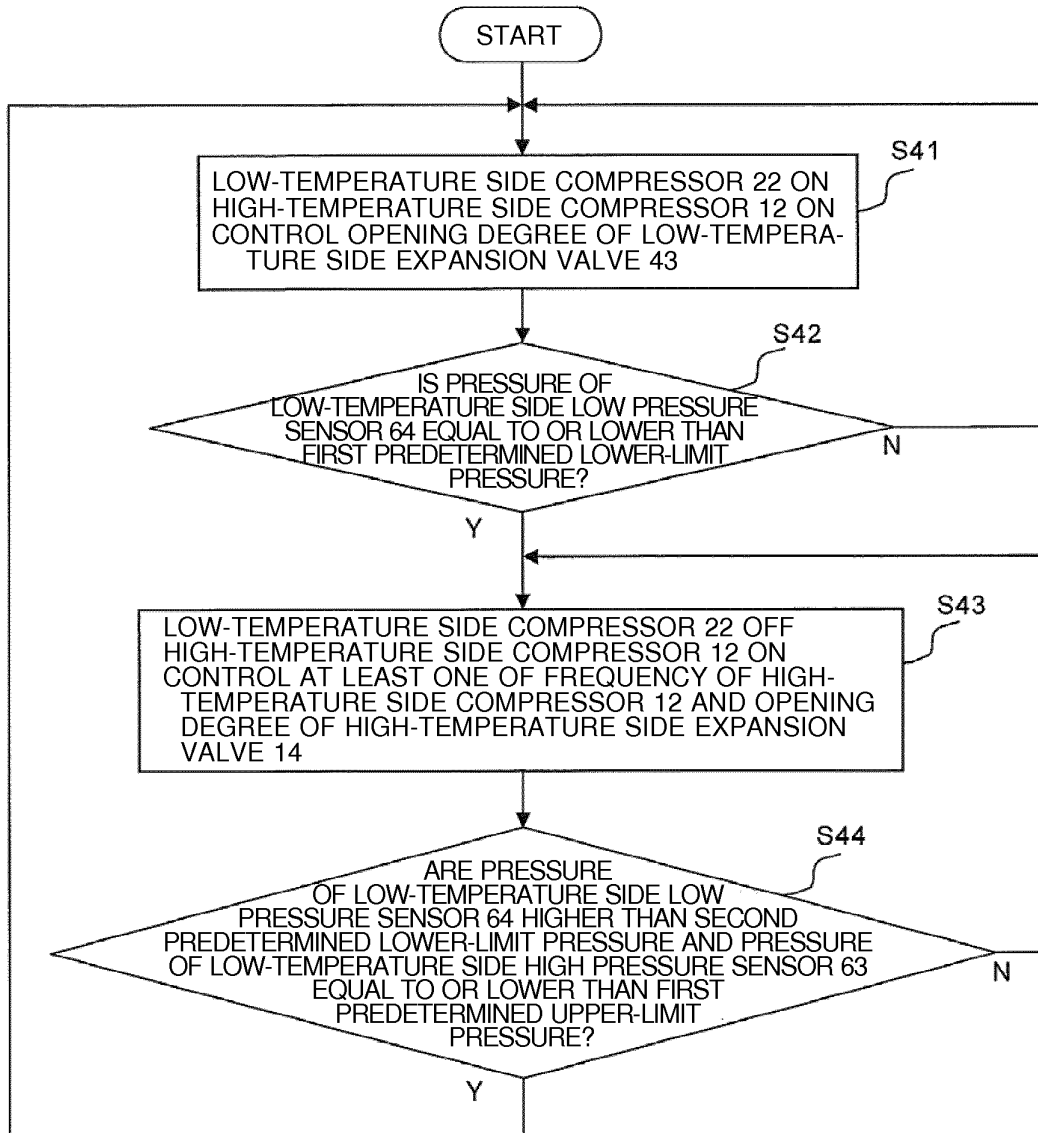


FIG. 5

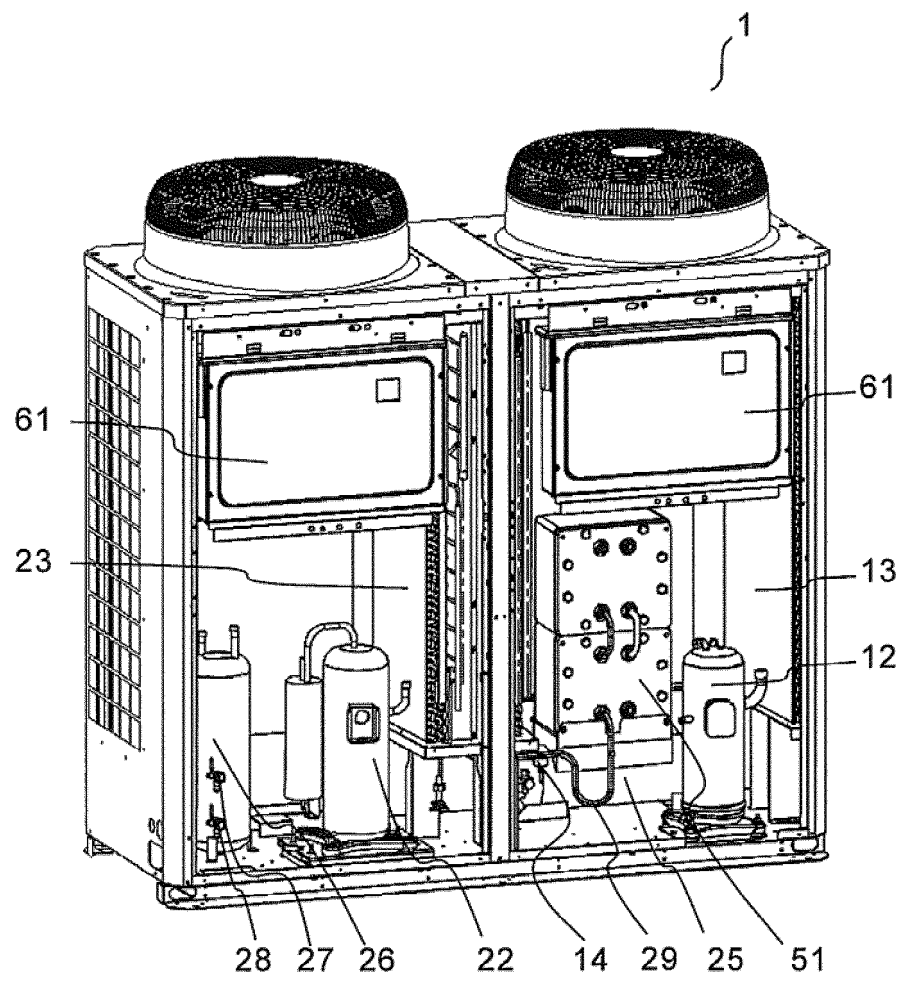


FIG. 6

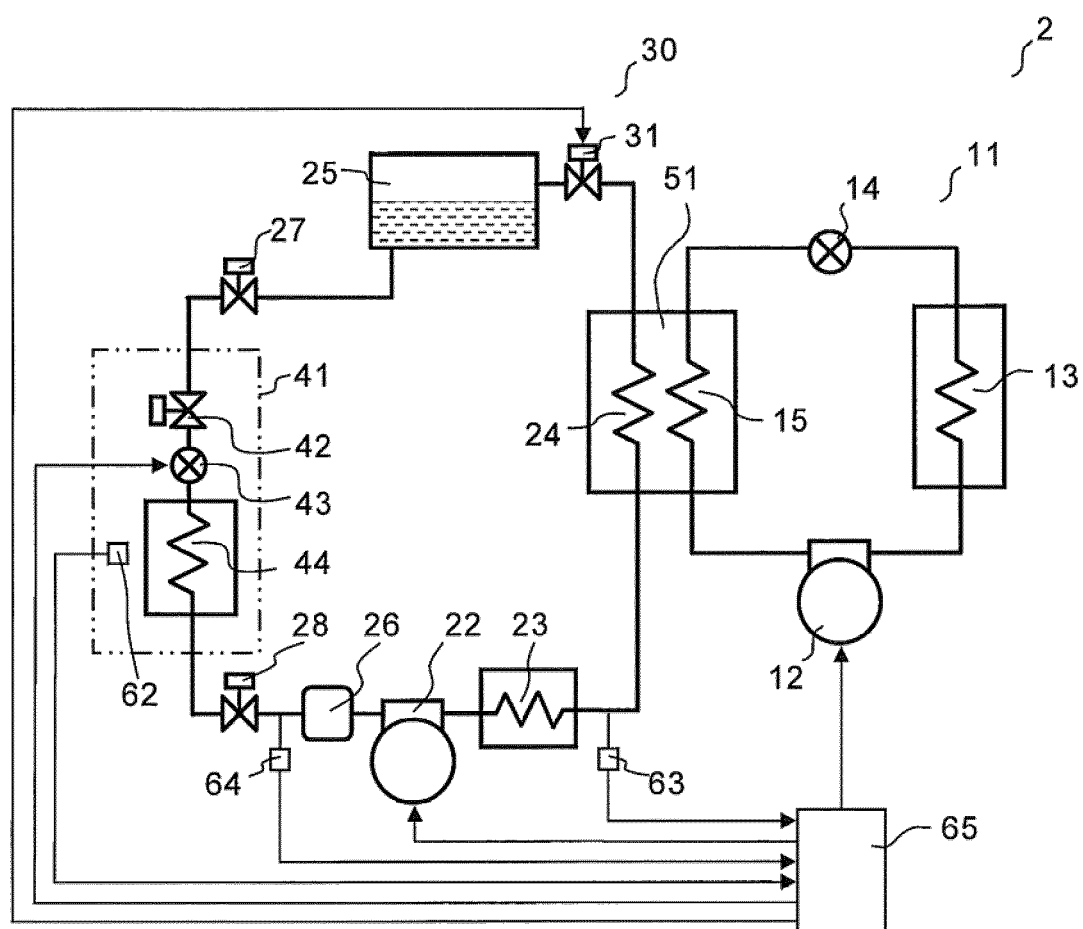


FIG. 7

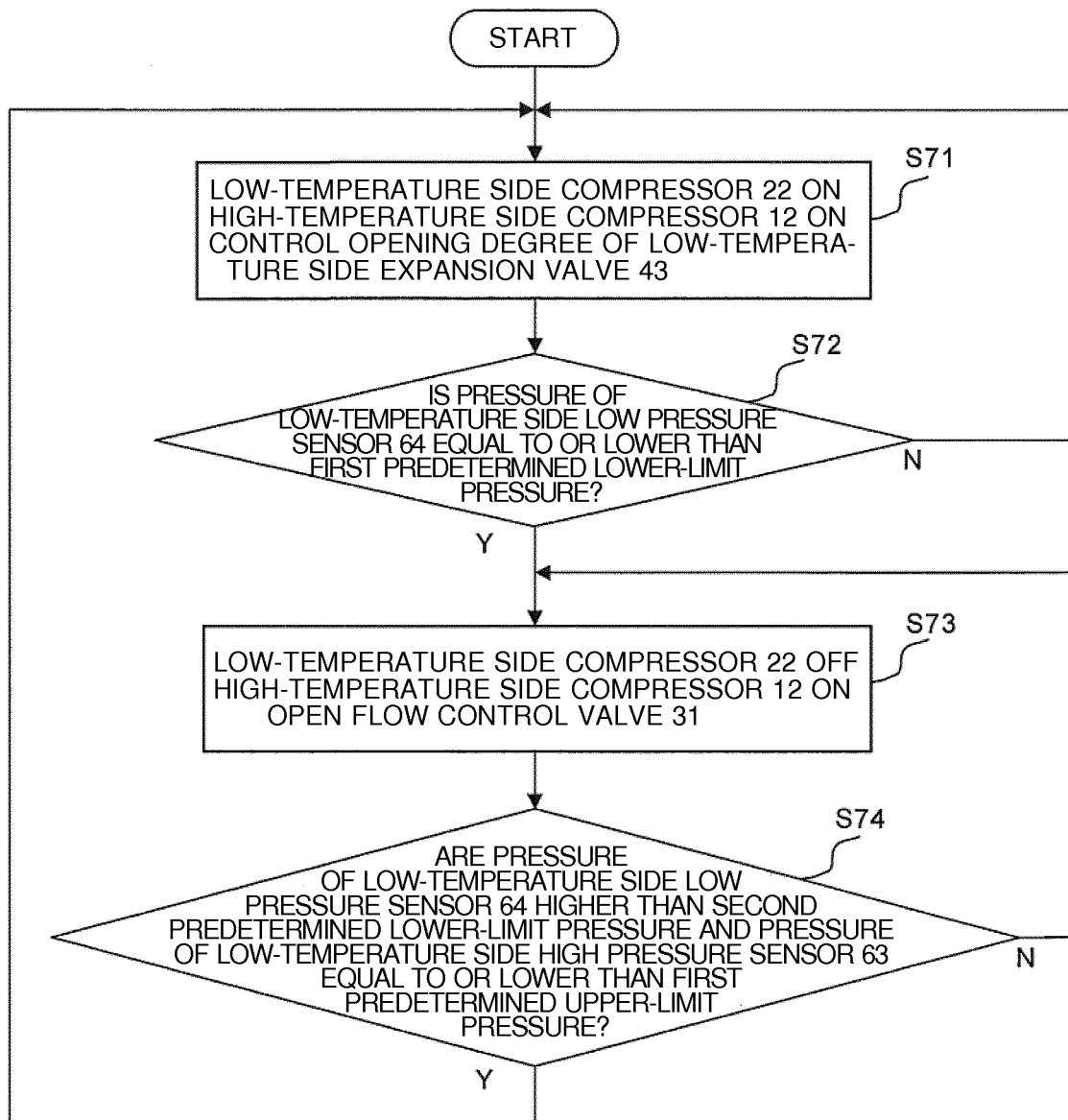


FIG. 8

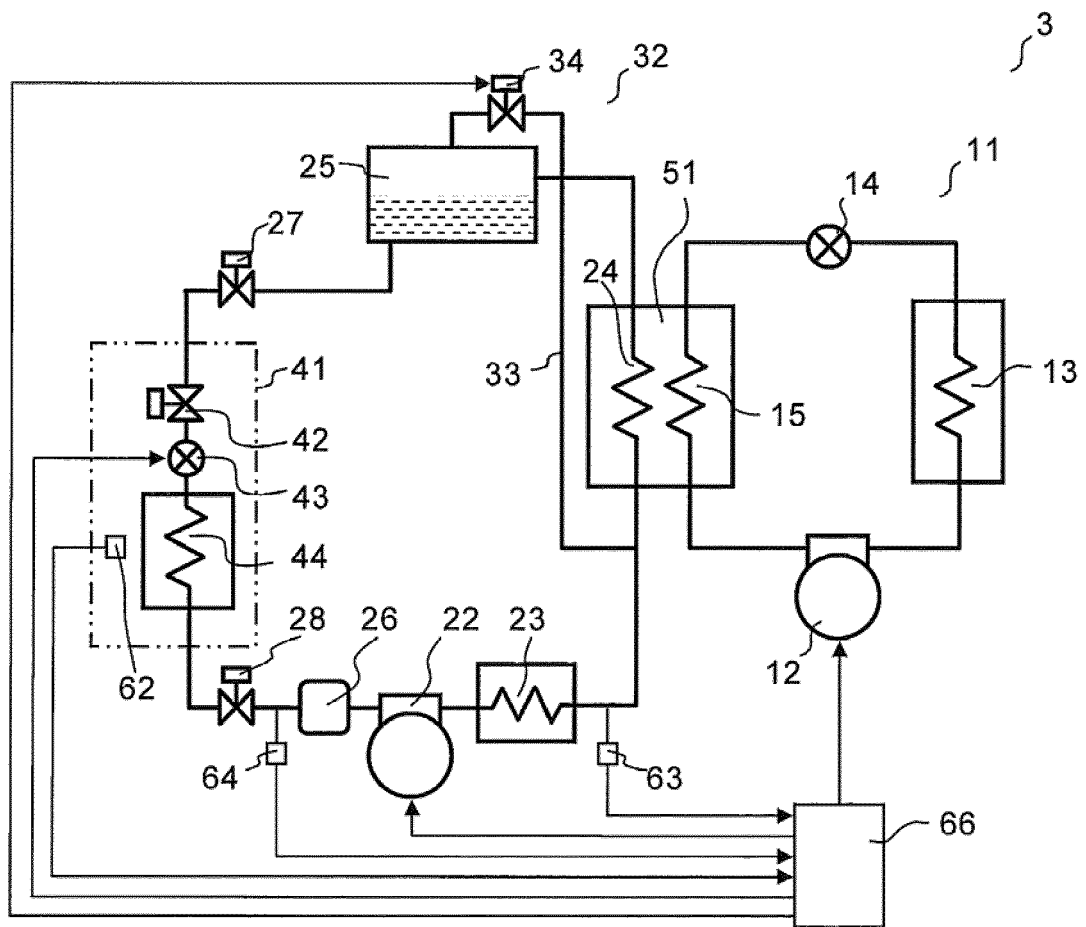


FIG. 9

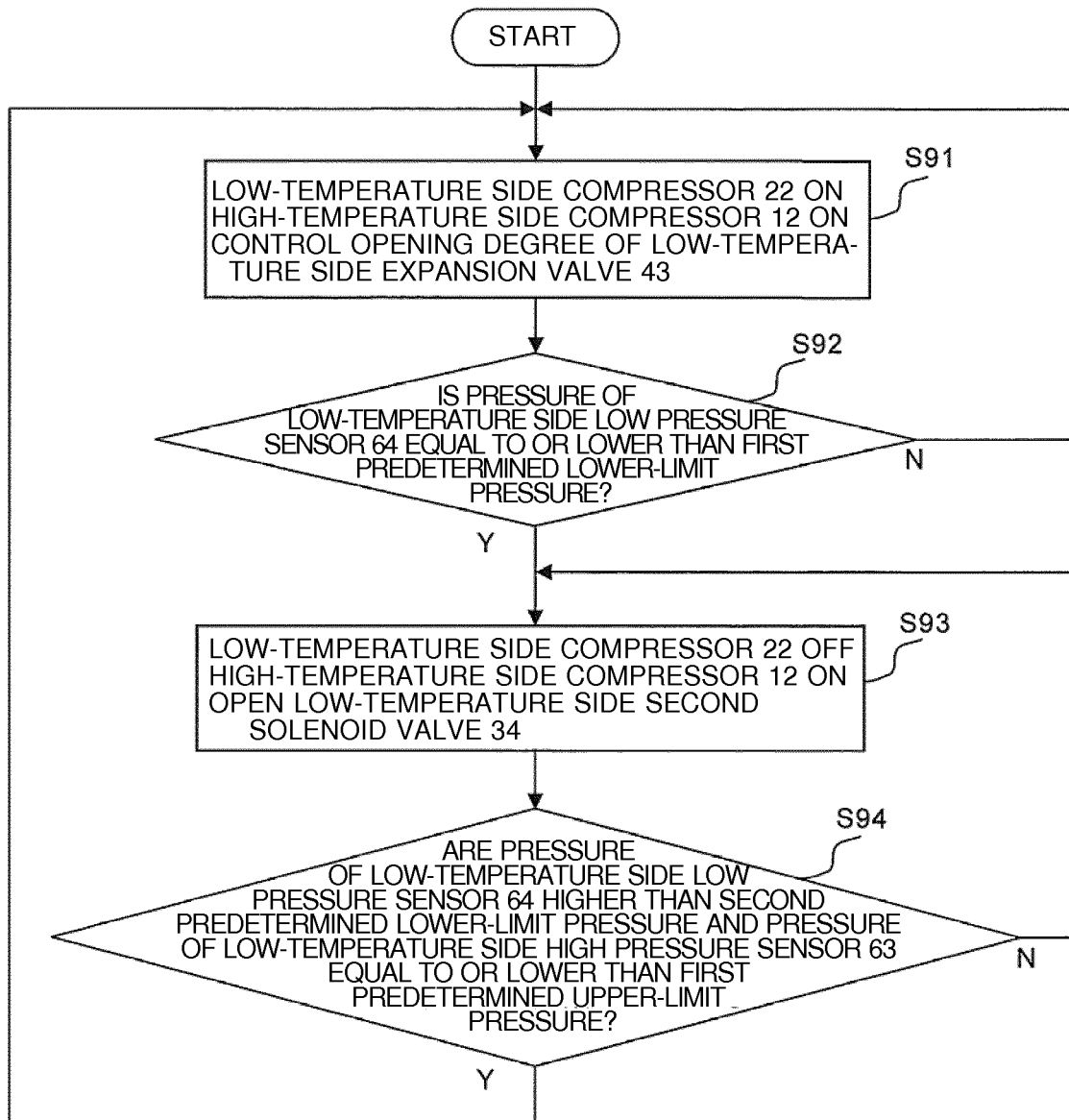


FIG. 10

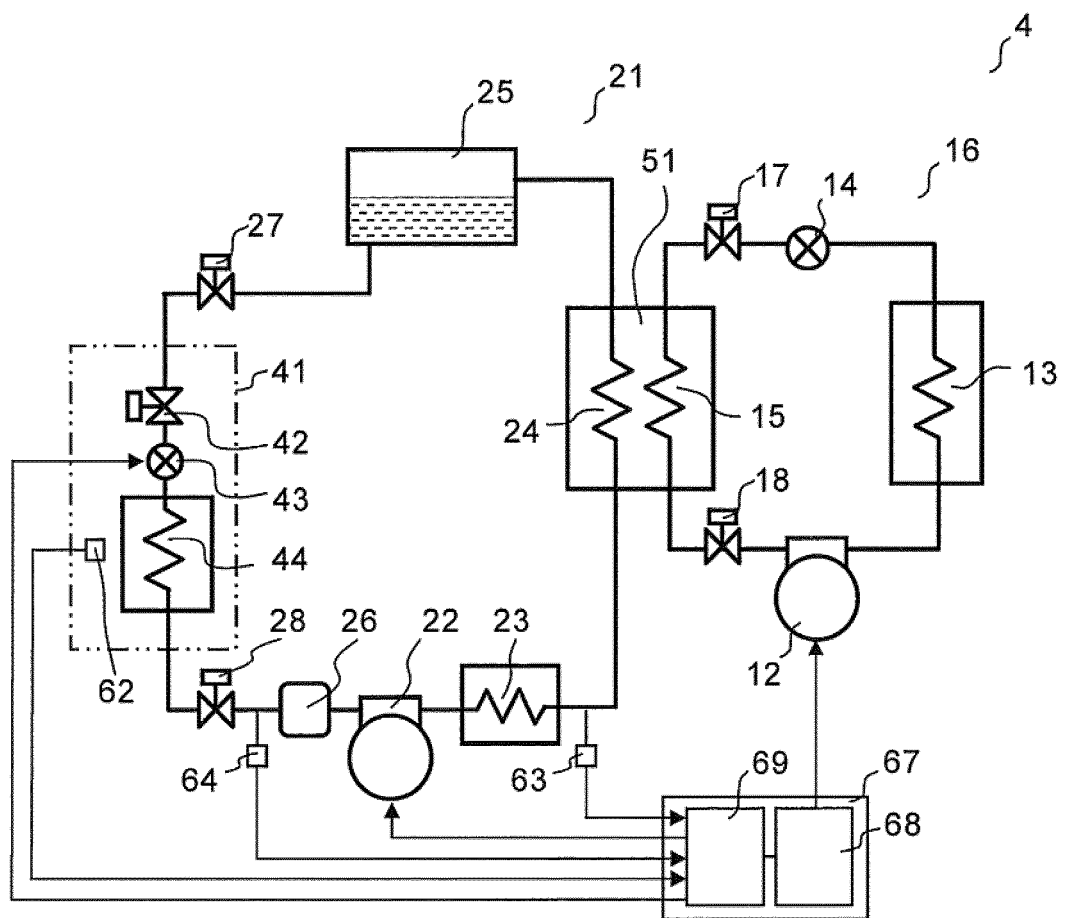
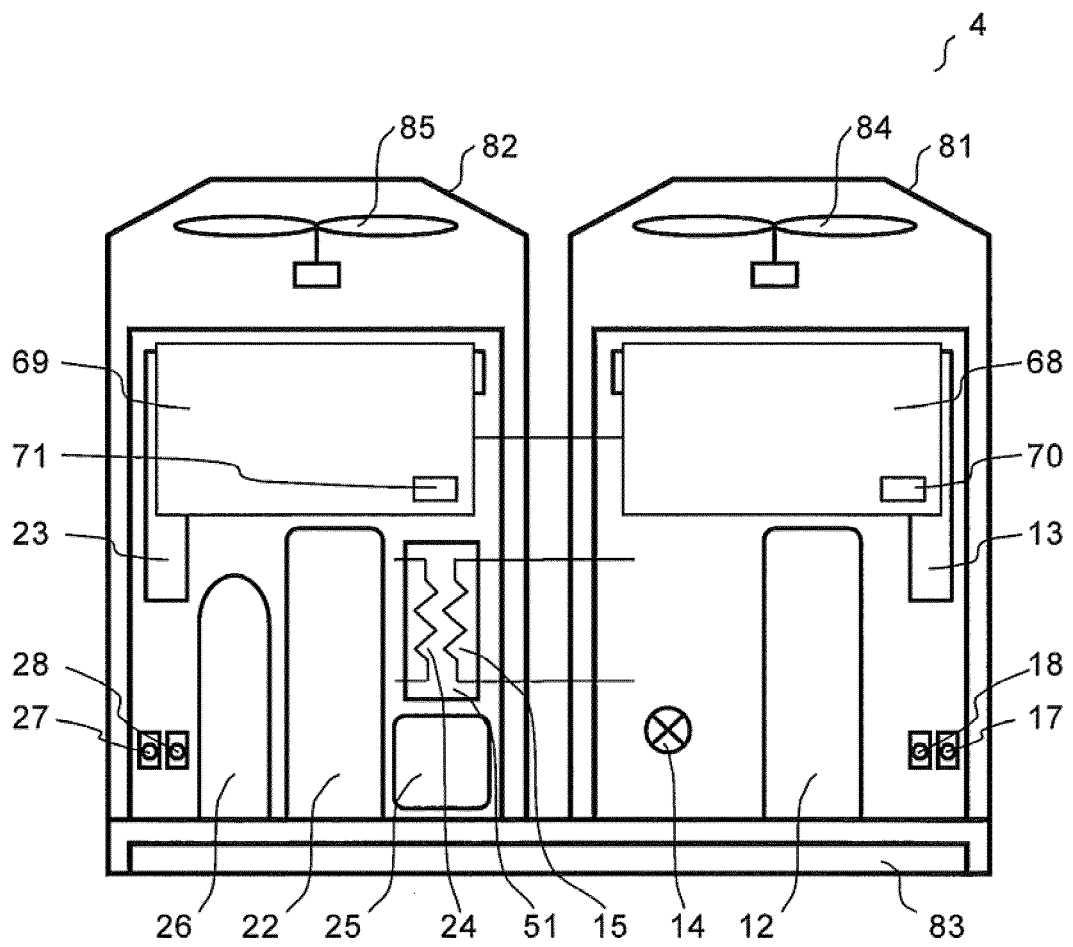


FIG. 11



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/074214

## A. CLASSIFICATION OF SUBJECT MATTER

F25B7/00 (2006.01) i, F25B1/00 (2006.01) i

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B7/00, F25B1/00

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                            | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X<br>Y    | JP 2005-77042 A (Yukinobu IKEMOTO),<br>24 March 2005 (24.03.2005),<br>claims 6, 7, 10; paragraphs [0034], [0035];<br>fig. 3<br>(Family: none) | 1, 2, 8<br>6, 7       |
| X         | JP 2000-35262 A (Daikin Industries, Ltd.),<br>02 February 2000 (02.02.2000),<br>fig. 1 to 3; paragraphs [0049], [0065]<br>(Family: none)      | 1                     |
| Y         | JP 2000-105011 A (Daikin Industries, Ltd.),<br>11 April 2000 (11.04.2000),<br>paragraphs [0065] to [0066]<br>(Family: none)                   | 6, 7                  |

☒ 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

"I" 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  
15 October, 2012 (15.10.12)Date of mailing of the international search report  
23 October, 2012 (23.10.12)Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/074214

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                       | Relevant to claim No. |
|-----------|--------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | JP 2008-175522 A (Mayekawa Mfg., Co., Ltd.),<br>31 July 2008 (31.07.2008),<br>paragraph [0030]; fig. 2<br>(Family: none) | 1-8                   |

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

**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 2012112615 A [0006]