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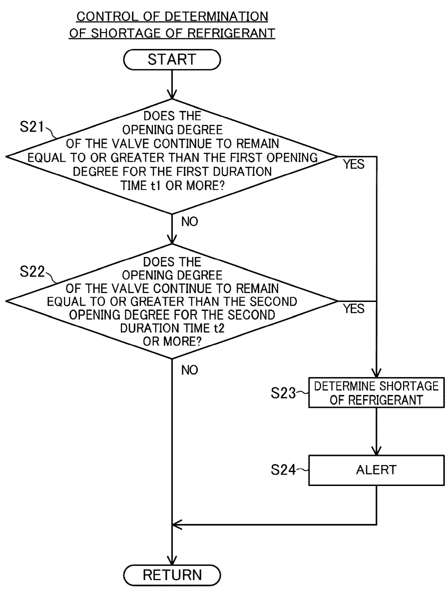
(54) # HEAT SOURCE UNIT AND FREEZING DEVICE

(57) A heat source unit includes a controller (130) configured to control the subcooling-side decompression valve (46) according to a degree of subcooling of a refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28). Under a condition that the opening degree of a subcooling-side decompression valve (46) is equal to or greater than a predetermined opening degree, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

FIG.12



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to a heat source unit and a refrigeration apparatus.

BACKGROUND ART

[0002] The refrigeration apparatus described in Patent Document 1 is provided with a heat source unit including a compression unit, a heat-source-side heat exchanger, and a subcooling heat exchanger. The refrigerant compressed by the compression unit dissipates heat in the heat-source-side heat exchanger and then flows through the first flow path of the subcooling heat exchanger. The subcooling heat exchanger exchanges heat between the refrigerant flowing through the first flow path and the refrigerant decompressed by the subcooling-side decompression valve and then flowing through the second flow path. Accordingly, the refrigerant flowing though the first flow path is cooled, and the degree of subcooling of the refrigerant is increased.

CITATION LIST

PATENT DOCUMENT

[0003] Patent Document 1: Japanese Unexamined Patent Publication No. 2019-184231

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0004] The refrigeration apparatus as described in Patent Document 1 might not be filled with an adequate amount of refrigerant at the time of shipment. Further, the refrigerant circuit might leak a refrigerant. As a result, there is a shortage of a refrigerant in the refrigerant circuit, and the refrigeration apparatus exhibits lower refrigerating capacity.

[0005] An object of the present disclosure is to provide a heat source unit capable of determining whether there is a shortage of a refrigerant in the refrigerant circuit and to provide a refrigeration apparatus.

SOLUTION TO THE PROBLEM

[0006] A first aspect is directed to a heat source unit including: a refrigerant circuit (6) including a compression unit (20), a heat-source-side heat exchanger (24), a subcooling-side decompression valve (46), and a subcooling heat exchanger (28) having a first flow path (28a) and a second flow path (28b), where the first flow path (28a) is a flow path through which a refrigerant having dissipated heat in the heat-source-side heat exchanger (24) flows, and where the second flow path (28b) is a flow path through which a refrigerant passing through the first flow path (28a) and then decompressed by the subcooling-side decompression valve (46) flows; and a controller (130) configured to control the subcooling-side decompression valve (46) according to a degree of subcooling of a refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28). Based on the fact that an opening degree of the subcooling-side decompression valve (46) becomes larger, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0007] A second aspect is an embodiment of the first aspect. In the second aspect, under a condition that the opening degree of a subcooling-side decompression valve (46) is equal to or greater than a predetermined opening degree, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0008] In the second aspect, the controller (130) controls the opening degree of the subcooling-side decompression valve (46) based on the degree of subcooling of the refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28). In other words, the opening degree of the subcooling-side decompression valve (46) is adjusted by what is called the control of the degree of subcooling. Here, if there is a shortage of a refrigerant in the refrigerant circuit (6), an adequate amount of liquid refrigerant cannot be sent to the first flow path (28a) of the subcooling heat exchanger (28). Thus, the degree of subcooling of the refrigerant flowing out of the first flow path (28a) becomes small or zero, and thus the opening degree of the subcooling-side decompression valve (46) becomes large. By using this, the controller (130) of the present disclosure determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). Specifically, under the condition that the opening degree of the subcooling-side decompression valve (46) is equal to or greater than a predetermined opening degree, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0009] Here, if the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6) by using the degree of subcooling itself of the refrigerant flowing out of the first flow path (28a), the controller (130) might determine erroneously whether there is a shortage of a refrigerant when the degree of subcooling temporarily changes for some reason. In contrast, the opening degree of the subcooling-side decompression valve (46) has a characteristic of fluctuating more gradually than the degree of subcooling itself. Thus, it is possible to determine less erroneously whether there is a shortage of a refrigerant in the refrigerant circuit (6) when the degree of subcooling temporarily changes.

[0010] A third aspect is an embodiment of the second aspect. In the third aspect, under a condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a predetermined opening degree for a predetermined duration time or more, the controller (130) determines that there is a shortage of a refrigerant.

[0011] In the third aspect, it is possible to determine less erroneously whether there is a shortage of a refrigerant in the refrigerant circuit (6) when the degree of subcooling of the refrigerant flowing out of the first flow path (28a) temporarily changes for some reason.

[0012] A fourth aspect is an embodiment of the third aspect. In the fourth aspect, under a condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a first opening degree for a first duration time or more, or under a condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a second opening degree for a second duration time or more, the controller (130) determines that there is a shortage of a refrigerant, the second duration time is longer than the first duration time, and the second opening degree is smaller than the first opening degree.

[0013] In the fourth aspect, if the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a relatively large first opening degree for a relatively short first duration time or more, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). Alternatively, if the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a relatively small second opening degree for a relatively long second duration time or more, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0014] A fifth aspect is an embodiment of any one of the first to third aspects. In the fifth aspect, under a condition that the opening degree of the subcooling-side decompression valve (46) is fully opened, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0015] If there is a shortage of a refrigerant in the refrigerant circuit (6) and then the degree of subcooling of the refrigerant flowing out of the first flow path (28a) becomes small or zero, the opening degree of the subcooling-side decompression valve (46) is eventually fully opened. The controller (130) of the fourth aspect determines that there is a shortage of a refrigerant in the refrigerant circuit (6) under the condition that the opening degree of the subcooling-side decompression valve (46) is fully opened, and thus the controller (130) can precisely determine that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0016] A sixth aspect is an embodiment of any one of the first to fifth aspects. In the sixth aspect, the refrigerant circuit (6) is configured to be able to perform a refrigeration cycle in which a high pressure is equal to or greater than a critical pressure.

[0017] In the sixth aspect, the refrigerant circuit (6) performs a refrigeration cycle in which the high pressure is equal to or greater than a critical pressure. In this refrigeration cycle, the degree of subcooling of the refrigerant flowing out of the first flow path (28a) is easily unstable. However, the controller (130) determines whether there is a shortage of a refrigerant by using the opening degree of the subcooling-side decompression valve (46) that fluctuates more gradually than the degree of subcooling, and thus it is possible to determine less erroneously whether there is a shortage of a refrigerant.

[0018] A seventh aspect is an embodiment of any one of the first to sixth aspects. In the seventh aspect, the refrigerant circuit (6) is provided with a gas-liquid separator (25) between the heat-source-side heat exchanger (24) and the first flow path (28a) of the subcooling heat exchanger (28).

[0019] In the seventh aspect, the refrigerant having dissipated heat in the heat-source-side heat exchanger (24) is sent to the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant. The liquid refrigerant separated by the gas-liquid separator (25) flows through the first flow path (28a) of the subcooling heat exchanger (28). In the subcooling heat exchanger (28), the liquid refrigerant in the first flow path (28a) is cooled by the refrigerant in the second flow path (28b), and the degree of subcooling of the liquid refrigerant in the first flow path (28a) increases.

[0020] In the configuration in which the refrigerant circuit (6) is provided with the gas-liquid separator (25), the gas refrigerant separated by the gas-liquid separator (25) might temporarily flow through the first flow path (28a). If the gas refrigerant flows temporarily into the first flow path (28a), the degree of subcooling decreases sharply, and it might be possible to determine erroneously whether there is a shortage of a refrigerant. However, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6) by using the opening degree of the subcooling-side decompression valve (46) that changes more gradually than the degree of subcooling. Thus, it is possible to reduce erroneous determination as to whether there is a shortage of a refrigerant due to the fact that the gas refrigerant separated by the gas-liquid separator (25) temporarily flows through the first flow path (28a).

[0021] An eighth aspect is directed to a refrigeration apparatus including: the heat source unit (10) of any one of the first to eighth aspects; and a utilization unit (60,70).

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG. 1 is a piping system diagram of a refrigeration apparatus according to an embodiment.

FIG. 2 is a block diagram showing the connections between controllers and devices around the controllers.

FIG. 3 is a diagram of a flow path switching mechanism.

FIG. 4 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the refrigeration-facility operation.

FIG. 5 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the cooling operation (the defrosting operation).

FIG. 6 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the cooling and refrigeration-facility operation (the defrosting operation).

FIG. 7 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the heating operation.

FIG. 8 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the first heating and refrigeration-facility operation.

FIG. 9 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the second heating and refrigeration-facility operation.

FIG. 10 is a piping system diagram of the refrigeration apparatus and shows the flow of a refrigerant in the third heating and refrigeration-facility operation.

FIG. 11 is a flowchart of the control of the degree of subcooling of an injection valve.

FIG. 12 is a flowchart of the control for determining shortage of refrigerant.

DESCRIPTION OF EMBODIMENTS

[0023] Embodiments of the present disclosure will be described in detail below with reference to the drawings. The present disclosure is not limited to the embodiments shown below, and various changes can be made within the scope without departing from the technical concept of the present disclosure. Since each of the drawings is intended to illustrate the present disclosure conceptually, dimensions, ratios, or numbers may be exaggerated or simplified as necessary for the sake of ease of understanding.

<<Embodiments>>

[0024] A refrigeration apparatus (1) according to an embodiment performs cooling of an object to be cooled and air-conditioning of an indoor space in parallel. The object to be cooled herein includes air in facilities such as a refrigerator, a freezer, and a show case. Hereinafter, such facilities are each referred to as a refrigeration facility.

(1) General Configuration

[0025] As illustrated in FIG. 1, the refrigeration apparatus (1) includes a heat source unit (10) placed outside, an air-conditioning unit (60) configured to perform air-conditioning of an indoor space, and a refrigeration-facility unit (70) configured to cool inside air. FIG. 1 shows a single air-conditioning unit (60). The refrigeration apparatus (1) may include two or more air-conditioning units (60) connected to each other in parallel. FIG. 1 shows a single refrigeration-facility unit (70). The refrigeration apparatus (1) may include two or more refrigeration-facility units (70) connected to each other in parallel.

[0026] The refrigeration apparatus (1) includes four connection pipes (2, 3, 4, 5) for connecting the heat source unit (10), the air-conditioning unit (60), and the refrigeration-facility unit (70). In the refrigeration apparatus (1), the heat source unit (10), the air-conditioning unit (60), and the refrigeration-facility unit (70) are connected by the connection pipes (2, 3, 4, 5), thereby forming a refrigerant circuit (6).

[0027] The refrigerant circuit (6) is filled with a refrigerant. The refrigerant circuit (6) circulates the refrigerant to perform a refrigeration cycle. The refrigerant of this embodiment is carbon dioxide. The refrigerant circuit (6) performs the refrigeration cycle so that the refrigerant has a pressure equal to or greater than a critical pressure. The refrigerant may be a natural refrigerant other than carbon dioxide.

(1-1) Connection Pipes

[0028] The four connection pipes (2, 3, 4, 5) include a first liquid connection pipe (2), a first gas connection pipe (3), a second liquid connection pipe (4), and a second gas connection pipe (5). The first liquid connection pipe (2) and the first gas connection pipe (3) correspond to the air-conditioning unit (60). The second liquid connection pipe (4) and the second gas connection pipe (5) correspond to the refrigeration-facility unit (70).

(2) Heat-Source Unit

[0029] The heat source unit (10) includes a heat source circuit (11) and an outdoor fan (12). The heat source circuit (11) includes a compression unit (20), an outdoor heat exchanger (24), and a gas-liquid separator (25). The heat source circuit (11) includes a first outdoor expansion valve (26) and a second outdoor expansion valve (27). The heat source circuit (11) also includes a subcooling heat exchanger (28) and an intercooler (29).

[0030] The heat source circuit (11) includes four shut-off valves (13, 14, 15, 16). The four shut-off valves include a first gas shut-off valve (13), a first liquid shut-off valve (14), a second gas shut-off valve (15), and a second liquid shut-off valve (16).

[0031] The first gas shut-off valve (13) is connected with the first gas connection pipe (3). The first liquid shut-off valve (14) is connected with the first liquid connection pipe (2). The second gas shut-off valve (15) is connected with the second gas connection pipe (5). The second liquid shut-off valve (16) is connected with the second liquid connection pipe (4).

[0032] The heat source unit (10) includes a flow path switching mechanism (30). In the piping system diagram of the refrigerant circuit in e.g., FIG. 1, the detailed illustration of the flow path switching mechanism (30) is omitted. The flow path switching mechanism (30) switches the flow path of a refrigerant in the refrigerant circuit (6). The flow path switching mechanism (30) will be described in detail later.

(2-1) Compression Unit

[0033] The compression unit (20) compresses a refrigerant. The compression unit (20) includes a first compressor (21), a second compressor (22), and a third compressor (23). The compression unit (20) performs an operation for compressing a refrigerant in a single stage and an operation for compressing a refrigerant in two stages.

[0034] The first compressor (21) is a refrigeration-facility compressor corresponding to the refrigeration-facility unit (70). The first compressor (21) is an example of a first compression element. The second compressor (22) is an air-conditioning compressor corresponding to the air-conditioning unit (60). The second compressor (22) is an example of a second compression element. The first compressor (21) and the second compressor (22) are lower-stage compressors. The first compressor (21) and the second compressor (22) are connected in parallel.

[0035] The third compressor (23) is a higher-stage compressor. The third compressor (23) is connected in series to the first compressor (21). The third compressor (23) is connected in series to the second compressor (22).

[0036] The first compressor (21), the second compressor (22), and the third compressor (23) are rotary-type compressors, each of which includes a compression mechanism driven by a motor. The first compressor (21), the second compressor (22), and the third compressor (23) are variable-capacity-type compressors. The number of rotations of the motors of the first compressor (21), the second compressor (22), and the third compressor (23) is adjusted by an inverter device. In other words, the operating capacities of the first compressor (21), the second compressor (22), and the third compressor (23) are adjustable.

[0037] The first compressor (21) is connected with a first suction pipe (21a) and a first discharge pipe (21b). The second compressor (22) is connected with a second suction pipe (22a) and a second discharge pipe (22b). The third compressor (23) is connected with a third suction pipe (23a) and a third discharge pipe (23b).

(2-2) Intermediate Flow Path

[0038] The heat source circuit (11) includes an intermediate flow path (18). The intermediate flow path (18) connects the discharge portions of the first compressor (21) and the second compressor (22) with the suction portion of the third compressor (23). The intermediate flow path (18) includes a first discharge pipe (21b), a second discharge pipe (22b), and a third suction pipe (23a).

(2-3) Outdoor Heat Exchanger and Outdoor Fan

[0039] The outdoor heat exchanger (24) is an example of a heat-source-side heat exchanger. The outdoor heat exchanger (24) is a fin-and-tube air heat exchanger. The outdoor fan (12) is disposed near the outdoor heat exchanger (24). The outdoor fan (12) transfers outdoor air. The outdoor heat exchanger exchanges heat between a refrigerant flowing therethrough and outdoor air transferred from the outdoor fan (12).

(2-4) Liquid-Side Flow Path

[0040] The heat source circuit (11) includes a liquid-side flow path (40). The liquid-side flow path (40) is provided between the liquid-side end of the outdoor heat exchanger (24) and the two liquid shut-off valves (14, 16). The liquid-side flow path (40) includes first to fifth pipes (40a, 40b, 40c, 40d, 40e).

[0041] One end of the first pipe (40a) is connected to the liquid-side end of the outdoor heat exchanger (24). The other end of the first pipe (40a) is connected to the top of the gas-liquid separator (25). One end of the second pipe (40b) is connected to the bottom of the gas-liquid separator (25). The other end of the second pipe (40b) is connected to the second liquid shut-off valve (16). One end of the third pipe (40c) is connected to an intermediate portion of the second pipe (40b). The other end of the third pipe (40c) is connected to the first liquid shut-off valve (14). One end of the fourth pipe (40d) is connected to the first pipe (40a) between the first outdoor expansion valve (26) and the gas-liquid separator (25). The other end of the fourth pipe (40d) is connected to an intermediate portion of the third pipe (40c). One end of the fifth pipe (40e) is connected to the first pipe (40a) between the outdoor heat exchanger (24) and the first outdoor expansion valve (26). The other end of the fifth pipe (40e) is connected to the second pipe (40b) between the gas-liquid separator (25) and the junction between the second pipe (40b) and the third pipe (40c).

(2-5) Outdoor Expansion Valve

[0042] The first outdoor expansion valve (26) is provided in the first pipe (40a). The first outdoor expansion valve (26) is provided in the first pipe (40a) between the liquid-side end of the outdoor heat exchanger (24) and the junction between the first pipe (40a) and the fourth pipe (40d). The second outdoor expansion valve (27) is provided in the fifth pipe (40e). The first outdoor expansion valve (26) and the second outdoor expansion valve (27) are expansion valves of which the opening degrees are adjustable. The first outdoor expansion valve (26) and the second outdoor expansion valve (27) are electronic expansion valves of which the opening degrees are adjusted based on pulse signals.

(2-6) Gas-Liquid Separator

[0043] The gas-liquid separator (25) is a hermetically closed container that stores a refrigerant. The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant. A gas layer and a liquid layer are formed inside the gas-liquid separator (25). The gas layer is formed near the top of the gas-liquid separator (25). The liquid layer is formed near the bottom of the gas-liquid separator (25).

(2-7) Venting Pipe

[0044] The heat source circuit (11) includes a venting pipe (41). One end of the venting pipe (41) is connected to the top of the gas-liquid separator (25). The other end of the venting pipe (41) is connected to the intermediate flow path (18). The venting pipe (41) sends the gas refrigerant in the gas-liquid separator (25) to the intermediate flow path (18).

[0045] The venting pipe (41) is provided with a venting valve (42). The venting valve (42) is an expansion valve of which the opening degree is adjustable. The venting valve (42) is an electronic expansion valve of which the opening degree is adjusted based on pulse signals.

(2-8) Subcooling Heat Exchanger

[0046] The subcooling heat exchanger (28) includes a first flow path (28a) as a high-pressure flow path and a second flow path (28b) as a low-pressure flow path. The subcooling heat exchanger (28) exchanges heat between the refrigerant in the first flow path (28a) and the refrigerant in the second flow path (28b). In other words, the subcooling heat exchanger (28) cools the refrigerant flowing in the first flow path (28a) by the refrigerant flowing in the second flow path (28b).

[0047] The second flow path (28b) is a part of the injection flow path (43). The injection flow path (43) includes an upstream flow path (44) and a downstream flow path (45).

[0048] One end of the upstream flow path (44) is connected to a portion of the third pipe (40c) upstream of the junction with the fourth pipe (40d). The other end of the upstream flow path (44) is connected to the inflow end of the second flow path (28b). The upstream flow path (44) is provided with an injection valve (46) as a subcooling-side decompression valve. The injection valve (46) is an expansion valve of which the opening degree is adjustable. The injection valve (46) is an electronic expansion valve of which the opening degree is adjusted based on pulse signals.

[0049] One end of the downstream flow path (45) is connected to the outflow end of the second flow path (28b). The other end of the downstream flow path (45) is connected to the intermediate flow path (18).

(2-9) Intercooler

[0050] The intercooler (29) is provided in the intermediate flow path (18). The intercooler (29) is a fin-and-tube air heat exchanger. A cooling fan (29a) is disposed near the intercooler (29). The intercooler (29) exchanges heat between the refrigerant flowing therethrough and the outdoor air transferred from the cooling fan (29a).

(2-10) Oil Separation Circuit

[0051] The heat source circuit (11) includes an oil separation circuit. The oil separation circuit includes an oil separator (50), a first oil return pipe (51), and a second oil return pipe (52).

[0052] The oil separator (50) is connected to the third discharge pipe (23b). The oil separator (50) separates oil from the refrigerant discharged from the compression unit (20). Inflow ends of the first oil return pipe (51) and the second oil return pipe (52) communicate with the oil separator (50). An outflow end of the first oil return pipe (51) is connected to the intermediate flow path (18). The first oil return pipe (51) is provided with a first oil level control valve (53).

[0053] An outflow portion of the second oil return pipe (52) branches into a first branch pipe (52a) and a second branch pipe (52b). The first branch pipe (52a) is connected to an oil reservoir of the first compressor (21). The second branch pipe (52b) is connected to an oil reservoir of the second compressor (22). The first branch pipe (52a) is provided with a second oil level control valve (54). The second branch pipe (52b) is provided with a third oil level control valve (55).

(2-11) Bypass Pipes

[0054] The heat source circuit (11) includes a first bypass pipe (56), a second bypass pipe (57), and a third bypass pipe (58). The first bypass pipe (56) is associated with the first compressor (21). The second bypass pipe (57) is associated with the second compressor (22). The third bypass pipe (58) is associated with the third compressor (23).

[0055] Specifically, the first bypass pipe (56) directly connects the first suction pipe (21a) and the first discharge pipe (21b) together. The second bypass pipe (57) directly connects the second suction pipe (22a) and the second discharge pipe (22b) together. The third bypass pipe (58) directly connects the third suction pipe (23a) and the third discharge pipe (23b) together.

(2-12) Check Valve

[0056] The heat source circuit (11) includes a plurality of check valves. The plurality of check valves includes first to twelfth check valves (CV1 to CV12). The check valves (CV1 to CV12) allow the flow of a refrigerant in the direction of the arrow in FIG. 1 and disallow the flow of a refrigerant in the reverse direction.

[0057] The first check valve (CV1) and the second check valve (CV2) are provided in a flow path switching mechanism (30) described in detail later.

[0058] The third check valve (CV3) is provided in the third discharge pipe (23b). The fourth check valve (CV4) is provided in the first pipe (40a). The fifth check valve (CV5) is provided in the third pipe (40c). The sixth check valve (CV6) is provided in the fourth pipe (40d). The seventh check valve (CV7) is provided in the fifth pipe (40e). The eighth check valve (CV8) is provided in the first bypass pipe (56). The ninth check valve (CV9) is provided in the second bypass pipe (57). The tenth check valve (CV10) is provided in the third bypass pipe (58). The eleventh check valve (CV11) is provided in the first discharge pipe (21b). The twelfth check valve (CV12) is provided in the second discharge pipe (22b).

(3) Air-Conditioning Unit

[0059] The air-conditioning unit (60) is a first utilization unit installed indoors. The air-conditioning unit (60) includes an indoor circuit (61) and an indoor fan (62). The liquid-side end of the indoor circuit (61) is connected with the first liquid connection pipe (2). The gas-side end of the indoor circuit (61) is connected with the first gas connection pipe (3).

[0060] The indoor circuit (61) includes an indoor expansion valve (63) and an indoor heat exchanger (64) in the sequence from the liquid-side end to the gas-side end. The indoor expansion valve (63) is an expansion valve of which the opening degree is adjustable. The indoor expansion valve (63) is an electronic expansion valve of which the opening degree is adjusted based on pulse signals.

[0061] The indoor heat exchanger (64) is a fin-and-tube air heat exchanger. The indoor heat exchanger (64) is an example of a first utilization-side heat exchanger. The indoor fan (62) is disposed near the indoor heat exchanger (64). The indoor fan (62) transfers indoor air. The indoor heat exchanger (64) exchanges heat between the refrigerant flowing therethrough and the indoor air transferred by the indoor fan (62).

(4) Refrigeration-Facility Unit

[0062] The refrigeration-facility unit (70) is a second utilization unit that cools its internal space. The refrigeration-facility unit (70) includes a refrigeration-facility circuit (71) and a refrigeration-facility fan (72). The liquid-side end of the refrigeration-facility circuit (71) is connected with the second liquid connection pipe (4). The gas-side end of the refrigeration-facility circuit (71) is connected with the second gas connection pipe (5).

[0063] The refrigeration-facility circuit (71) includes a refrigeration-facility expansion valve (73) and a refrigeration-facility heat exchanger (74) in the sequence from the liquid-side end to the liquid-side end. The refrigeration-facility expansion valve (73) is an expansion valve of which the opening degree is adjustable. The refrigeration-facility expansion valve (73) is an electronic expansion valve of which the opening degree is adjusted based on pulse signals.

[0064] The refrigeration-facility heat exchanger (74) is a fin-and-tube air heat exchanger. The refrigeration-facility heat exchanger (74) is an example of a second utilization-side heat exchanger. The refrigeration-facility fan (72) is disposed near the refrigeration-facility heat exchanger (74). The refrigeration-facility fan (72) transfers inside air. The refrigeration-facility heat exchanger (74) exchanges heat between the refrigerant flowing therethrough and the inside air transferred by the refrigeration-facility fan (72).

[0065] The evaporation temperature of the refrigeration-facility heat exchanger (74) is lower than the evaporation temperature of the indoor heat exchanger (64).

(5) Flow Path Switching Mechanism

[0066] The flow path switching mechanism (30) is provided in the heat source circuit (11). As illustrated in FIGS. 1 and 3, the flow path switching mechanism (30) includes a first port (P1), a second port (P2), a third port (P3), a fourth port (P4), a first switching flow path (31), a second switching flow path (32), a third switching flow path (33), and a fourth switching flow path (34). The first switching flow path (31) is provided with a first opening/closing mechanism (81); the second switching flow path (32) is provided with a second opening/closing mechanism (82); the third switching flow path (33) is provided with a third opening/closing mechanism (83); and the fourth switching flow path (34) is provided with a fourth opening/closing mechanism (84).

(5-1) Port

[0067] The first port (P1) is connected with the discharge portion of the first compressor (21) and the discharge portion of the second compressor (22). The discharge portion of the first compressor (21) is connected with the first port (P1) via a first discharge line (L1). The first discharge line (L1) is a flow path, one end of which is connected with the discharge portion of the first compressor (21) and the other end of which is connected with the first port (P1). In other words, the first discharge line (L1) is a flow path extending from the discharge portion of the first compressor (21) to the first port (P1).

[0068] The discharge portion of the second compressor (22) is connected with the first port (P1) via a second discharge line (L2). The second discharge line (L2) is a flow path, one end of which is connected with the discharge portion of the second compressor (22) and the other end of which is connected with the first port (P1). In other words, the second discharge line (L2) is a flow path extending from the discharge portion of the second compressor (22) to the first port (P1).

[0069] The second port (P2) is connected with the suction portion of the second compressor (22). The second port (P2) is not connected with the suction portion of the first compressor (21). The second port (P2) is connected with the suction portion of the second compressor (22) via a suction line (L3). The suction line (L3) is a flow path, one end of which is connected with the suction portion of the second compressor (22) and the other end of which is connected with the second port (P2). In other words, the suction line (L3) is a flow path extending from the suction portion of the second compressor (22) to the second port (P2).

[0070] The third port (P3) is connected with the gas end portion of the indoor heat exchanger (64). The third port (P3) is connected with the gas end portion of the indoor heat exchanger (64) via a first gas line (L4). The first gas line (L4) is a flow path, one end of which is connected with the indoor heat exchanger (64) and the other end of which is connected with the third port (P3). In other words, the first gas line (L4) is a flow path extending from the gas end portion of the indoor heat exchanger (64) to the third port (P3).

[0071] The fourth port (P4) is connected with the gas end portion of the outdoor heat exchanger (24). The fourth port (P4) is connected with the gas end portion of the outdoor heat exchanger (24) via a second gas line (L5). The second gas line (L5) is a flow path, one end of which is connected with the gas end portion of the outdoor heat exchanger (24) and the other end of which is connected with the fourth port (P4). The second gas line (L5) is a flow path extending from the gas end portion of the outdoor heat exchanger (24) to the fourth port (P4).

[0072] The first discharge line (L1), the second discharge line (L2), the suction line (L3), the first gas line (L4), and the second gas line (L5) refer to the flow paths including pipes and elements connected to the pipes.

(5-2) Flow Path

[0073] As schematically shown in FIG. 1, the first switching flow path (31), the second switching flow path (32), the third switching flow path (33), and the fourth switching flow path (34) are connected in a bridge shape. The first switching flow path (31) connects the first port (P1) and the third port (P3). The second switching flow path (32) connects the first port (P1) and the fourth port (P4). The third switching flow path (33) connects the second port (P2) and the third port (P3). The fourth switching flow path (34) connects the second port (P2) and the fourth port (P4). The first switching flow path (31) and the second switching flow path (32) are high-pressure flow paths on which high pressure acts. In other words, the first switching flow path (31) and the second switching flow path (32) are discharge flow paths on which the discharge pressure of the compression unit (20) acts. The third switching flow path (33) and the fourth switching flow path (34) are low-pressure flow paths on which low pressure acts. The third switching flow path (33) and the fourth switching flow path (34) are suction flow paths on which the suction pressure of the compression unit (20) acts.

[0074] As illustrated in FIG. 3, the first switching flow path (31) includes two or more first branch flow paths (31a) provided in parallel with each other. The first switching flow path (31) of this example includes seven first branch flow paths (31a). The second switching flow path (32) of this example includes two or more second branch flow paths (32a) provided in parallel with each other. The second switching flow path (32) includes seven second branch flow paths (32a). The third switching flow path (33) includes third branch flow paths (33a) provided in parallel with each other. The third switching flow path (33) of this example includes four third branch flow paths (33a). The fourth switching flow path (34) consists of a single flow path.

(5-3) Opening/Closing Mechanism

[0075] The first opening/closing mechanism (81) includes a plurality of first on-off valves (V1). The first switching flow path (31) is provided with two or more first on-off valves (V1) provided in parallel. The first switching flow path (31) of this example is provided with seven first on-off valves (V1). Each first branch flow path (31a) is provided with one first on-off valve (V1). The plurality of first on-off valves (V1) include a first expansion valve (91) and a first electromagnetic on-off valve (92). The number of the first expansion valves (91) is one, and the number of the first electromagnetic on-off valves (92) is six. The first expansion valve (91) is an electronic expansion valve of which the opening degree is variable.

[0076] The second opening/closing mechanism (82) includes a plurality of second on-off valves (V2). The second switching flow path (32) is provided with two or more second on-off valves (V2) provided in parallel. The second switching flow path (32) of this example is provided with seven second on-off valves (V2). Each second branch flow path (32a) is provided with one second on-off valve (V2). The plurality of second on-off valves (V2) include a second expansion valve (93) and a second electromagnetic on-off valve (94). The number of the second expansion valves (93) is one, and the number of the second electromagnetic on-off valves (94) is six. The second expansion valve (93) is an electronic expansion valve of which the opening degree is variable.

[0077] The third opening/closing mechanism (83) includes a plurality of third on-off valves (V3). The third switching flow path (33) is provided with two or more third on-off valves (V3) provided in parallel. The third switching flow path (33) of this example is provided with four third on-off valves (V3). Each third branch flow path (33a) is provided with one third on-off valve (V3). The third on-off valves (V3) are electromagnetic on-off valves.

[0078] The fourth opening/closing mechanism (84) includes one fourth on-off valve (V4). The fourth switching flow path (34) is provided with the fourth on-off valve (V4). The fourth on-off valve (V4) is an electromagnetic on-off valve.

[0079] The first on-off valve (V1), the second on-off valve (V2), the third on-off valve (V3), and the fourth on-off valve (V4) may be simply referred to as the on-off valve (V) as shown in FIG. 2.

(5-5) Check Valve

[0080] The flow path switching mechanism (30) includes check valves (CV1, CV2). Specifically, the fourth switching flow path (34) is provided with the first check valve (CV1). The first switching flow path (31) is provided with the second check valve (CV2).

[0081] The first check valve (CV1) in the fourth switching flow path (34) restricts the flow of a refrigerant from the second port (P2) to the fourth port (P4). More precisely, the first check valve (CV1) in the fourth switching flow path (34) allows the flow of a refrigerant from the fourth port (P4) to the second port (P2) and disallows the flow of a refrigerant from the second port (P2) to the fourth port (P4). The first check valve (CV1) in the fourth switching flow path (34) is provided closer to the second port (P2) than the on-off valve (V) is.

[0082] The second check valve (CV2) in the first switching flow path (31) restricts the flow of a refrigerant from the third port (P3) to the first port (P1). More precisely, the second check valve (CV2) in the first switching flow path (31) allows the flow of a refrigerant from the first port (P1) to the third port (P3) and disallows the flow of a refrigerant from the third port (P3) to the first port (P1). The second check valve (CV2) is provided in the main flow path (31b) of the first switching flow path (31). The main flow path (31b) is a flow path connected with the ends of the plurality of first branch flow paths (31a). The second check valve (CV2) in the first switching flow path (31) is provided closer to the third port (P3) than the on-off valve (V) is.

(6) Sensor

[0083] As illustrated in FIG. 1, the refrigeration apparatus (1) includes a plurality of sensors. The plurality of sensors include a refrigerant pressure sensor that detects the pressure of a refrigerant; a refrigerant temperature sensor that detects the temperature of a refrigerant; and an air temperature sensor that detects the temperature of air.

[0084] The refrigerant pressure sensors include a high pressure sensor (101), an intermediate pressure sensor (102), a first suction pressure sensor (103), a second suction pressure sensor (104), and a liquid-side pressure sensor (105). The high pressure sensor (101) is provided in the third discharge pipe (23b). The high pressure sensor (101) detects the pressure of a refrigerant on the discharge side of the compression unit (20), in other words, detects the high pressure of the refrigerant circuit (6). The intermediate pressure sensor (102) is provided in the third suction pipe (23a). The intermediate pressure sensor (102) detects the pressure of a refrigerant between the lower-stage compressor and the higher-stage compressor, in other words, detects the intermediate pressure of the refrigerant circuit (6). The first suction pressure sensor (103) is provided in the first suction pipe (21a). The first suction pressure sensor (103) detects the pressure of a refrigerant on the suction side of the first compressor (21). The second suction pressure sensor (104) is provided in the second suction pipe (22a). The second suction pressure sensor (104) detects the pressure of a refrigerant on the suction side of the second compressor (22).

[0085] The liquid-side pressure sensor (105) is provided in the liquid-side flow path (40). Specifically, the liquid-side pressure sensor (105) is provided in the second pipe (40b). The liquid-side pressure sensor (105) detects the pressure corresponding to the internal pressure of the gas-liquid separator (25). The liquid-side pressure sensor (105) detects the pressure corresponding to the pressure of the refrigerant in the first flow path (28a).

[0086] The refrigerant temperature sensor includes a first discharge temperature sensor (111), a first suction temperature sensor (112), a second discharge temperature sensor (113), a second suction temperature sensor (114), a third discharge temperature sensor (115), a third suction temperature sensor (116), a liquid-side temperature sensor (117), an injection-side temperature sensor (118), and a heat-source-side temperature sensor (119). The first discharge temperature sensor (111) is provided in the first discharge pipe (21b) and detects the temperature of the refrigerant discharged from the first compressor (21). The first suction temperature sensor (112) is provided in the first suction pipe (21a) and detects the temperature of the refrigerant sucked into the first compressor (21). The second discharge temperature sensor (113) is provided in the second discharge pipe (22b) and detects the temperature of the refrigerant discharged from the second compressor (22). The second suction temperature sensor (114) is provided in the second suction pipe (22a) and detects the temperature of the refrigerant sucked into the second compressor (22). The third discharge temperature sensor (115) is provided in the third discharge pipe (23b) and detects the temperature of the refrigerant discharged from the third compressor (23). The third suction temperature sensor (116) is provided in the third suction pipe (23a) and detects the temperature of the refrigerant sucked into the third compressor (23).

[0087] The liquid-side temperature sensor (117) is provided in the liquid-side flow path (40). Specifically, the liquid-side temperature sensor (117) is provided on the outflow side of the first flow path (28a) of the subcooling heat exchanger (28) in the liquid-side flow path (40). More specifically, the liquid-side temperature sensor (117) is provided in the liquid-side flow path (40) between the outflow end of the first flow path (28a) and the inflow end of the injection flow path (43). The liquid-side temperature sensor (117) detects the temperature of the refrigerant flowing out of the first flow path (28a).

[0088] The injection-side temperature sensor (118) is provided in the downstream flow path (45) of the injection flow path (43). In other words, the injection-side temperature sensor (118) is provided on the outflow side of the second flow path (28b) of the subcooling heat exchanger (28). The injection-side temperature sensor (118) detects the temperature of the refrigerant flowing out of the second flow path (28b).

[0089] The heat-source-side temperature sensor (119) is provided in the heat transfer tube of the outdoor heat exchanger (24). The heat-source-side temperature sensor (119) is provided at the liquid-side end of the outdoor heat exchanger (24). The heat-source-side temperature sensor (119) detects the temperature of the refrigerant at the liquid-side end of the outdoor heat exchanger (24).

[0090] The air temperature sensor includes an outdoor air temperature sensor (121). The outdoor air temperature sensor (121) detects the temperature of outdoor air.

(7) Controller

[0091] As illustrated in FIG. 2, the refrigeration apparatus (1) includes a controller (130) configured to control the refrigerant circuit (6). The controller (130) includes a microcomputer mounted on a control board and a memory device (specifically, a semiconductor memory) storing software for operating the microcomputer.

[0092] As illustrated in FIG. 2, the controller (130) includes an outdoor controller (131), an indoor controller (132), and a refrigeration-facility controller (133). As illustrated in FIG. 1, the outdoor controller (131) is provided in the heat source unit (10). The indoor controller (132) is provided in the air-conditioning unit (60). The refrigeration-facility controller (133) is provided in the refrigeration-facility unit (70). The outdoor controller (131) is capable of communicating with the indoor controller (132) and the refrigeration-facility controller (133).

[0093] The controller (130) receives control commands and detection signals from the sensors. The controller (130) controls each device of the refrigeration apparatus (1). Specifically, the controller (130) controls ON/OFF of the first compressor (21), the second compressor (22), and the third compressor (23). The controller (130) regulates the capacities of the first compressor (21), the second compressor (22), and the third compressor (23) (more precisely, the number of revolutions of the motor). The controller (130) controls ON/OFF of each fan (12, 62, 72). The controller (130) adjusts the opening degree of each expansion valve (26, 27, 63). The controller (130) switches the on/off state of each valve (42, 43). The controller (130) switches the on/off state of each on-off valve (V) and adjusts the opening degree of each on-off valve (V).

[0094] The controller (130) determines the degree of subcooling (sc) of the refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28). The controller (130) determines the degree of subcooling (sc) based on the values detected by the liquid-side pressure sensor (105) and the liquid-side temperature sensor (117). Specifically, the controller (130) determines the difference between the saturated temperature corresponding to the pressure detected by the liquid-side pressure sensor (105) and the temperature detected by the liquid-side temperature sensor (117) as the degree of subcooling (sc). The liquid-side pressure sensor (105) and the liquid-side temperature sensor (117) constitute a degree-of-subcooling determination unit for determining the degree of subcooling (sc).

[0095] The controller (130) controls the opening degree of the injection valve (46) according to the degree of subcooling (sc). The controller (130) controls the opening degree of the injection valve (46) so that the current degree of subcooling (sc) becomes the target degree of subcooling (Tsc). The control of the degree of subcooling will be described in detail later.

[0096] When controlling the degree of subcooling, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). Here, the shortage of a refrigerant in the refrigerant circuit (6) means that the amount of a refrigerant in the refrigerant circuit (6) is smaller than a predetermined amount. If there is a shortage of a refrigerant in the refrigerant circuit (6), a desired refrigeration cycle fails to be executed, and the refrigeration apparatus (1) exhibits lower refrigerating capacity.

[0097] Based on the opening degree of the injection valve (46), the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). Under the condition that the opening degree of the injection valve (46) is equal to or greater than a predetermined value, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6). The detail of this determination will be described later.

[0098] The controller (130) includes an alerting unit (134) that alerts that there is a shortage of a refrigerant in the refrigerant circuit (6). As illustrated in FIG. 2, the alerting unit (134) is provided in the outdoor controller (130), for example. If the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6), the alerting unit (134) alerts a target entity that there is a shortage of a refrigerant in the refrigerant circuit (6). The target entity includes users, service providers, maintenance providers, manufacturers, and the like. The alerting unit (134) may be a display unit like a monitor on which characters, symbols, icons, and the like, appear to alert that there is a shortage of a refrigerant. The alerting unit (134) may be a light emitting unit like an LED which emits light or the like to alert that there is a shortage of a refrigerant. The alerting unit (134) may be a notifying unit which sends e-mail or the like to notify the target entity that there is a shortage of a refrigerant.

(8) Operation

[0099] The operation of the refrigeration apparatus (1) will be described. The operation of the refrigeration apparatus (1) includes a refrigeration-facility operation, a cooling operation, a cooling and refrigeration-facility operation, a heating operation, a heating and refrigeration-facility operation, and a defrosting operation. The heating and refrigeration-facility operation includes a first heating and refrigeration-facility operation, a second heating and refrigeration-facility operation, and a third heating and refrigeration-facility operation.

[0100] In the refrigeration-facility operation, the refrigeration-facility unit (70) cools inside air, and the air-conditioning unit (60) is stopped. In the cooling operation, the refrigeration-facility unit (70) is stopped, and the air-conditioning unit (60) performs cooling of the indoor space. In the cooling and refrigeration-facility operation, the refrigeration-facility unit (70) cools inside air, and the air-conditioning unit (60) performs cooling of the indoor space. In the heating operation, the refrigeration-facility unit (70) is stopped, and the air-conditioning unit (60) performs heating of the indoor space. In the heating and refrigeration-facility operation, the refrigeration-facility unit (70) cools inside air, and the air-conditioning unit (60) performs heating of the indoor space. In the defrosting operation, the frost on the outdoor heat exchanger (24) is melted.

[0101] The first heating and refrigeration-facility operation is an operation in which the heat taken by the refrigerant in the outdoor heat exchanger (24) and the refrigeration-facility heat exchanger (74) is used for heating. The second heating and refrigeration-facility operation is an operation in which the outdoor heat exchanger (24) is deactivated and the heat taken by the refrigerant in the refrigeration-facility heat exchanger (74) is used for heating. The third heating and refrigeration-facility operation is an operation in which the heat of the refrigerant is released from the outdoor heat exchanger (24).

[0102] The outline of each operation will be described with reference to FIGS. 4 to 10. In the drawings, the flows of refrigerants are indicated by the broken arrows, and the flow paths through which the refrigerants flow are indicated by the thick lines. In the drawings, the heat exchanger functioning as a radiator is hatched, and the heat exchanger functioning as an evaporator is dotted.

(8-1) Refrigeration-Facility Operation

[0103] In the refrigeration-facility operation shown in FIG. 4, the controller (130) closes the first on-off valve (V1), the third on-off valve (V3), and the fourth on-off valve (V4), and opens the second on-off valve (V2). The controller (130) stops the second compressor (22), and operates the first compressor (21) and the third compressor (23). The controller (130) opens the first outdoor expansion valve (26) and the injection valve (46) at a predetermined opening degree, and closes the second outdoor expansion valve (27). The controller (130) closes the indoor expansion valve (63), and adjusts the opening degree of the refrigeration-facility expansion valve (73). The controller (130) operates the outdoor fan (12) and the refrigeration-facility fan (72), and stops the indoor fan (62).

[0104] In the refrigeration-facility operation, the refrigeration cycle is performed in which the outdoor heat exchanger (24) functions as a radiator, the function of the indoor heat exchanger (64) is substantially deactivated, and the refrigeration-facility heat exchanger (74) functions as an evaporator.

[0105] Specifically, the refrigerant compressed by the first compressor (21) is cooled in the intercooler (29), and then is sucked into the third compressor (23). The refrigerant compressed to a pressure equal to or greater than the critical pressure by the third compressor (23) dissipates heat in the outdoor heat exchanger (24), and then passes through the first outdoor expansion valve (26). The first outdoor expansion valve (26) decompresses the refrigerant to a pressure lower than the critical pressure.

[0106] The refrigerant in a subcritical state flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0107] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0108] The refrigerant cooled by the subcooling heat exchanger (28) is sent to the refrigeration-facility unit (70). The refrigerant sent to the refrigeration-facility unit (70) is decompressed by the refrigeration-facility expansion valve (73), and then evaporates in the refrigeration-facility heat exchanger (74). As a result, the inside air is cooled. The refrigerant evaporated in the refrigeration-facility heat exchanger (74) is sucked into and compressed again by the first compressor (21).

(8-2) Cooling Operation

[0109] In the cooling operation shown in FIG. 5, the controller (130) closes the first on-off valve (V1) and the fourth on-off valve (V4), and opens the second on-off valve (V2) and the third on-off valve (V3). The controller (130) stops the first compressor (21), and operates the second compressor (22) and the third compressor (23). The controller (130) opens the first outdoor expansion valve (26) and the injection valve (46) at a predetermined opening degree, and closes the second outdoor expansion valve (27). The controller (130) closes the refrigeration-facility expansion valve (73), and adjusts the opening degree of the indoor expansion valve (63). The controller (130) operates the outdoor fan (12) and the indoor fan (62), and stops the refrigeration-facility fan (72).

[0110] In the cooling operation, the refrigeration cycle is performed in which the outdoor heat exchanger (24) functions as a radiator, the indoor heat exchanger (64) functions as an evaporator, and the function of the refrigeration-facility heat exchanger (74) is substantially deactivated.

[0111] Specifically, the refrigerant compressed by the second compressor (22) is cooled in the intercooler (29), and then is sucked into the third compressor (23). The refrigerant compressed to a pressure equal to or greater than the critical pressure by the third compressor (23) dissipates heat in the outdoor heat exchanger (24), and then passes through the first outdoor expansion valve (26). The first outdoor expansion valve (26) decompresses the refrigerant to a pressure lower than the critical pressure.

[0112] The refrigerant in a subcritical state flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0113] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0114] The refrigerant cooled by the subcooling heat exchanger (28) is sent to the air-conditioning unit (60). The refrigerant sent to the air-conditioning unit (60) is decompressed by the indoor expansion valve (63), and then evaporates in the indoor heat exchanger (64). As a result, the indoor air is cooled. The refrigerant evaporated in the indoor heat exchanger (64) is sucked into and compressed again by the second compressor (22).

(8-3) Cooling and Refrigeration-Facility Operation

[0115] In the cooling and refrigeration-facility operation shown in FIG. 6, the controller (130) closes the first on-off valve (V1) and the fourth on-off valve (V4), and opens the second on-off valve (V2) and the third on-off valve (V3). The controller (130) operates the first compressor (21), the second compressor (22), and the third compressor (23). The controller (130) opens the first outdoor expansion valve (26) and the injection valve (46) at a predetermined opening degree, and closes the second outdoor expansion valve (27). The controller (130) adjusts the opening degrees of the refrigeration-facility expansion valve (73) and the indoor expansion valve (63). The controller (130) operates the outdoor fan (12), the indoor fan (62), and the refrigeration-facility fan (72).

[0116] **In** the cooling and refrigeration-facility operation, the refrigeration cycle is performed in which the outdoor heat exchanger (24) functions as a radiator, and the indoor heat exchanger (64) and the refrigeration-facility heat exchanger (74) function as evaporators.

[0117] Specifically, the refrigerant compressed by the first compressor (21) and the second compressor (22) is cooled by the intercooler (29), and then is sucked into the third compressor (23). The refrigerant compressed to a pressure equal to or greater than the critical pressure by the third compressor (23) dissipates heat in the outdoor heat exchanger (24), and then passes through the first outdoor expansion valve (26). The first outdoor expansion valve (26) decompresses the refrigerant to a pressure lower than the critical pressure.

[0118] The refrigerant in a subcritical state flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0119] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0120] The refrigerant cooled by the subcooling heat exchanger (28) is sent to the air-conditioning unit (60) and the refrigeration-facility unit (70). The refrigerant sent to the air-conditioning unit (60) is decompressed by the indoor expansion valve (63), and then evaporates in the indoor heat exchanger (64). As a result, the indoor air is cooled. The refrigerant evaporated in the indoor heat exchanger (64) is sucked into and compressed again by the first compressor (21).

[0121] The refrigerant sent to the refrigeration-facility unit (70) is decompressed by the refrigeration-facility expansion valve (73), and then evaporates in the refrigeration-facility heat exchanger (74). As a result, the inside air is cooled. The refrigerant evaporated in the refrigeration-facility heat exchanger (74) is sucked into and compressed again by the second compressor (22).

(8-4) Heating Operation

[0122] **In** the heating operation shown in FIG. 7, the controller (130) closes the second on-off valve (V2) and the third on-off valve (V3), and opens the first on-off valve (V1) and the fourth on-off valve (V4). The controller (130) stops the first compressor (21), and operates the second compressor (22) and the third compressor (23). The controller (130) opens the second outdoor expansion valve (27) and the injection valve (46) at a predetermined opening degree, and closes the first outdoor expansion valve (26). The controller (130) closes the refrigeration-facility expansion valve (73), and adjusts the opening degree of the indoor expansion valve (63). The controller (130) operates the outdoor fan (12) and the indoor fan (62), and stops the refrigeration-facility fan (72).

[0123] In the heating operation, the refrigeration cycle is performed in which the indoor heat exchanger (64) functions as a radiator, the outdoor heat exchanger (24) functions as an evaporator, and the function of the refrigeration-facility heat exchanger (74) is substantially deactivated.

[0124] Specifically, the refrigerant compressed by the second compressor (22) is cooled in the intercooler (29), and then is sucked into the third compressor (23). The refrigerant compressed by the third compressor (23) is sent to the air-conditioning unit (60).

[0125] The refrigerant sent to the air-conditioning unit (60) dissipates heat in the indoor heat exchanger (64). As a result, the indoor air is heated. The refrigerant having dissipated heat in the indoor heat exchanger (64) flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0126] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0127] The refrigerant cooled by the subcooling heat exchanger (28) is decompressed by the second outdoor expansion valve (27), and then evaporates in the outdoor heat exchanger (24). The refrigerant evaporated in the outdoor heat exchanger (24) is sucked into and compressed again by the second compressor (22).

(8-5) First Heating and Refrigeration-Facility Operation

[0128] The first heating and refrigeration-facility operation shown in FIG. 8 is executed when the heating load of the air-conditioning unit (60) is high. In the first heating and refrigeration-facility operation, the controller (130) closes the second on-off valve (V2) and the third on-off valve (V3), and opens the first on-off valve (V1) and the fourth on-off valve (V4). The controller (130) operates the first compressor (21), the second compressor (22), and the third compressor (23). The controller (130) opens the second outdoor expansion valve (27) and the injection valve (46) at a predetermined opening degree, and closes the first outdoor expansion valve (26). The controller (130) adjusts the opening degrees of the indoor expansion valve (63) and the refrigeration-facility expansion valve (73). The controller (130) operates the outdoor fan (12), the indoor fan (62), and the refrigeration-facility fan (72).

[0129] **In** the first heating and refrigeration-facility operation, the refrigeration cycle is performed in which the indoor heat exchanger (64) functions as a radiator, and the outdoor heat exchanger (24) and the refrigeration-facility heat exchanger (74) function as evaporators.

[0130] Specifically, the refrigerant compressed by the first compressor (21) and the second compressor (22) is cooled by the intercooler (29), and then is sucked into the third compressor (23). The refrigerant compressed by the third compressor (23) is sent to the air-conditioning unit (60).

[0131] The refrigerant sent to the air-conditioning unit (60) dissipates heat in the indoor heat exchanger (64). As a result, the indoor air is heated. The refrigerant having dissipated heat in the indoor heat exchanger (64) flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0132] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0133] A part of the refrigerant cooled by the subcooling heat exchanger (28) is decompressed by the second outdoor expansion valve (27), and then evaporates in the outdoor heat exchanger (24). The refrigerant evaporated in the outdoor heat exchanger (24) is sucked into and compressed again by the first compressor (21).

[0134] The rest of the refrigerant cooled by the subcooling heat exchanger (28) is sent to the refrigeration-facility unit (70). The refrigerant sent to the refrigeration-facility unit (70) is decompressed by the refrigeration-facility expansion valve (73), and then evaporates in the refrigeration-facility heat exchanger (74). As a result, the inside air is cooled. The refrigerant evaporated in the refrigeration-facility heat exchanger (74) is sucked into and compressed again by the second compressor (22).

(8-6) Second Heating and Refrigeration-Facility Operation

[0135] The second heating and refrigeration-facility operation shown in FIG. 9 is executed when the heating load of the air-conditioning unit (60) is neither excessively high nor low. **In** the second heating and refrigeration-facility operation, the controller (130) closes the second on-off valve (V2), the third on-off valve (V3), and the fourth on-off valve (V4), and opens the first on-off valve (V1). The controller (130) operates the first compressor (21) and the third compressor (23), and stops the second compressor (22). The controller (130) opens the injection valve (46) at a predetermined opening degree, and closes the first outdoor expansion valve (26) and the second outdoor expansion valve (27). The controller (130) adjusts the opening degrees of the indoor expansion valve (63) and the refrigeration-facility expansion valve (73). The controller (130) stops the outdoor fan (12), and operates the indoor fan (62) and the refrigeration-facility fan (72).

[0136] **In** the second heating and refrigeration-facility operation, the refrigeration cycle is performed in which the indoor heat exchanger (64) functions as a radiator, the outdoor heat exchanger (24) is substantially stopped, and the refrigeration-facility heat exchanger (74) functions as an evaporator.

[0137] Specifically, the refrigerant compressed by the first compressor (21) is cooled in the intercooler (29), and then is sucked into the third compressor (23). The refrigerant compressed by the third compressor (23) is sent to the air-conditioning unit (60).

[0138] The refrigerant sent to the air-conditioning unit (60) dissipates heat in the indoor heat exchanger (64). As a result, the indoor air is heated. The refrigerant having dissipated heat in the indoor heat exchanger (64) flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0139] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0140] The refrigerant cooled by the subcooling heat exchanger (28) is decompressed by the refrigeration-facility expansion valve (73), and then evaporates in the refrigeration-facility heat exchanger (74). As a result, the inside air is cooled. The refrigerant evaporated in the refrigeration-facility heat exchanger (74) is sucked into and compressed again by the first compressor (21).

(8-7) Third Heating and Refrigeration-Facility Operation

[0141] The third heating and refrigeration-facility operation shown in FIG. 10 is executed when the heating load of the air-conditioning unit (60) is low. **In** the second heating and refrigeration-facility operation, the controller (130) closes the third on-off valve (V3) and the fourth on-off valve (V4), and opens the first on-off valve (V1) and the second on-off valve (V2). The controller (130) operates the first compressor (21) and the third compressor (23), and stops the second compressor (22). The controller (130) opens the injection valve (46) and the first outdoor expansion valve (26) at a predetermined opening degree, and closes the second outdoor expansion valve (27). The controller (130) adjusts the opening degrees of the indoor expansion valve (63) and the refrigeration-facility expansion valve (73). The controller (130) operates the outdoor fan (12), the indoor fan (62), and a refrigeration-facility fan (72).

[0142] In the third heating and refrigeration-facility operation, the refrigeration cycle is performed in which the indoor heat exchanger (64) and the outdoor heat exchanger (24) function as radiators, and the refrigeration-facility heat exchanger (74) functions as an evaporator.

[0143] Specifically, the refrigerant compressed by the first compressor (21) is cooled in the intercooler (29), and then is sucked into the third compressor (23). A part of the refrigerant compressed by the third compressor (23) is sent to the air-conditioning unit (60). The refrigerant sent to the air-conditioning unit (60) dissipates heat in the indoor heat exchanger (64). As a result, the indoor air is heated. The refrigerant having dissipated heat in the indoor heat exchanger (64) flows into the gas-liquid separator (25). The rest of the refrigerant compressed by the third compressor (23) dissipates heat in the outdoor heat exchanger (24), and then flows into the gas-liquid separator (25). The gas-liquid separator (25) separates the refrigerant into a gas refrigerant and a liquid refrigerant.

[0144] The liquid refrigerant separated by the gas-liquid separator (25) is cooled in the subcooling heat exchanger (28) by the refrigerant flowing through the injection flow path (43). The refrigerant in the injection flow path (43) is sent to the intermediate flow path (18).

[0145] The refrigerant cooled by the subcooling heat exchanger (28) is decompressed by the refrigeration-facility expansion valve (73), and then evaporates in the refrigeration-facility heat exchanger (74). As a result, the inside air is cooled. The refrigerant evaporated in the refrigeration-facility heat exchanger (74) is sucked into and compressed again by the first compressor (21).

(8-8) Defrosting Operation

[0146] The defrosting operation is executed to melt the frost on the outdoor heat exchanger (24) in winter or the like. For example, during the heating and refrigeration-facility operation, the controller (130) executes the defrosting operation if the condition for the outdoor heat exchanger (24) being frosted is satisfied. The basic operation of the defrosting operation is the same as the cooling operation shown in FIG. 5 and the cooling and refrigeration-facility operation shown in FIG. 6. In the outdoor heat exchanger (24), the high-pressure refrigerant dissipates heat to the outside, thereby melting the frost on the surface of the outdoor heat exchanger (24).

(9) Control of Degree of Subcooling

[0147] In each of the above operations, the refrigeration apparatus (1) controls the degree of subcooling (sc) of the refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28). The control of the degree of subcooling will be described with reference to FIG. 11.

[0148] In step S11, the controller (130) determines whether the degree of subcooling (sc) is smaller than the target degree of subcooling (Tsc). Here, the degree of subcooling (sc) may be an average value of the degree of subcooling at the present time and one or more degrees of subcooling at some time back from that present time by predetermined time. If the degree of subcooling (sc) is smaller than the target degree of subcooling (Tsc), the process proceeds to step S13. In step S13, the controller (130) adds a pulse corresponding to the difference (Tsc-sc) between the target degree of subcooling (Tsc) and the degree of subcooling (sc) to the current pulse of the injection valve (46). This pulse refers to the modulation width of a pulse signal for controlling the opening degree of the injection valve (46) (a command for the opening degree). As a result, the opening degree of the injection valve (46) increases according to the added pulse. As the difference between the target degree of subcooling (Tsc) and the degree of subcooling (sc) becomes larger, the pulse added in step S13 becomes larger. In other words, as the difference between the target degree of subcooling (Tsc) and the degree of subcooling (sc) becomes larger, the amount of an increase in the opening degree of the injection valve (46) becomes larger. As the difference becomes smaller, the amount of a decrease in the opening degree of the injection valve (46) becomes smaller.

[0149] In step S12, the controller (130) determines whether the degree of subcooling (sc) is larger than the target degree of subcooling (Tsc). If the degree of subcooling (sc) is larger than the target degree of subcooling (Tsc), the process proceeds to step S14. In step S14, the controller (130) subtracts a pulse corresponding to the difference (sc-Tsc) between the degree of subcooling (sc) and the target degree of subcooling (Tsc) from the current pulse of the injection valve (46). As a result, the opening degree of the injection valve (46) decreases according to the subtracted pulse. As the difference between the degree of subcooling (sc) and the target degree of subcooling (Tsc) becomes larger, the pulse subtracted in step S14 becomes larger. In other words, as the difference between the degree of subcooling (sc) and the target degree of subcooling (Tsc) becomes larger, the amount of a decrease in the opening degree of the injection valve (46) becomes larger. As the difference becomes smaller, the amount of a decrease in the opening degree of the injection valve (46) becomes smaller.

[0150] In the control of the degree of subcooling, the control of steps S11 to S14 is repeated every predetermined time (e.g., every 10 seconds). Accordingly, the degree of subcooling (sc) converges to the target degree of subcooling (Tsc).

(10) Shortage of Refrigerant

(10-1) Problems

[0151] When the refrigeration apparatus (1) is shipped out or installed, the amount of filling in the refrigerant circuit (6) is small in some cases. In particular, for the refrigeration apparatus (1) using carbon dioxide where the high pressure is equal to or greater than the critical pressure, the amount of filling in the refrigerant circuit (6) is set relatively small in some cases in consideration of the endurance pressure of the gas-liquid separator (25) and the like. Further, in the refrigeration apparatus (1) after installation, the refrigerant circuit (6) might leak a refrigerant. In this way, if there is a shortage of a refrigerant in the refrigerant circuit (6), the refrigeration apparatus (1) exhibits lower cooling capacity.

(10-2) Control of Determination

[0152] In this embodiment, in order to solve the above problems, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). When the degree of subcooling is being controlled as described above, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). This control of determination will be described in detail with reference to FIG. 12.

[0153] In step S21, the controller (130) determines whether the opening degree of the injection valve (46) continues to remain equal to or greater than the first opening degree for a predetermined duration time (the first duration time) or more. In this embodiment, the first opening degree is the opening degree of the injection valve (46) that is fully opened. In other words, in step S22, the controller (130) determines whether the opening degree of the injection valve (46) continues to remain the opening degree of the injection valve (46) that is fully opened for the first duration time or more. If the condition of step S21 is satisfied, the process proceeds to step S23, and the controller (130) determines that there is a shortage of a refrigerant.

[0154] If there is a shortage of a refrigerant in the refrigerant circuit (6), a gas refrigerant might flow through the subcooling heat exchanger (28) or a gas-liquid two-phase refrigerant of which the dryness is relatively high might flow through the subcooling heat exchanger (28). In particular, if there is a shortage of a refrigerant in the refrigerant circuit (6) and there is almost no liquid refrigerant in the gas-liquid separator (25), a gas refrigerant flows through the first flow path (28a). In this case, the degree of subcooling of the refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28) continues to remain low or zero. If, under this situation, the degree of subcooling is controlled as described above, the opening degree of the injection valve (46) gradually increases, and in the end, the injection valve (46) continues to remain fully opened. Then, if the condition of step S21 is satisfied, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6). If it is determined that there is a shortage of a refrigerant, the alerting unit (134) alerts in step S24 that there is a shortage of a refrigerant. Accordingly, the target entity can be promptly informed that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0155] In step S22, the controller (130) determines whether the opening degree of the injection valve (46) continues to remain equal to or greater than the second opening degree for a predetermined duration time (the second duration time) or more. In this embodiment, the second opening degree is a predetermined opening degree smaller than the first opening degree. The second duration time is a predetermined duration time longer than the first duration time. That is, the condition of step S22 is satisfied if the opening degree of the injection valve (46) continues to remain the second opening degree smaller than the first opening degree for the second duration time longer than the first duration time. If the condition of step S22 is satisfied, the process proceeds to step S23, and the controller (130) determines that there is a shortage of a refrigerant.

[0156] If, as described above, there is a shortage of a refrigerant in the refrigerant circuit (6), and a gas refrigerant or a gas-liquid two-phase refrigerant of which the dryness is relatively high flows through the first flow path (28a), the opening degree of the injection valve (46) continues to remain relatively large for a long duration time due to the control of the degree of subcooling. Then, if the condition of step S22 is satisfied, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6). If it is determined that there is a shortage of a refrigerant, the alerting unit (134) alerts in step S24 that there is a shortage of a refrigerant.

(10-3) Advantage of Determination According to Opening Degree of Injection Valve

[0157] It is conceivable that, in the control of the degree of subcooling, whether there is a shortage of a refrigerant in the refrigerant circuit (6) is determined using the degree of subcooling itself. Specifically, in the control of the degree of subcooling, if the condition that the degree of subcooling is smaller than a predetermined value is satisfied, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6). However, the degree of subcooling tends to change sharply according to the state of the refrigerant in comparison with the opening degree of the injection valve (46) in the control of the degree of subcooling. This is because, as described above, the opening degree of the injection valve (46) changes according to the value obtained by adding or subtracting the pulse based on the difference between the degree of subcooling (sc) and the target degree of subcooling (Tsc), whereas the degree of subcooling (sc) is an index that directly reflects a change in the state of the refrigerant.

[0158] If whether there is a shortage of a refrigerant in the refrigerant circuit (6) is determined according to the degree of subcooling, whether there is a shortage of a refrigerant in the refrigerant circuit (6) might be determined erroneously if the state of the refrigerant is temporarily changed due to some influence. Specifically, for example, if the separated gas refrigerant temporarily flows into the first flow path (28a) in a state in which the liquid surface in the gas-liquid separator (25) is unstable, the degree of subcooling might temporarily fall below a predetermined value. In this case, despite the fact that there is no shortage of a refrigerant in the refrigerant circuit (6), it might be determined erroneously that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0159] In contrast, in this embodiment, whether there is a shortage of a refrigerant in the refrigerant circuit (6) is determined using the opening degree of the injection valve (46) which changes more gradually than the degree of subcooling. Thus, for the above reasons, it is possible to determine less erroneously whether there is a shortage of a refrigerant in the refrigerant circuit (6) when the gas refrigerant temporarily flows through the first flow path (28a).

(10-4) Further Conditions for Less Erroneous Determination

[0160] In order to reduce erroneous determination about the refrigerant circuit (6), the controller (130) under the conditions described below refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6). The following conditions can be interpreted as the conditions that the degree of subcooling (sc) of the refrigerant flowing out of the first flow path (28a) is unstable. In other words, under the condition that the degree of subcooling (sc) is stable, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0161] Condition (a): During the period between when the compression unit (20) starts to operate and when a predetermined time (15 minutes) elapses, the controller (130) refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6). This is because during the period between when the compression unit (20) starts to operate and when a predetermined time (e.g., 15 minutes) elapses, the degree of subcooling (sc) is unstable. In other words, after the period between when the compression unit (20) starts to operate and when a predetermined time elapses, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0162] Condition (b): If the outdoor heat exchanger (24) operates as a radiator and the outside air temperature is higher than a predetermined temperature Ta (e.g., 32°C), the controller (130) controls the opening degree of the injection valve (46) so that the intermediate pressure of the refrigerant circuit (6) approaches a predetermined target value in order to increase the high pressure of the refrigerant circuit (6). Here, the intermediate pressure is detected by the intermediate pressure sensor (102). Under this condition, the injection valve (46) is not subjected to the control of the degree of subcooling, and thus the controller (130) refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0163] Condition (c): If the indoor heat exchanger (64) operates as a radiator and the outside air temperature is lower than a predetermined temperature Tb (e.g., 10°C), the controller (130) controls the opening degree of the injection valve (46) so that the intermediate pressure of the refrigerant circuit (6) approaches a predetermined target value in order to increase the high pressure of the refrigerant circuit (6). Under this condition, the injection valve (46) is not subjected to the control of the degree of subcooling, and thus the controller (130) refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0164] Condition (d): Under the condition that the outside air temperature is higher than a predetermined temperature (e.g., 32°C), the high pressure of the refrigerant circuit (6) or the internal pressure of the gas-liquid separator (25) increases. Thus, the controller (130) increases the opening degree of the venting valve (42) or decreases the opening degree of the first outdoor expansion valve (26). Under this condition, the degree of subcooling (sc) of the refrigerant flowing out of the first flow path (28a) is unstable, and thus the controller (130) refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6). That is, under the condition that the outside air temperature is higher than a predetermined temperature; the condition that the high pressure is higher than a predetermined value; or the condition that the internal pressure of the gas-liquid separator (25) is higher than a predetermined value, the controller (130) refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0165] Condition (e): During the period between when the various operations described above switch from one operation to another and when a predetermined time elapses, the controller (130) refuses to determine whether there is a shortage of a refrigerant in the refrigerant circuit (6). This is because during the period between when the various operations described above switch from one operation to another and when a predetermined time elapses, the degree of subcooling (sc) is unstable. In other words, after the period between when the various operations described above switch from one operation to another and when a predetermined time elapses, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6).

(11) Advantages of Embodiment

[0166] Under the condition that the opening degree of a subcooling-side decompression valve (46) is equal to or greater than a predetermined opening degree, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0167] If there is a shortage of a refrigerant in the refrigerant circuit (6), the degree of subcooling of the refrigerant flowing out of the first flow path (28a) is small or zero, and the opening degree of the subcooling-side decompression valve (46) is equal to or greater than a predetermined opening degree. By using this, it is possible to determine that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0168] The opening degree of the subcooling-side decompression valve (46) fluctuates more gradually than the degree of subcooling itself, and thus it is possible to determine less erroneously whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0169] In particular, under the condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a predetermined opening degree for a predetermined duration time or more, the controller (130) determines that there is a shortage of a refrigerant.

[0170] Thus, it is possible to further determine less erroneously whether there is a shortage of a refrigerant in the refrigerant circuit (6).

[0171] Under the condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than the first opening degree for the first duration time or more, or under the condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than the second opening degree for the second duration time or more, the controller (130) determines that there is a shortage of a refrigerant. The second duration time is longer than the first duration time, and the second opening degree is smaller than the first opening degree.

[0172] According to these conditions, if the opening degree of the subcooling-side decompression valve (46) is relatively large, it is possible to relatively promptly determine that there is a shortage of a refrigerant in the refrigerant circuit (6). Also if the opening degree of the subcooling-side decompression valve (46) is relatively small and this situation continues for a relatively long duration time, it is possible to determine that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0173] Under the condition that the opening degree of the subcooling-side decompression valve (46) is the opening degree of the subcooling-side decompression valve (46) that is fully opened, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0174] If there is a shortage of a refrigerant in the refrigerant circuit (6), the degree of subcooling of the refrigerant flowing out of the first flow path (28a) should be zero, and thus in the end, the subcooling-side decompression valve (46) reaches the maximum opening degree in the possible control range. Thus, by employing the condition that the opening degree of the subcooling-side decompression valve (46) is the opening degree of the subcooling-side decompression valve (46) that is fully opened, it is possible to precisely determine that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0175] The refrigerant circuit (6) is configured to be able to perform a refrigeration cycle in which the high pressure is equal to or greater than the critical pressure. Thus, the degree of subcooling (sc) of the refrigerant flowing out of the first flow path (28a) is easily unstable. In contrast, the opening degree of the subcooling-side decompression valve (46) changes more gradually than the degree of subcooling itself, and thus it is possible to reduce erroneous determination as to whether there is a shortage of a refrigerant in the refrigerant circuit (6) due to the degree of subcooling (sc) being unstable.

[0176] The refrigerant circuit (6) is provided with the gas-liquid separator (25) between the outdoor heat exchanger (24) and the first flow path (28a) of the subcooling heat exchanger (28). Thus, when the liquid surface of the gas-liquid separator (25) is unstable, a gas refrigerant might temporarily flow through the first flow path (28a). In contrast, the opening degree of the subcooling-side decompression valve (46) changes more gradually than the degree of subcooling itself, and thus it is possible to reduce erroneous determination as to whether there is a shortage of a refrigerant in the refrigerant circuit (6) due to the degree of subcooling (sc) being unstable.

(12) Other Embodiments

[0177] If the opening degree of the subcooling-side decompression valve (46) instantaneously becomes equal to or greater than a predetermined opening degree, the controller (130) may determine that there is a shortage of a refrigerant in the refrigerant circuit (6).

[0178] If determining that there is a shortage of a refrigerant, the controller (130) may execute a predetermined control such as stopping the operation of the refrigeration apparatus (1).

[0179] The compression unit (20) may be a single compressor.

[0180] The injection flow path (43) may send the refrigerant to the suction side of the compression unit (20).

[0181] The first utilization-side heat exchanger (64) may be a heat exchanger for heating or cooling water, brine, and the like. The first utilization-side heat exchanger (64) may be used as a heat source for a water heater.

[0182] While the embodiments and variations thereof have been described above, it will be understood that various changes in form and details may be made without departing from the spirit and scope of the claims. The elements according to the embodiment, the variations thereof, and the other embodiments may be combined and replaced with each other.

[0183] The ordinal numbers such as "first," "second," "third," . . . , described above are used to distinguish the terms to which these expressions are given, and do not limit the number and order of the terms.

INDUSTRIAL APPLICABILITY

[0184] As described above, the present disclosure is useful for a heat source unit, and a refrigeration apparatus.

DESCRIPTION OF REFERENCE CHARACTERS

[0185]

1	Refrigeration Apparatus
6	Refrigerant Circuit
10	Heat Source Unit
20	Compression Unit
24	Outdoor Heat Exchanger (Heat-Source-Side Heat Exchanger)
25	Gas-Liquid Separator
28	Subcooling Heat Exchanger
28a	First Flow Path
28b	Second Flow Path
46	Injection Valve (Subcooling-Side Decompression Valve)
60, 70	Utilization Unit

Claims

1. A heat source unit, comprising:

a refrigerant circuit (6) including a compression unit (20), a heat-source-side heat exchanger (24), a subcooling-side decompression valve (46), and a subcooling heat exchanger (28) having a first flow path (28a) and a second flow path (28b), where the first flow path (28a) is a flow path through which a refrigerant having dissipated heat in the heat-source-side heat exchanger (24) flows, and where the second flow path (28b) is a flow path through which a refrigerant passing through the first flow path (28a) and then decompressed by the subcooling-side decompression valve (46) flows; and

a controller (130) configured to control the subcooling-side decompression valve (46) according to a degree of subcooling of a refrigerant flowing out of the first flow path (28a) of the subcooling heat exchanger (28), wherein

based on a fact that an opening degree of the subcooling-side decompression valve (46) becomes larger, the controller (130) determines whether there is a shortage of a refrigerant in the refrigerant circuit (6).

2. The heat source unit of claim 1, wherein under a condition that the opening degree of a subcooling-side decompression valve (46) is equal to or greater than a predetermined opening degree, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

3. The heat source unit of claim 2, wherein under a condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a predetermined opening degree for a predetermined duration time or more, the controller (130) determines that there is a shortage of a refrigerant.

4. The heat source unit of claim 3, wherein

under a condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a first opening degree for a first duration time or more, or under a condition that the opening degree of the subcooling-side decompression valve (46) continues to remain equal to or greater than a second opening degree for a second duration time or more, the controller (130) determines that there is a shortage of a refrigerant,

the second duration time is longer than the first duration time, and

the second opening degree is smaller than the first opening degree.

5. The heat source unit of any one of claims 1 to 3, wherein under a condition that the opening degree of the subcooling-side decompression valve (46) is the opening degree of the subcooling-side decompression valve (46) that is fully opened, the controller (130) determines that there is a shortage of a refrigerant in the refrigerant circuit (6).

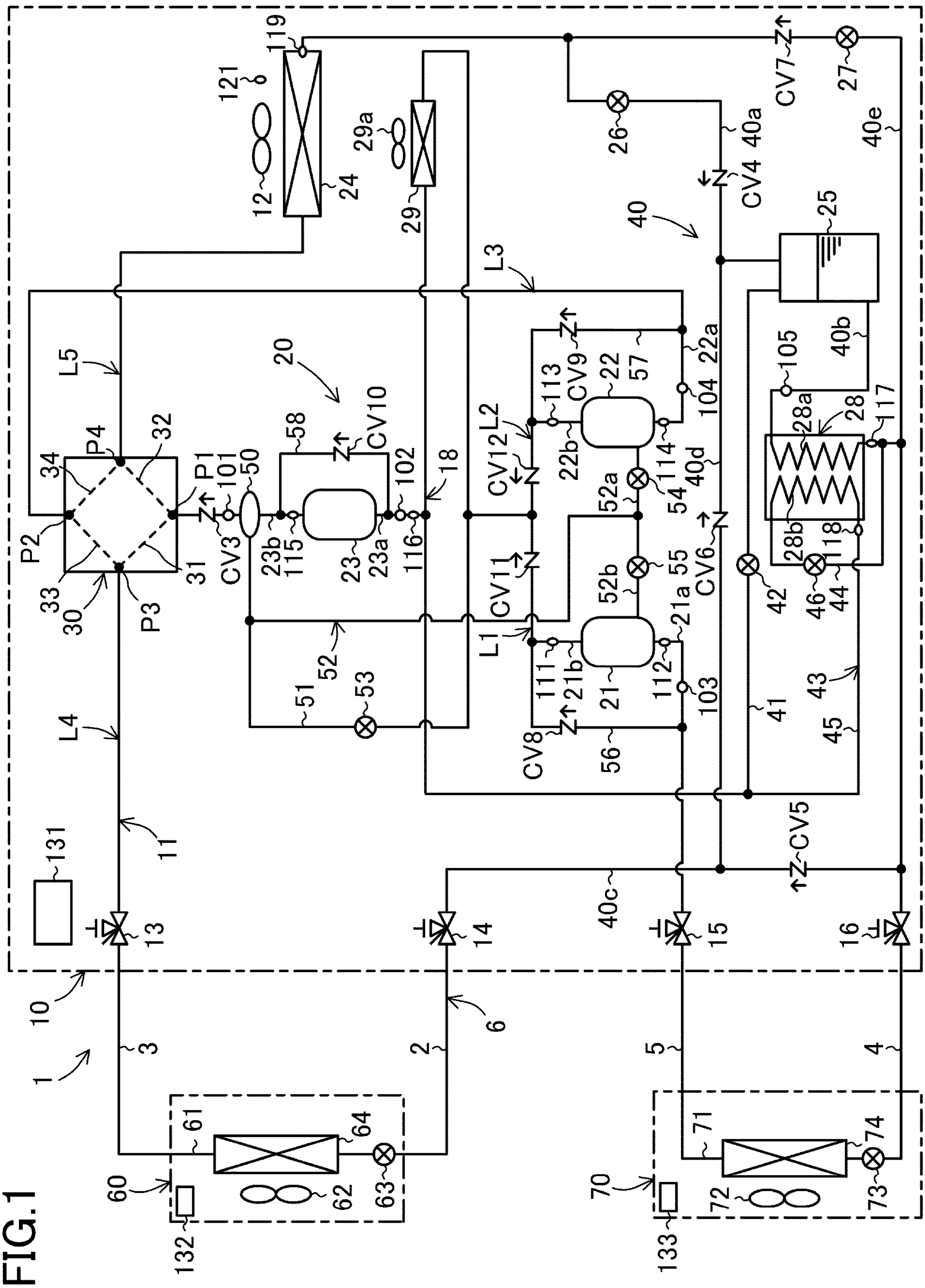
6. The heat source unit of any one of claims 1 to 5, wherein
the refrigerant circuit (6) is configured to be able to perform a refrigeration cycle in which a high pressure is equal to or greater than a critical pressure.

7. The heat source unit of any one of claims 1 to 6, wherein
the refrigerant circuit (6) is provided with a gas-liquid separator (25) between the heat-source-side heat exchanger (24) and the first flow path (28a) of the subcooling heat exchanger (28).

8. A refrigeration apparatus, comprising:

the heat source unit (10) of any one of claims 1 to 7; and
a utilization unit (60,70).

FIG.1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40b
40c
40d
40e
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42
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52a
52b
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114
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118
119
121
131
132
133
2
3
4
5
6
P1
P2
P3
P4
L1
L2
L3
L4
L5
CV3
CV4
CV5
CV6
CV7
CV8
CV9
CV10
CV11
CV12

FIG.2

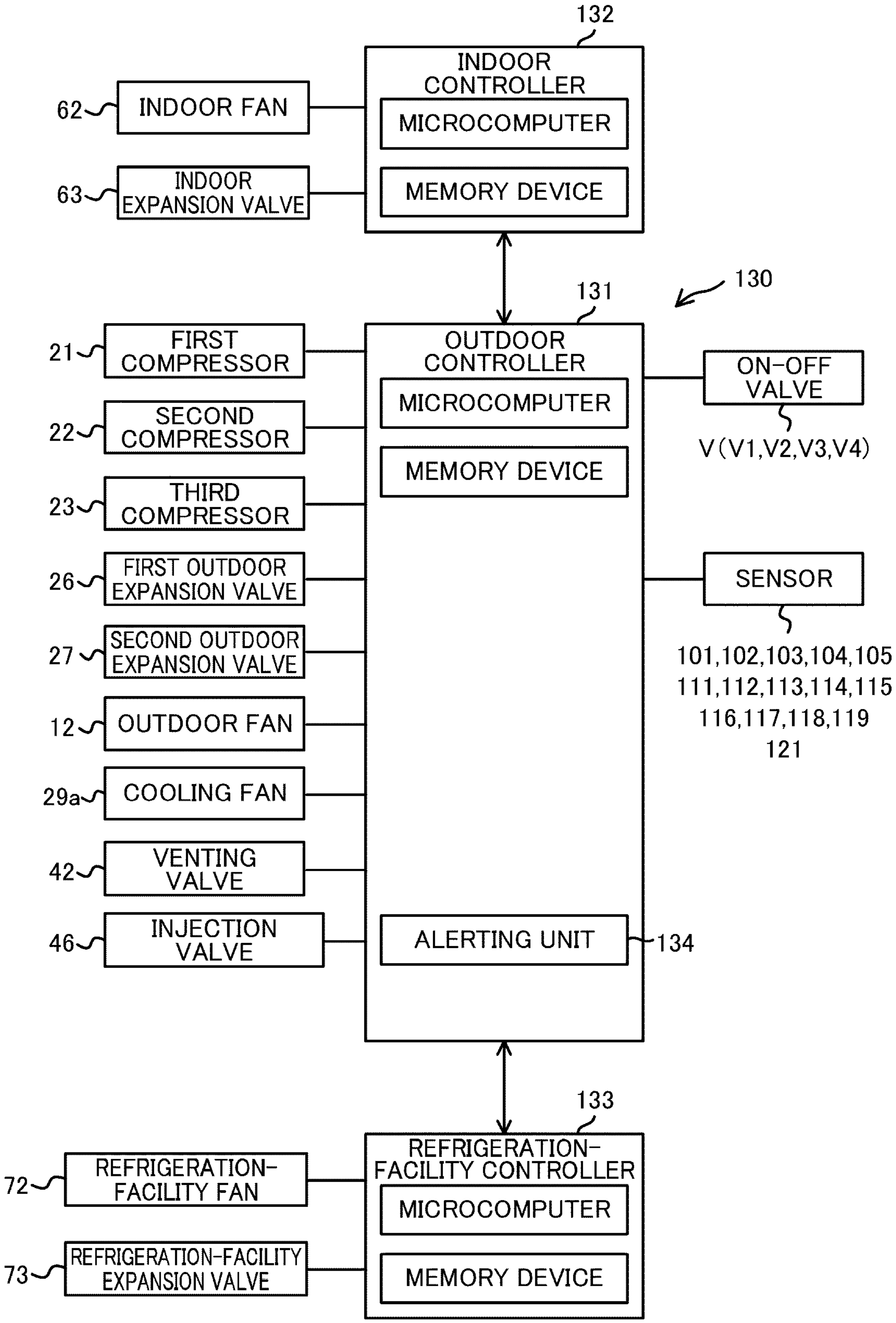
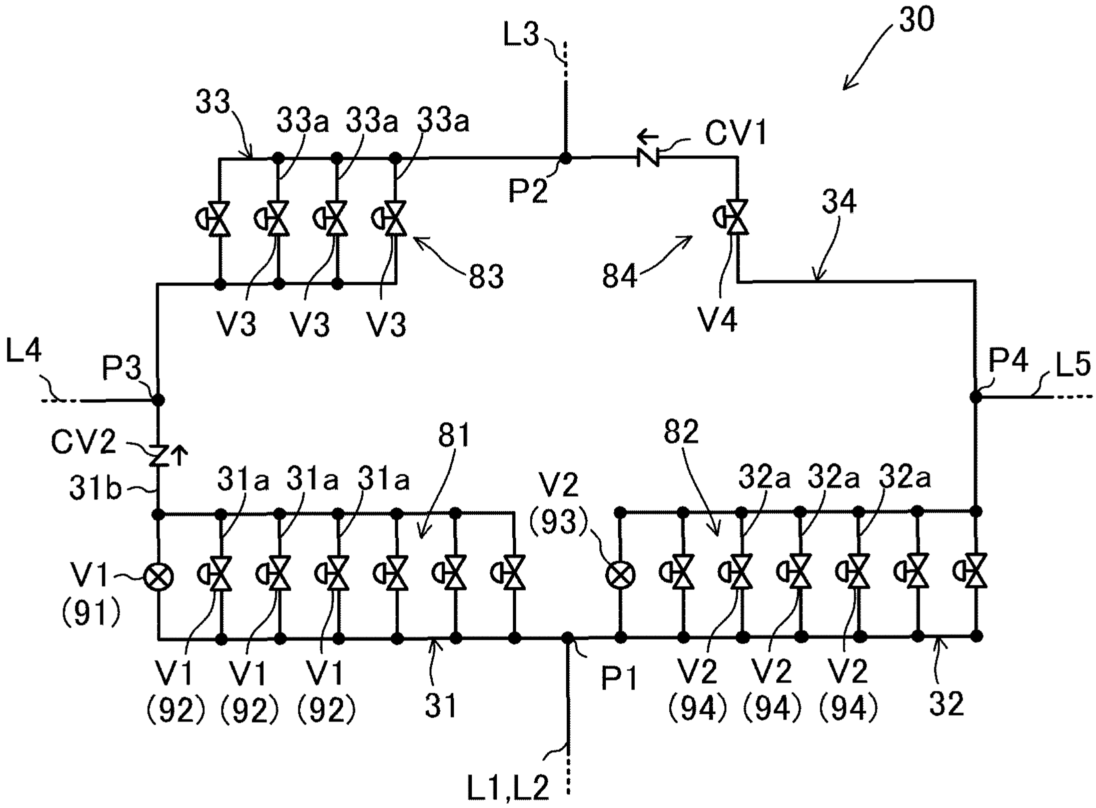

132
INDOOR CONTROLLER
MICROCOMPUTER
MEMORY DEVICE
62
INDOOR FAN
63
INDOOR EXPANSION VALVE
130
131
OUTDOOR CONTROLLER
MICROCOMPUTER
MEMORY DEVICE
ALERTING UNIT
134
21
FIRST COMPRESSOR
22
SECOND COMPRESSOR
23
THIRD COMPRESSOR
26
FIRST OUTDOOR EXPANSION VALVE
27
SECOND OUTDOOR EXPANSION VALVE
12
OUTDOOR FAN
29a
COOLING FAN
42
VENTING VALVE
46
INJECTION VALVE
ON-OFF VALVE
V(V1,V2,V3,V4)
SENSOR
101,102,103,104,105
111,112,113,114,115
116,117,118,119
121
133
REFRIGERATION-FACILITY CONTROLLER
MICROCOMPUTER
MEMORY DEVICE
72
REFRIGERATION-FACILITY FAN
73
REFRIGERATION-FACILITY EXPANSION VALVE

FIG.3


30
L3
33
33a 33a 33a
CV1
P2
34
83
84
V3 V3 V3
V4
L4
P3
P4
L5
CV2
31b
81
82
31a 31a 31a
V2
(93)
32a 32a 32a
V1
(91)
V1 V1 V1
(92) (92) (92)
31
P1
V2 V2 V2
(94) (94) (94)
32
L1,L2

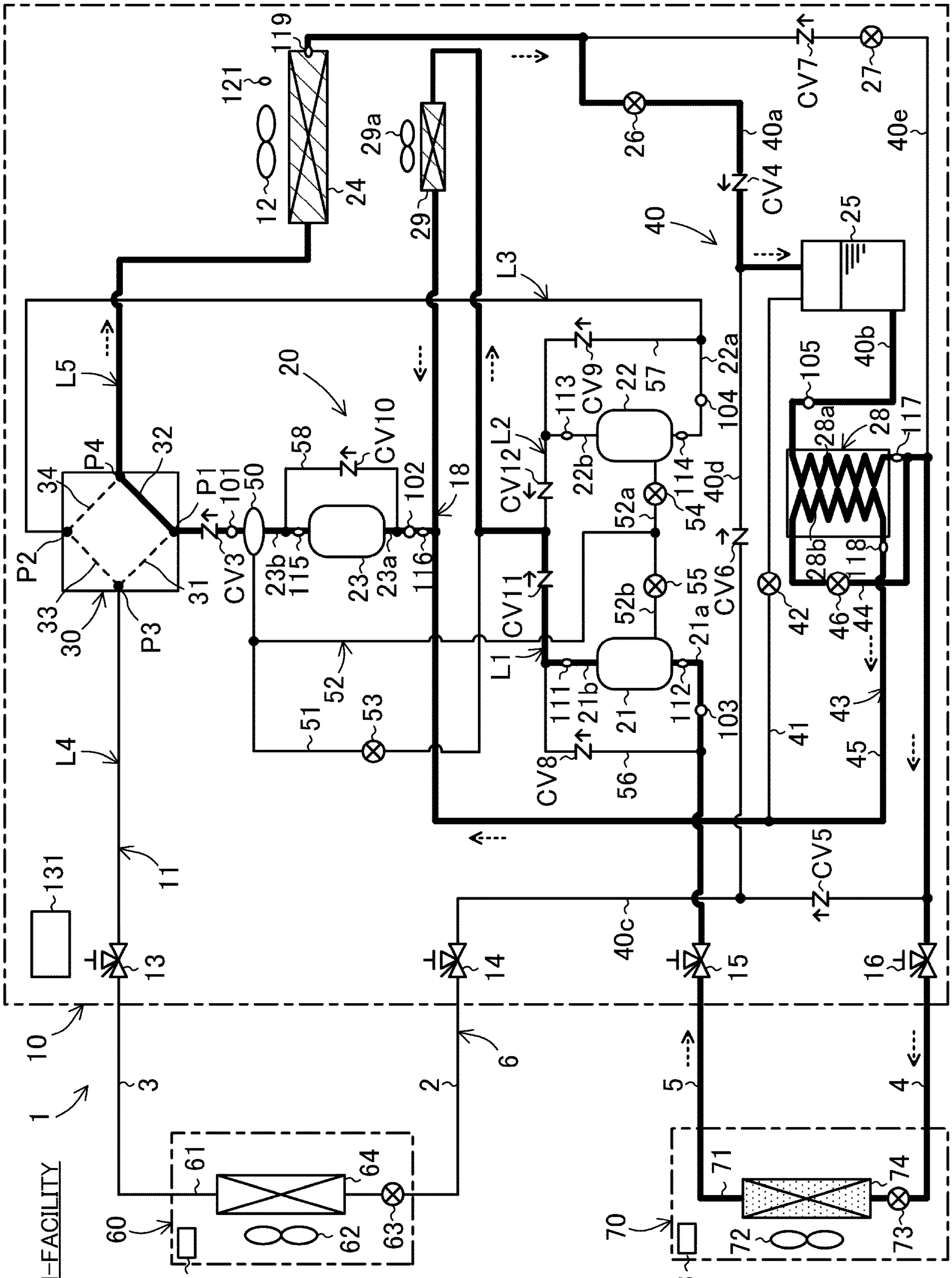
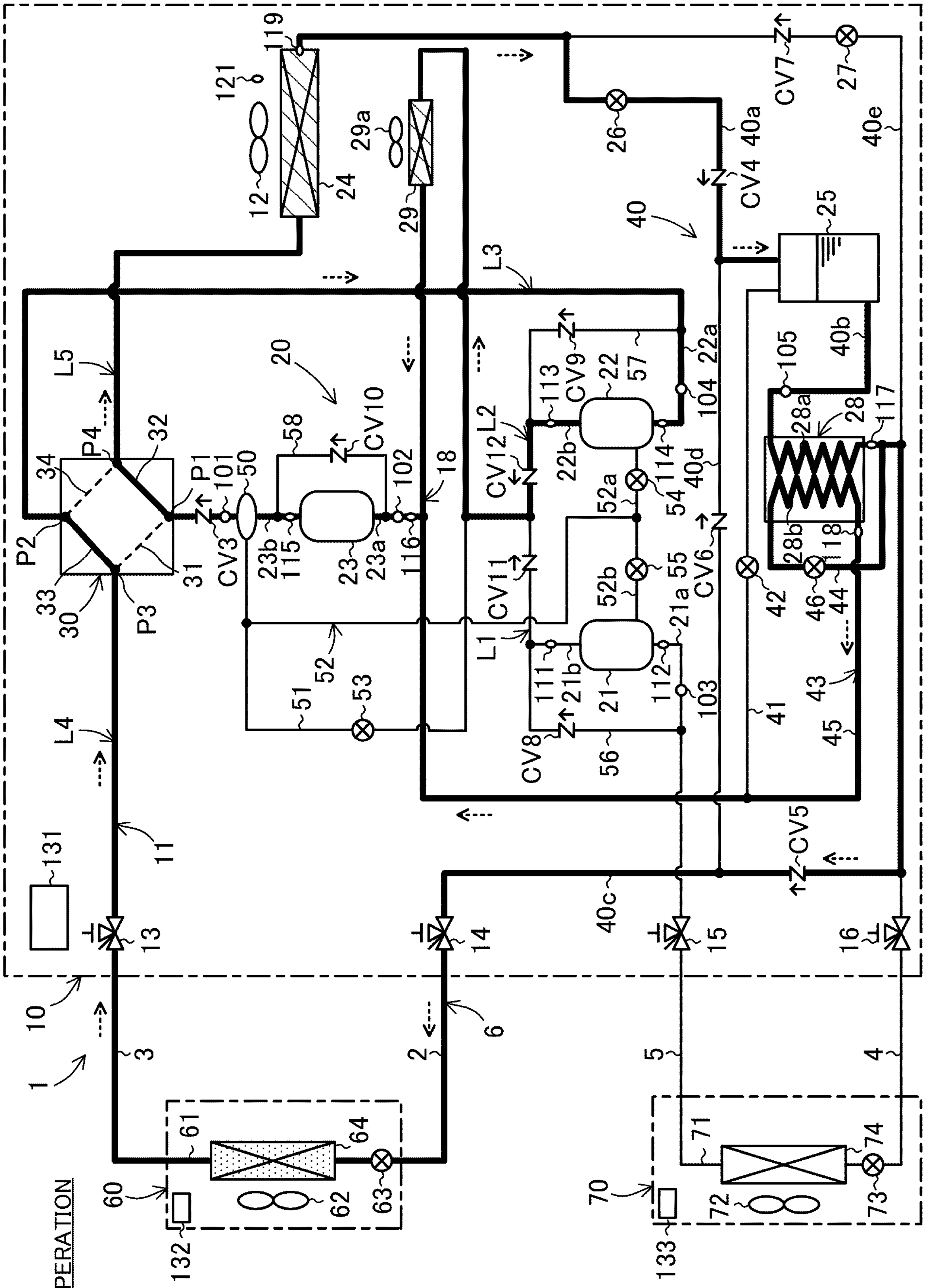


FIG.4

REFRIGERATION-FACILITY OPERATION

FIG.5

COOLING OPERATION



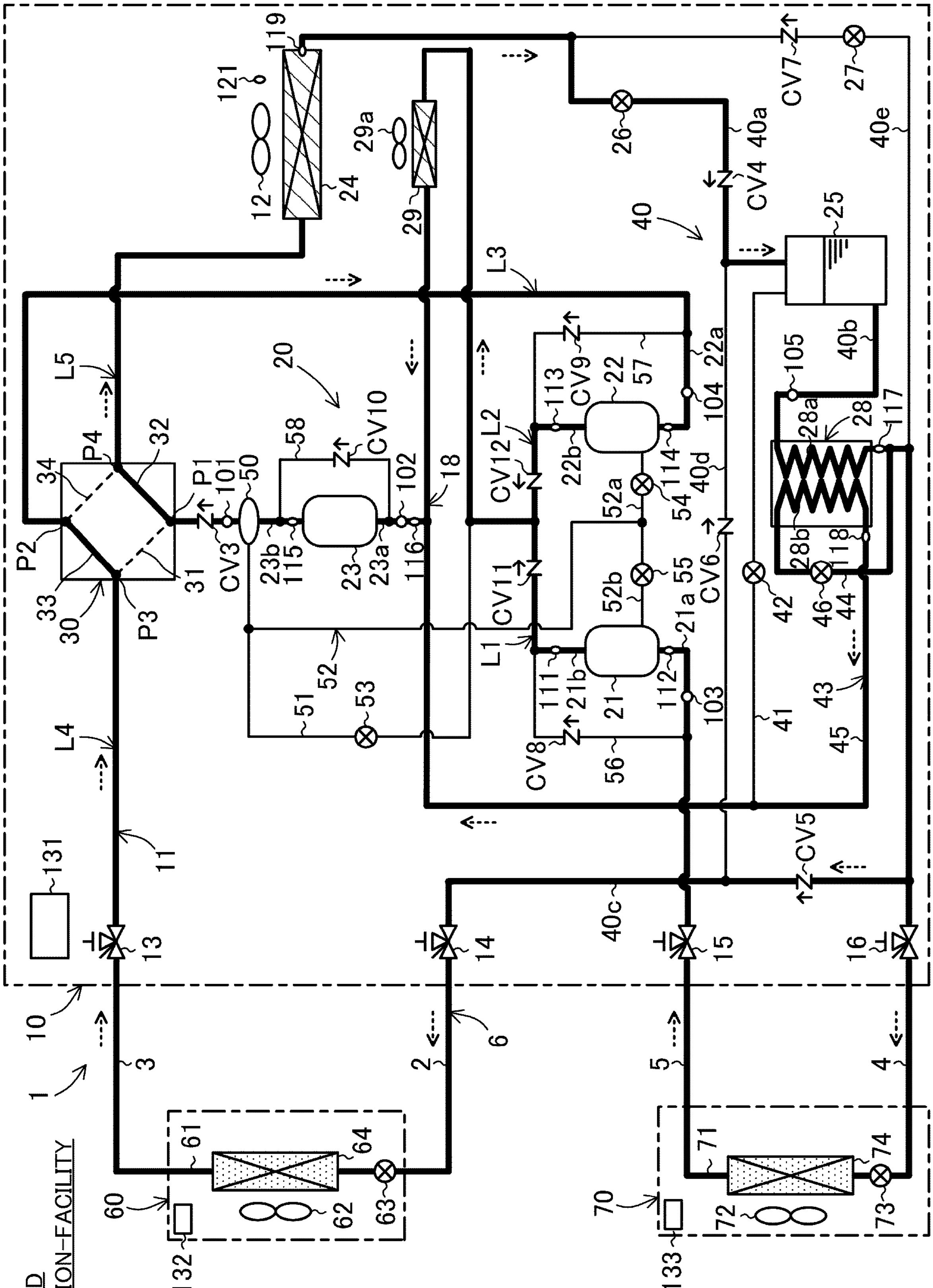


FIG.6
COOLING AND
REFRIGERATION-FACILITY
OPERATION

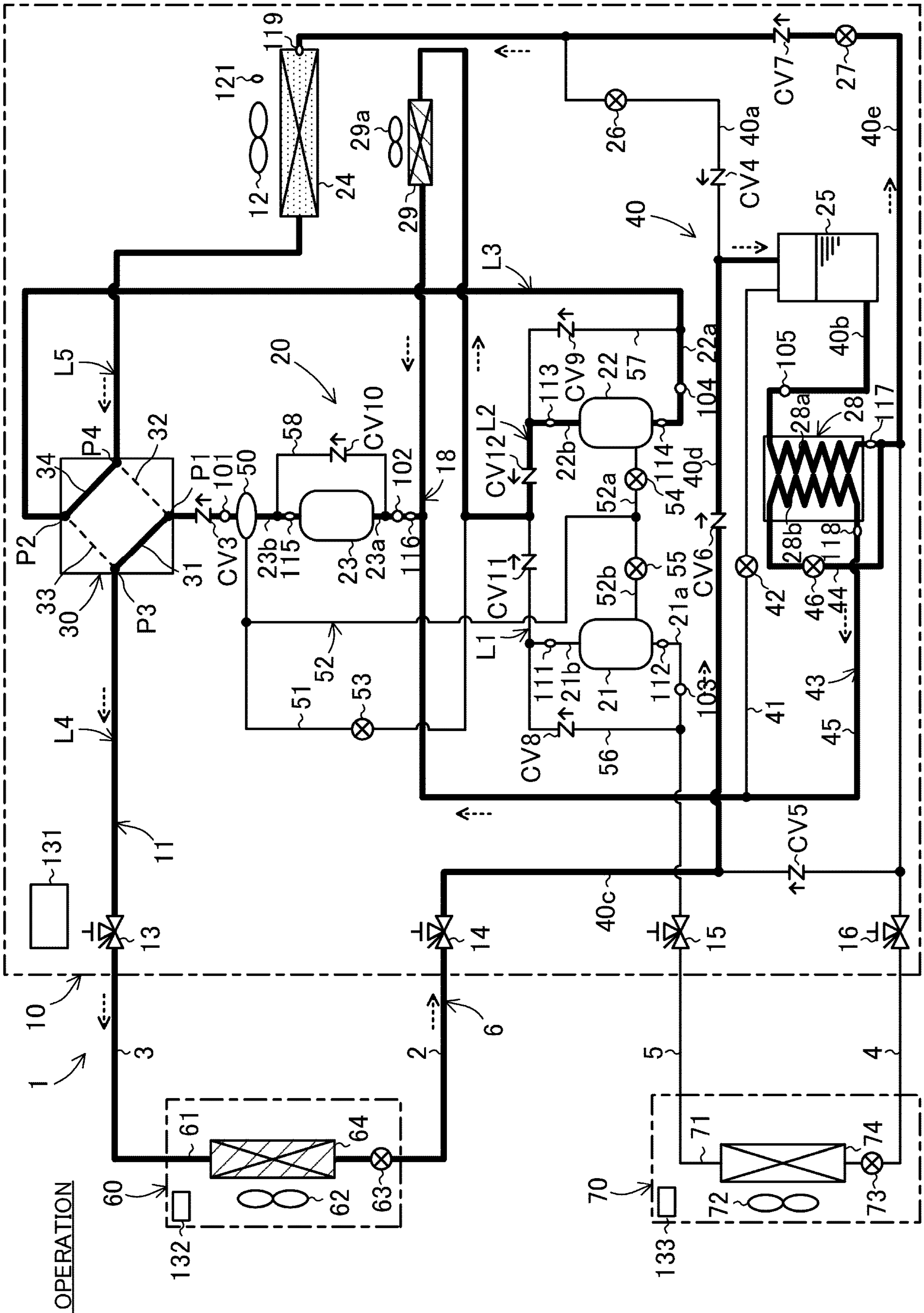


FIG.7

HEATING OPERATION

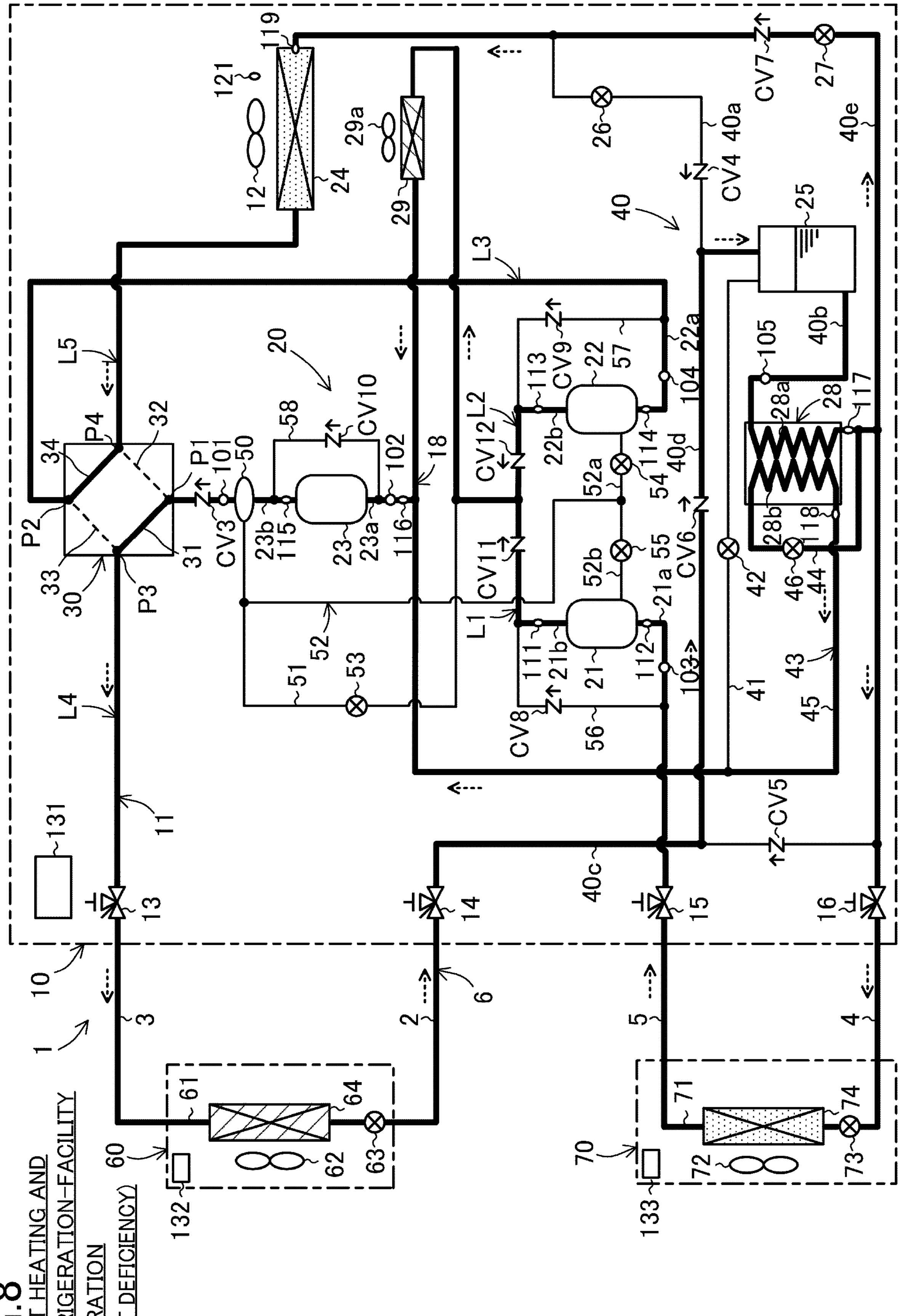


FIG.8 FIRST HEATING AND REFRIGERATION-FACILITY OPERATION (HEAT DEFICIENCY)

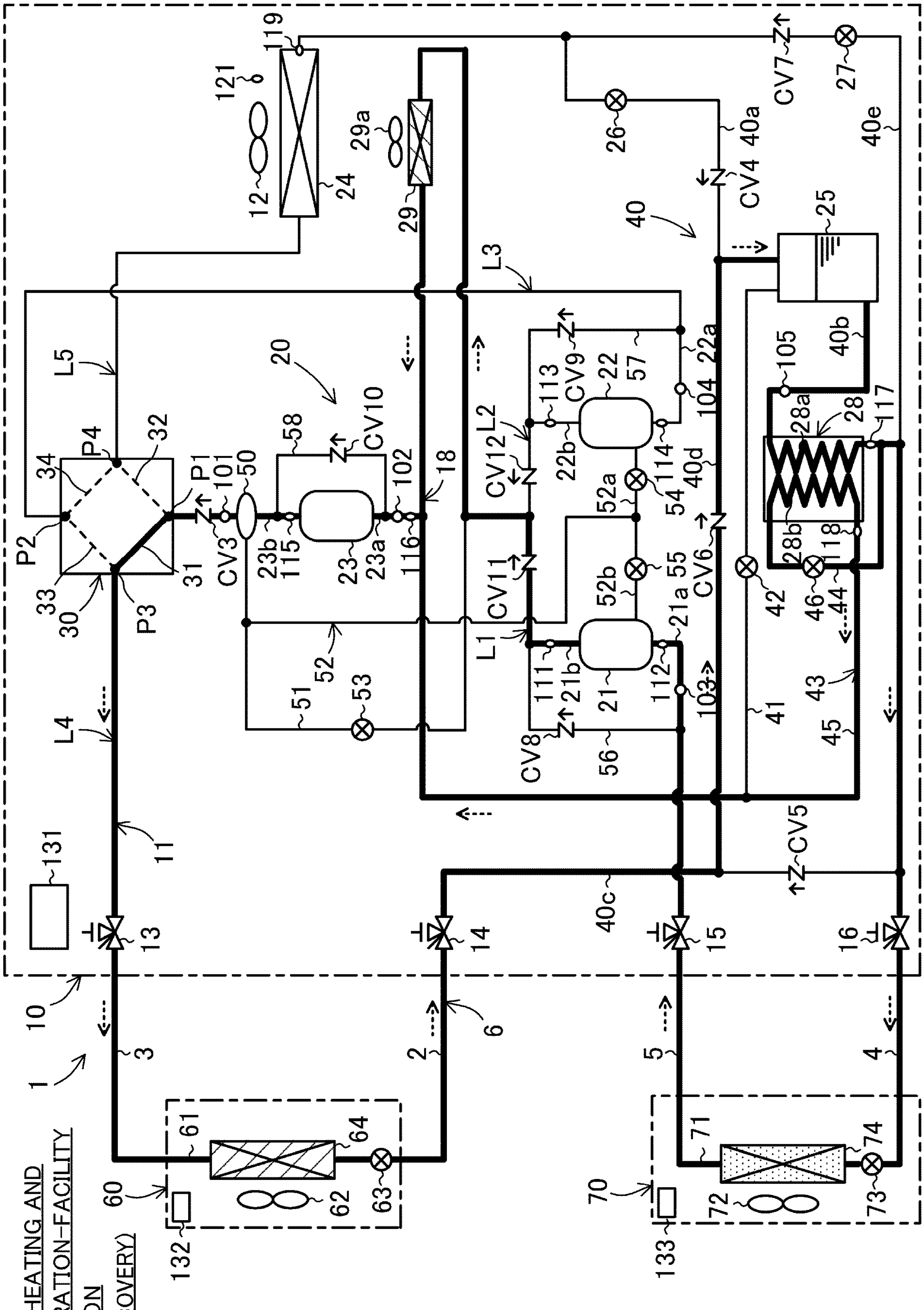


FIG.9 SECOND HEATING AND REFRIGERATION-FACILITY OPERATION (HEAT RECOVERY)

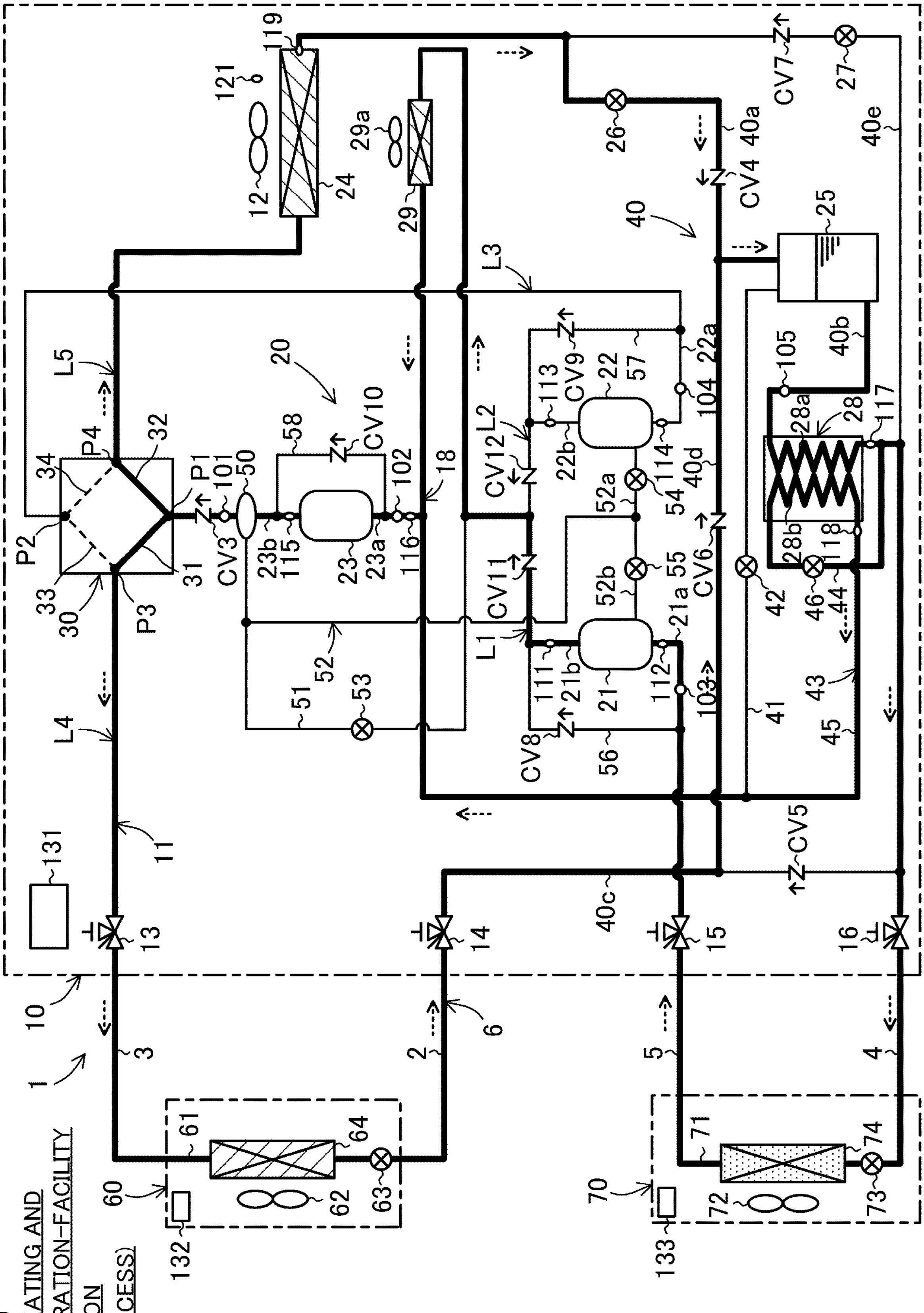


FIG.10

THIRD HEATING AND REFRIGERATION-FACILITY OPERATION (HEAT EXCESS)

FIG.11

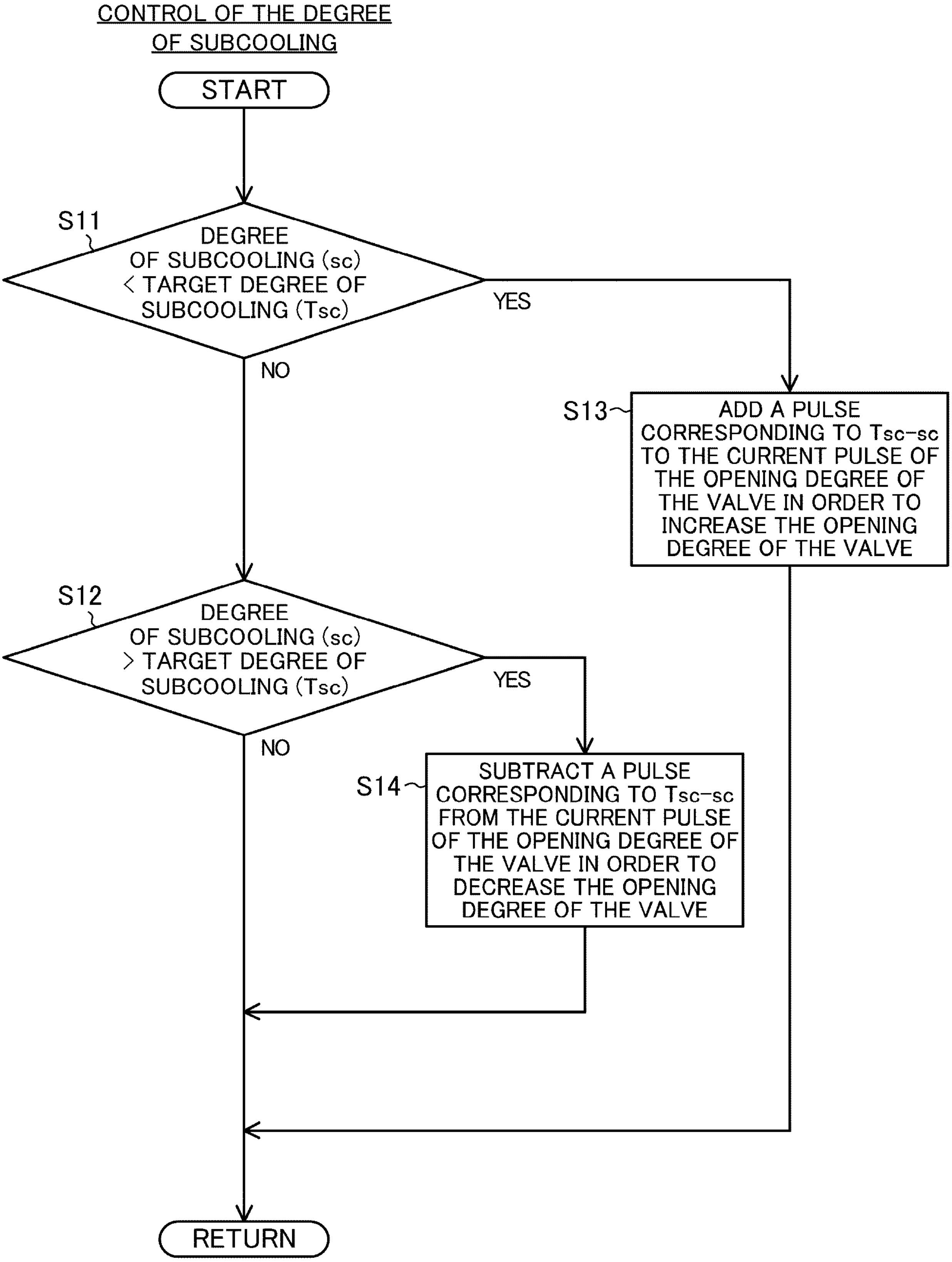
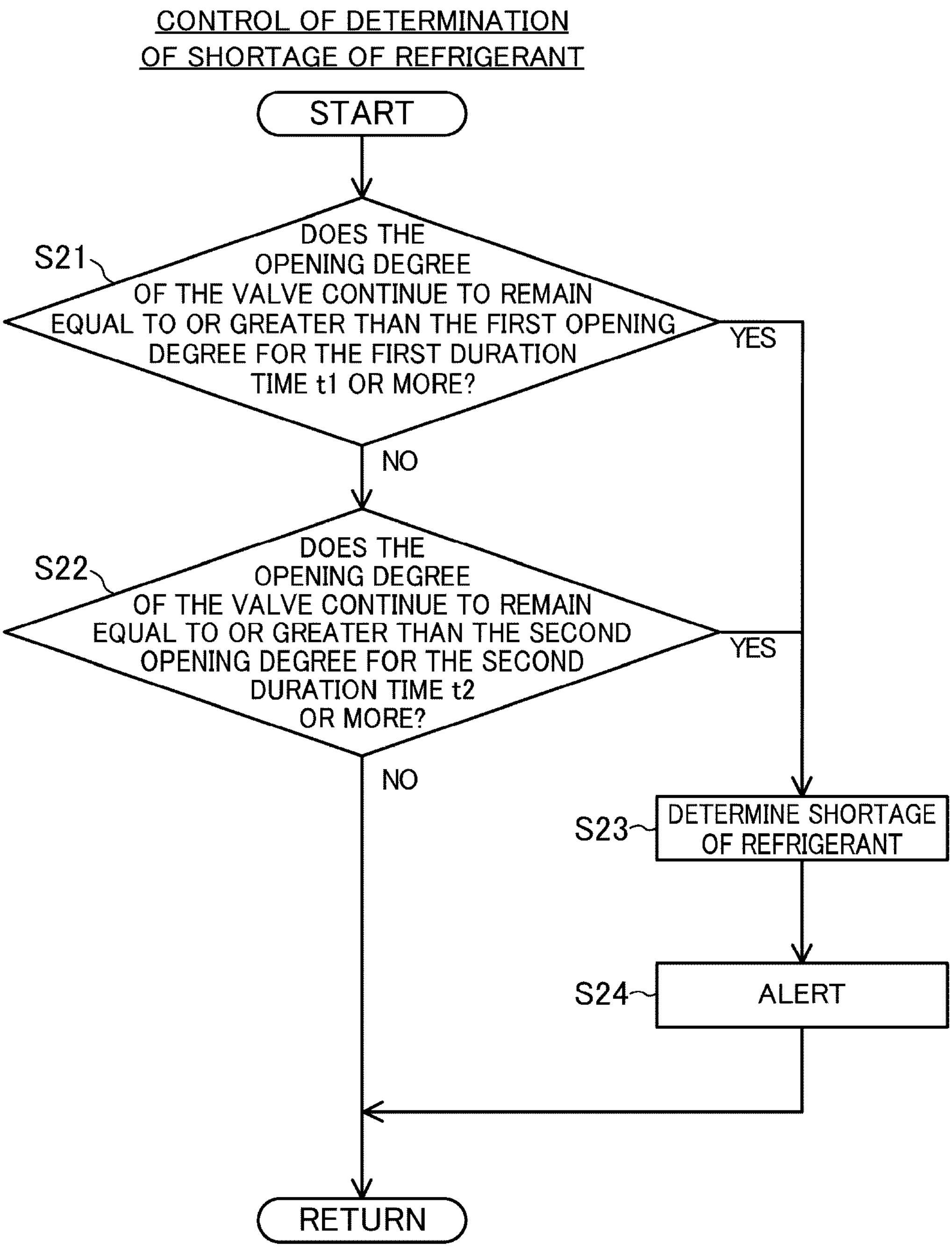

CONTROL OF THE DEGREE OF SUBCOOLING
START
S11
DEGREE OF SUBCOOLING (sc) < TARGET DEGREE OF SUBCOOLING (Tsc)
YES
NO
S13
ADD A PULSE CORRESPONDING TO Tsc-sc TO THE CURRENT PULSE OF THE OPENING DEGREE OF THE VALVE IN ORDER TO INCREASE THE OPENING DEGREE OF THE VALVE
S12
DEGREE OF SUBCOOLING (sc) > TARGET DEGREE OF SUBCOOLING (Tsc)
YES
NO
S14
SUBTRACT A PULSE CORRESPONDING TO Tsc-sc FROM THE CURRENT PULSE OF THE OPENING DEGREE OF THE VALVE IN ORDER TO DECREASE THE OPENING DEGREE OF THE VALVE
RETURN

FIG.12


CONTROL OF DETERMINATION
OF SHORTAGE OF REFRIGERANT
START
S21
DOES THE OPENING DEGREE OF THE VALVE CONTINUE TO REMAIN EQUAL TO OR GREATER THAN THE FIRST OPENING DEGREE FOR THE FIRST DURATION TIME t1 OR MORE?
YES
NO
S22
DOES THE OPENING DEGREE OF THE VALVE CONTINUE TO REMAIN EQUAL TO OR GREATER THAN THE SECOND OPENING DEGREE FOR THE SECOND DURATION TIME t2 OR MORE?
YES
NO
S23
DETERMINE SHORTAGE OF REFRIGERANT
S24
ALERT
RETURN

INTERNATIONAL SEARCH REPORT

International application No. **PCT/JP2023/032832**

A. CLASSIFICATION OF SUBJECT MATTER

F25B 49/02(2006.01)i; ***F25B 1/00***(2006.01)i; ***F25B 43/00***(2006.01)i
FI: F25B49/02 520Z; F25B1/00 331E; F25B1/00 396D; F25B43/00 L

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F25B49/02; F25B1/00

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2023
Registered utility model specifications of Japan 1996-2023
Published registered utility model applications of Japan 1994-2023

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 Y	JP 2013-164242 A (PANASONIC CORP) 22 August 2013 (2013-08-22) paragraphs [0011]-[0015], [0032], [0065], [0068]-[0071], fig. 1-2	1-3, 6, 8 1-8
Y	JP 2008-96051 A (MITSUBISHI HEAVY IND LTD) 24 April 2008 (2008-04-24) paragraphs [0023]-[0024], [0030]-[0035], fig. 1, 3	1-8
Y	WO 2021/048905 A1 (MITSUBISHI ELECTRIC CORPORATION) 18 March 2021 (2021-03-18) paragraphs [0036]-[0038], fig. 3	3, 5
Y	JP 2019-43422 A (SANDEN AUTOMOTIVE CLIMATE SYSTEMS CORP) 22 March 2019 (2019-03-22) paragraphs [0103]-[0106], fig. 7	4
A	JP 2018-141607 A (MITSUBISHI HEAVY IND THERMAL SYSTEMS LTD) 13 September 2018 (2018-09-13) paragraphs [0034]-[0036], [0039], fig. 2, 4-5	1-2, 7-8

☑ 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
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 November 2023	**21 November 2023**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Telephone No.

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2023/032832

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 6-273013 A (TOSHIBA CORP) 30 September 1994 (1994-09-30) paragraph [0013], fig. 1, 3	2-5

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/032832

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2013-164242 A	22 August 2013	(Family: none)	
JP 2008-96051 A	24 April 2008	(Family: none)	
WO 2021/048905 A1	18 March 2021	EP 4030122 A1 paragraphs [0036]-[0038], fig. 3 CN 114364934 A	
JP 2019-43422 A	22 March 2019	WO 2019/049636 A1	
JP 2018-141607 A	13 September 2018	EP 3561413 A1 paragraphs [0050]-[0053], [0062], fig. 2, 4-5 CN 110199163 A WO 2018/159202 A1	
JP 6-273013 A	30 September 1994	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2019184231 A **[0003]**