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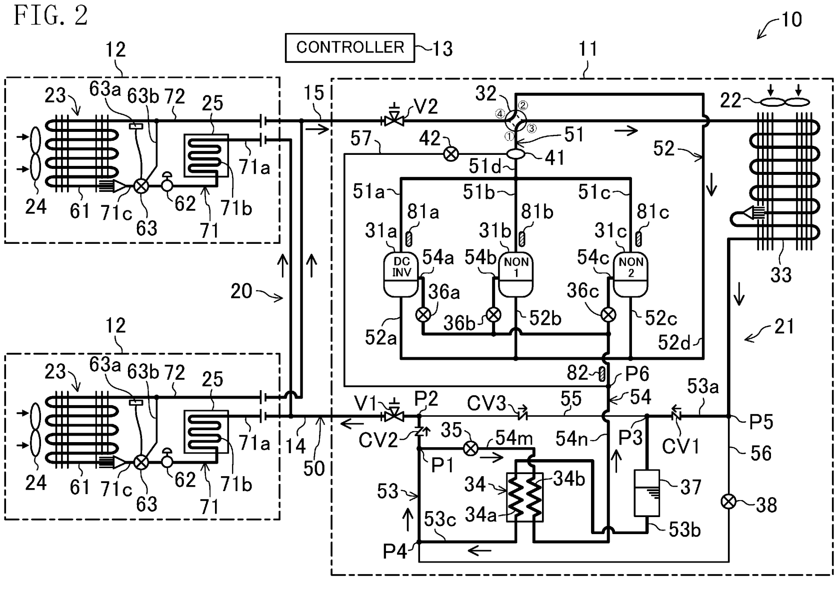
(54) REFRIGERATION APPARATUS

(57) A control section (13) performs first and second degree-of-opening adjusting operations in a cooling mode. In the first degree-of-opening adjusting operation, the control section (13) adjusts the degree of opening of an intermediate expansion valve (36a, 36b, 36c) such that the temperature (Td) of a refrigerant discharged from a compressor (31 a, 31b, 31c) is below a higher discharged refrigerant temperature threshold (Tdth). In the second degree-of-opening adjusting operation, the control section (13) adjusts the degree of opening of a supercooling expansion valve (35) such that the temperature of a refrigerant flowing through a portion of an injection pipe (54) between a supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is above a freezing temperature threshold (Tfth).

FIG. 2



EP 3 290 825 A1

Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] A refrigeration apparatus using a refrigeration cycle has been known in the art. Such a refrigeration apparatus has been widely used to cool the interiors of a refrigerator and a freezer and condition inside air. For example, Patent Document 1 discloses a refrigeration apparatus including a refrigerant circuit that circulates a refrigerant therethrough to perform a refrigeration cycle. The refrigerant circuit includes a compressor, a heat-source-side heat exchanger, an expansion valve, and a utilization-side heat exchanger. The utilization-side heat exchanger is provided in a freezer. The refrigeration apparatus of Patent Document 1 operates in a cooling mode. In the cooling mode, the utilization-side heat exchanger allows a refrigerant to absorb heat from inside air, and to evaporate. Thus, the air in the freezer is cooled. The refrigerant circuit is provided with a supercooling heat exchanger and a supercooling expansion valve.

CITATION LIST

PATENT DOCUMENTS

[0003] [Patent Document 1] Japanese Unexamined Patent Publication No. 2009-287800

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0004] In the refrigeration apparatus of Patent Document 1, the refrigerant circuit is provided with a liquid refrigerant pipe through which the liquid end of the heat-source-side heat exchanger and the liquid end of the utilization-side heat exchanger are connected together, and an injection pipe through which an intermediate portion of the liquid refrigerant pipe and an intermediate port of the compressor are connected together. The supercooling heat exchanger is connected to the liquid refrigerant pipe and the injection pipe, and is configured to exchange heat between a refrigerant flowing through the liquid refrigerant pipe and a refrigerant flowing through the injection pipe. The supercooling expansion valve is disposed on a portion of the injection pipe between the intermediate portion of the liquid refrigerant pipe and the supercooling heat exchanger.

[0005] In the cooling mode, the supercooling heat exchanger allows a refrigerant (high-pressure refrigerant) that has flowed from the heat-source-side heat exchanger through the liquid refrigerant pipe into the supercooling heat exchanger to have its heat absorbed by a refrigerant (intermediate-pressure refrigerant) that has flowed from the supercooling expansion valve through the injection pipe into the supercooling heat exchanger, and to be supercooled. This can enhance the cooling capability of the utilization-side heat exchanger. The refrigerant (intermediate-pressure refrigerant) is supplied from the supercooling heat exchanger through the injection pipe to the intermediate port of the compressor. This can reduce the temperature of the refrigerant in the compressor (specifically, the internal temperature of a compression chamber at intermediate pressure) to reduce the temperature of the refrigerant discharged from the compressor. Thus, the compressor can be protected from abnormally high temperatures.

[0006] However, in the refrigeration apparatus of Patent Document 1, if the pressure of a refrigerant (intermediate-pressure refrigerant) flowing from the supercooling expansion valve into the supercooling heat exchanger decreases in the injection pipe, so that the evaporation temperature of a refrigerant (intermediate-pressure refrigerant) in the supercooling heat exchanger decreases, the temperature of a refrigerant traveling from the supercooling heat exchanger toward the intermediate port of the compressor may decrease in the injection pipe, and the injection pipe may thus be frozen. If the degree to which the injection pipe is frozen increases, ice formed on the injection pipe may cause the injection pipe to buckle, or may come into contact with any other component (e.g., a casing) of the refrigeration apparatus to create vibrations or noise.

[0007] It is therefore an object of the present disclosure to provide a refrigeration apparatus that can protect a compressor from abnormally high temperatures and reduce the degree to which an injection pipe is frozen.

SOLUTION TO THE PROBLEM

[0008] A first aspect of the disclosure is directed to a refrigeration apparatus including a refrigerant circuit (20) and a control section (13). The refrigerant circuit (20) includes a compressor (31a, 31b, 31c), a heat-source-side heat exchanger (33), a utilization-side heat exchanger (61), a liquid refrigerant pipe (50) connecting a liquid end of the heat-source-side heat exchanger (33) to a liquid end of the utilization-side heat exchanger (61), an injection pipe (54) connecting an intermediate portion (P1) of the liquid refrigerant pipe (50) to an intermediate port of the compressor (31a, 31b, 31c), a supercooling heat exchanger (34) connected to the liquid refrigerant pipe (50) and the injection pipe (54) to exchange heat between a refrigerant flowing through the liquid refrigerant pipe (50) and a refrigerant flowing through the injection pipe (54), a supercooling expansion valve (35) provided on a portion of the injection pipe (54) between the intermediate portion (P1) of the liquid refrigerant pipe (50) and the supercooling heat exchanger (34), and an intermediate expansion valve (36a, 36b, 36c) provided on a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate port of the compressor (31a, 31b, 31c). The control section (13) is configured to perform first and second degree-of-opening adjusting operations in a cooling mode in which the refrigerant circuit (20) performs a refrigeration cycle where the heat-source-side heat exchanger (33) functions as a condenser, the supercooling heat exchanger (34) functions as a supercooler, and the utilization-side heat exchanger (61) functions as an evaporator. A degree of opening of the intermediate expansion valve (36a, 36b, 36c) is adjusted in the first degree-of-opening adjusting operation such that a temperature (Td) of a refrigerant discharged from the compressor (31 a, 31b, 31 c) is below a predetermined higher discharged refrigerant temperature threshold (Tdth). A degree of opening of the supercooling expansion valve (35) is adjusted in the second degree-of-opening adjusting operation such that a temperature of a refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is above a predetermined freezing temperature threshold (Tfth).

[0009] According to the first aspect, the degree of opening of the intermediate expansion valve (36a, 36b, 36c) can be adjusted in the first degree-of-opening adjusting operation to adjust the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31a, 31b, 31c). As a result, how much the temperature of the refrigerant in the compressor (31a, 31b, 31c) is to decrease can be adjusted. This allows the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) to be adjusted. Adjusting the degree of opening of the supercooling expansion valve (35) in the second degree-of-opening adjusting operation allows the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the supercooling heat exchanger (34) in the injection pipe (54) to be adjusted. Thus, the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) can be adjusted.

[0010] According to a second aspect of the disclosure which is an embodiment of the first aspect, if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) may perform the second degree-of-opening adjusting operation, and if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is not below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) may increase the degree of opening of the supercooling expansion valve (35).

[0011] According to the second aspect, increasing the degree of opening of the supercooling expansion valve (35) can increase the flow rate of the refrigerant flowing from the supercooling expansion valve (35) into the supercooling heat exchanger (34) in the injection pipe (54), and thus can increase the flow rate (injection amount) of the refrigerant flowing from the supercooling heat exchanger (34) through the intermediate expansion valve (36a, 36b, 36c) into the intermediate port of the compressor (31a, 31b, 31c). This can increase how much the temperature of the refrigerant in the compressor (31a, 31b, 31c) is to decrease, and can reduce the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c). Increasing the degree of opening of the supercooling expansion valve (35) can increase the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the supercooling heat exchanger (34) in the injection pipe (54). Thus, the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) can be increased.

[0012] According to a third aspect of the disclosure which is an embodiment of the first or second aspect, in the first degree-of-opening adjusting operation, if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) may adjust the degree of opening of the intermediate expansion valve (36a, 36b, 36c) such that a degree of superheat of the refrigerant discharged from the compressor (31a, 31b, 31c) is equal to a predetermined target degree of superheat, and if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is not below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) may increase the degree of opening of the intermediate expansion valve (36a, 36b, 36c).

[0013] According to the third aspect, increasing the degree of opening of the intermediate expansion valve (36a, 36b, 36c) triggers an increase in the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31a, 31b, 31c). This can increase how much the temperature of the refrigerant in the compressor (31a, 31b, 31c) is to decrease, and can reduce the temperature (Td) of the refrigerant discharged from the compressor (31 a, 31 b, 31 c).

[0014] According to a fourth aspect of the disclosure which is an embodiment of any one of the first through third aspects, in the second degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth), the control section (13) may reduce the degree of opening of the supercooling expansion valve (35), and if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), the control section (13) may increase the degree of opening of the supercooling expansion valve (35).

[0015] According to the fourth aspect, reducing the degree of opening of the supercooling expansion valve (35) triggers a reduction in the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the supercooling heat exchanger (34) in the injection pipe (54). This can increase the degree of subcooling of the refrigerant in the supercooling heat exchanger (34). On the other hand, increasing the degree of opening of the supercooling expansion valve (35) can increase the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the supercooling heat exchanger (34) in the injection pipe (54). Thus, the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) can be increased.

[0016] According to a fifth aspect of the disclosure which is an embodiment of any one of the first through fifth aspects, the refrigerant circuit (20) may include an oil separator (41) configured to separate refrigerating machine oil from the refrigerant discharged from the compressor (31a, 31b, 31c), an oil return pipe (57) having two ends respectively connected to the oil separator (41) and an intermediate portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c), and an oil return expansion valve (42) provided on the oil return pipe (57), and in the cooling mode, the control section (13) may perform a third degree-of-opening adjusting operation in which a degree of opening of the oil return expansion valve (42) is adjusted such that a temperature of a refrigerant flowing through a portion of the injection pipe (54) between a junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth).

[0017] According to the fifth aspect, adjusting the degree of opening of the oil return expansion valve (42) in the third degree-of-opening adjusting operation allows the flow rate of refrigerating machine oil (relatively high-temperature refrigerating machine oil) flowing from the oil separator (41) through the oil return pipe (57) into the injection pipe (54) to be adjusted. Thus, the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) can be adjusted.

[0018] According to a sixth aspect of the disclosure which is an embodiment of the fifth aspect, in the third degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth), the control section (13) may intermittently place the oil return expansion valve (42) in an open state so that a flow rate of refrigerating machine oil passing through the oil return pipe (57) within a predetermined unit period of time is equal to a predetermined flow rate, and if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), the control section (13) may intermittently place the oil return expansion valve (42) in the open state so that the flow rate of the refrigerating machine oil passing through the oil return pipe (57) within the predetermined unit period of time increases.

[0019] According to the sixth aspect, increasing the flow rate of the refrigerating machine oil (relatively high-temperature refrigerating machine oil) passing through the oil return pipe (57) within a predetermined unit period of time triggers an increase in the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c).

ADVANTAGES OF THE INVENTION

[0020] According to the first aspect of the disclosure, adjusting the degree of opening of an intermediate expansion valve (36a, 36b, 36c) in a first degree-of-opening adjusting operation allows the temperature (Td) of a refrigerant discharged from a compressor (31 a, 31b, 31c) to be adjusted so that the temperature (Td) is below a higher discharged refrigerant temperature threshold (Tdth). Thus, the compressor (31a, 31b, 31c) can be protected from abnormally high temperatures. Furthermore, adjusting the degree of opening of a supercooling expansion valve (35) in a second degree-of-opening adjusting operation allows the temperature of a refrigerant flowing through a portion of an injection pipe (54) between a supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) to be adjusted so that the temperature of the refrigerant is above a freezing temperature threshold (Tfth). This can reduce the degree to which the injection pipe (54) is frozen.

[0021] According to the second aspect of the disclosure, if the temperature (Td) of the refrigerant discharged from the compressor (31 a, 31 b, 31 c) is not below the higher discharged refrigerant temperature threshold (Tdth), increasing the degree of opening of the supercooling expansion valve (35) can reduce the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c), and can increase the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c). Thus, the compressor (31a, 31b, 31c) can be protected from abnormally high temperatures, and the degree to which the injection pipe (54) is frozen can be reduced.

[0022] According to the third aspect of the disclosure, in the first degree-of-opening adjusting operation, if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is not below the higher discharged refrigerant temperature threshold (Tdth), increasing the degree of opening of the intermediate expansion valve (36a, 36b, 36c) can reduce the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c). Thus, the compressor (31a, 31b, 31c) can be protected from abnormally high temperatures.

[0023] According to the fourth aspect of the disclosure, in the second degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth), reducing the degree of opening of the supercooling expansion valve (35) can increase the degree of subcooling of the refrigerant in the supercooling heat exchanger (34). This can enhance the cooling capability of the utilization-side heat exchanger (61). On the other hand, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), increasing the degree of opening of the supercooling expansion valve (35) triggers an increase in the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c). This can reduce the degree to which the injection pipe (54) is frozen.

[0024] According to the fifth aspect of the disclosure, adjusting the degree of opening of an oil return expansion valve (42) in a third degree-of-opening adjusting operation allows the temperature of a refrigerant flowing through a portion of the injection pipe (54) between a junction (P6) of the injection pipe (54) and an oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) to be adjusted so that the temperature of the refrigerant is above the freezing temperature threshold (Tfth). This can reduce the degree to which the injection pipe (54) is frozen.

[0025] According to the sixth aspect of the disclosure, in the third degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), increasing the flow rate of the refrigerating machine oil (relatively high-temperature refrigerating machine oil) passing through the oil return pipe (57) within a predetermined unit period of time triggers an increase in the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c). This can reduce the degree to which the injection pipe (54) is frozen.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026]

[FIG. 1] FIG. 1 is a piping system diagram showing an exemplary configuration for a refrigeration apparatus according to an embodiment.

[FIG. 2] FIG. 2 is a piping system diagram for explaining an operation in a cooling mode.

[FIG. 3] FIG. 3 is a piping system diagram for explaining an operation in a defrosting mode.

[FIG. 4] FIG. 4 is a flowchart for explaining how the degree of opening of an intermediate expansion valve is adjusted.

[FIG. 5] FIG. 5 is a flowchart for explaining how the degree of opening of a supercooling expansion valve is adjusted.

[FIG. 6] FIG. 6 is a flowchart for explaining how the degree of opening of an oil return expansion valve is adjusted.

DETAILED DESCRIPTION

[0027] Embodiments will now be described in detail with reference to the drawings. Note that like reference characters denote the same or equivalent components in the drawings, and the description thereof will not be repeated.

(Refrigeration Apparatus)

[0028] FIG. 1 shows an exemplary configuration for a refrigeration apparatus (10) according to an embodiment. The refrigeration apparatus (10) includes a heat-source-side unit (11), a plurality of (in this example, two) utilization-side units (12) connected in parallel to the heat-source-side unit (11), and a controller (13). For example, the heat-source-side unit (11) is provided outdoors, and the utilization-side units (12) are provided indoors.

[0029] The heat-source-side unit (11) is provided with a heat-source-side circuit (21) and a heat-source-side fan (22). Each utilization-side unit (12) is provided with a utilization-side circuit (23), a utilization-side fan (24), and a drain pan (25). In this refrigeration apparatus (10), the heat-source-side circuit (21) of the heat-source-side unit (11) and the utilization-side circuits (23) of the utilization-side units (12) are connected together through a liquid interconnecting pipe (14) and a gas interconnecting pipe (15) to form a refrigerant circuit (20) that circulates a refrigerant therethrough to perform a vapor compression refrigeration cycle.

[0030] Specifically, the heat-source-side circuit (21) has liquid and gas ends respectively provided with a liquid stop valve (V1) and a gas stop valve (V2). The liquid stop valve (V1) and the gas stop valve (V2) are respectively connected to one end of the liquid interconnecting pipe (14) and one end of the gas interconnecting pipe (15).

The liquid interconnecting pipe (14) is connected to the liquid ends of the utilization-side circuits (23), and the gas interconnecting pipe (15) is connected to the gas ends of the utilization-side circuits (23).

<Heat-Source-Side Circuit>

[0031] The heat-source-side circuit (21) includes first through third compressors (31a-31c), a four-way valve (32), a heat-source-side heat exchanger (33), a supercooling heat exchanger (34), a supercooling expansion valve (35), first through third intermediate expansion valves (36a-36c), a receiver (37), a heat-source-side expansion valve (38), first through third check valves (CV1-CV3), an oil separator (41), and an oil return expansion valve (42). The heat-source-side circuit (21) is provided with a discharge refrigerant pipe (51), a suction refrigerant pipe (52), a heat-source-side liquid refrigerant pipe (53), an injection pipe (54), a first connection pipe (55), a second connection pipe (56), and an oil return pipe (57). In the following description, the first through third compressors (31a-31c) are collectively referred to as "the compressor (31a, 31b, 31c)," and the first through third intermediate expansion valves (36a-36c) are collectively referred to as "the intermediate expansion valve (36a, 36b, 36c)."

«Compressors»

[0032] The compressor (31a, 31b, 31c) is configured to compress, and discharge, a refrigerant sucked thereinto. The compressor (31a, 31b, 31c) has a suction port, an intermediate port, and a discharge port. The suction port communicates with a compression chamber (i.e., a compression chamber in a low pressure phase) during a suction stroke of the compressor (31a, 31b, 31c). The intermediate port communicates with a compression chamber (i.e., a compression chamber in an intermediate pressure phase) in the middle of a compression stroke of the compressor (31a, 31b, 31c). The discharge port communicates with a compression chamber (i.e., a compression chamber in a high pressure phase) during a discharge stroke of the compressor (31a, 31b, 31c). The compressor (31a, 31b, 31c) is configured as, for example, a scroll compressor including a compression chamber defined between a fixed scroll and an orbiting scroll, which mesh with each other.

[0033] Note that in this example, the first compressor (31a) has a variable capacity. Specifically, changing the output frequency of an inverter (not shown) triggers a change in the rotational speed of an electric motor provided inside the first compressor (31a). This causes the capacity of the first compressor (31a) to vary. The second and third compressors (31b, 31c) each have a fixed capacity. Specifically, the second and third compressors (31b, 31c) each include therein an electric motor rotating at a constant rotational speed, and each have a constant capacity.

«Four-Way Valve»

[0034] The four-way valve (32) is switchable between a first state (indicated by the solid curves shown in FIG. 1) and a second state (indicated by the dashed curves shown in FIG. 1). In the first state, a first port communicates with a third port, and a second port communicates with a fourth port. In the second state, the first port communicates with the fourth port, and the second port communicates with the third port.

[0035] The first port of the four-way valve (32) is connected to the discharge ports of the compressors (31a, 31b, 31c) through the discharge refrigerant pipe (51). The second port of the four-way valve (32) is connected to the suction ports of the compressors (31a, 31b, 31c) through the suction refrigerant pipe (52). The third port of the four-way valve (32) is connected to the gas end of the heat-source-side heat exchanger (33). The fourth port of the four-way valve (32) is connected to the gas stop valve (V2).

<<Discharge Refrigerant Pipe, Suction Refrigerant Pipe>>

[0036] In this example, the discharge refrigerant pipe (51) includes first, second, and third discharge pipes (51a, 51b, 51c) one end of each of which is connected to the discharge port of an associated one of the first, second and third compressors (31a, 31b,31c), and a discharge collection pipe (51d) connecting the other end of each of the first, second and third discharge pipes (51a, 51b, 51c) to the first port of the four-way valve (32). The suction refrigerant pipe (52) includes first, second, and third suction pipes (52a, 52b, 52c) one end of each of which is connected to the suction port of an associated one of the first, second and third compressors (31a, 31b, 31c), and a main suction pipe (52d) connecting the other end of each of the first, second and third suction pipes (52a, 52b, 52c) to the second port of the four-way valve (32).

«Heat-Source-Side Heat Exchanger»

[0037] The heat-source-side heat exchanger (33) has its liquid end connected to one end of the heat-source-side liquid refrigerant pipe (53), and has its gas end connected to the third port of the four-way valve (32). The heat-source-side fan (22) is disposed near the heat-source-side heat exchanger (33). The heat-source-side heat exchanger (33) is configured to exchange heat between a refrigerant and heat-source-side air (e.g., outdoor air) transferred by the heat-source-side fan (22). The heat-source-side heat exchanger (33) is configured as, for example, a cross-fin, fin-and-tube heat exchanger.

<<Heat-Source-Side Liquid Refrigerant Pipe>>

[0038] The heat-source-side liquid refrigerant pipe (53) has two ends respectively connected to the heat-source-side heat exchanger (33) and the liquid stop valve (V1). In this example, the heat-source-side liquid refrigerant pipe (53) includes a first heat-source-side liquid pipe (53a) connecting the liquid end of the heat-source-side heat exchanger (33) to the receiver (37), a second heat-source-side liquid pipe (53b) connecting the receiver (37) to the supercooling heat exchanger (34), and a third heat-source-side liquid pipe (53c) connecting the supercooling heat exchanger (34) to the liquid stop valve (V1).

«Injection Pipe»

[0039] The injection pipe (54) connects a first intermediate portion (P1) of the heat-source-side liquid refrigerant pipe (53) to the intermediate ports of the compressors (31a, 31b, 31c). In this example, the injection pipe (54) includes a first main injection pipe (54m) connecting the first intermediate portion (P1) of the heat-source-side liquid refrigerant pipe (53) to the supercooling heat exchanger (34), a second main injection pipe (54n) one end of which is connected to the supercooling heat exchanger (34), and first, second, and third injection branch pipes (54a, 54b, 54c) each connecting the other end of the second main injection pipe (54n) to the intermediate port of an associated one of the first, second, and third compressors (31a, 31b, 31c). In the following description, the first, second, and third injection branch pipes (54a, 54b, 54c) are collectively referred to as "the injection branch pipe (54a, 54b, 54c)."

«Supercooling Heat Exchanger»

[0040] The supercooling heat exchanger (34) is connected to the heat-source-side liquid refrigerant pipe (53) and the injection pipe (54), and is configured to exchange heat between a refrigerant flowing through the heat-source-side liquid refrigerant pipe (53) and a refrigerant flowing through the injection pipe (54). In this example, the supercooling heat exchanger (34) has first channels (34a) connected between the second heat-source-side liquid pipe (53b) and the third heat-source-side liquid pipe (53c), and second channels (34b) connected between the first main injection pipe (54m) and the second main injection pipe (54n), and is configured to exchange heat between a refrigerant flowing through the first channels (34a) and a refrigerant flowing through the second channels (34b). The supercooling heat exchanger (34) is configured as, for example, a plate heat exchanger.

<<Supercooling Expansion Valve>>

[0041] The supercooling expansion valve (35) is provided on a portion of the injection pipe (54) between the first intermediate portion (P1) of the heat-source-side liquid refrigerant pipe (53) and the supercooling heat exchanger (34) (in this example, on the first main injection pipe (54m)). The supercooling expansion valve (35) has an adjustable degree of opening. The supercooling expansion valve (35) is configured as, for example, an electronic expansion valve (motor-operated valve).

<<Intermediate Expansion Valves>>

[0042] The intermediate expansion valve (36a, 36b, 36c) is disposed on a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate port of the compressor (31a, 31b, 31c). In this example, the first, second, and third intermediate expansion valves (36a, 36b, 36c) are associated with the first, second, and third compressors (31 a, 31 b, 31 c), respectively, and are provided on the first, second, and third injection branch pipes (54a, 54b, 54c), respectively. The intermediate expansion valves (36a, 36b, 36c) also have an adjustable degree of opening. The intermediate expansion valves (36a, 36b, 36c) are configured as, for example, electronic expansion valves (motor-operated valves).

<<Receiver>>

[0043] The receiver (37) is connected to a portion of the heat-source-side liquid refrigerant pipe (53) between the heat-source-side heat exchanger (33) and the supercooling heat exchanger (34), and is capable of temporarily storing a refrigerant condensed in the condenser (specifically, the heat-source-side heat exchanger (33) or the utilization-side heat exchangers (61)). In this example, the receiver (37) has its top and bottom respectively connected to the first and second heat-source-side liquid pipes (53a, 53b).

<<Connection Pipes>>

[0044] The first connection pipe (55) connects second and third intermediate portions (P2, P3) of the heat-source-side liquid refrigerant pipe (53) together. The second intermediate portion (P2) is a portion of the heat-source-side liquid refrigerant pipe (53) between the first intermediate portion (P1) and the liquid stop valve (V1), and the third intermediate portion (P3) is a portion of the heat-source-side liquid refrigerant pipe (53) between the liquid end of the heat-source-side heat exchanger (33) and the receiver (37).

[0045] The second connection pipe (56) connects fourth and fifth intermediate portions (P4, P5) of the heat-source-side liquid refrigerant pipe (53) together. The fourth intermediate portion (P4) is a portion of the heat-source-side liquid refrigerant pipe (53) between the supercooling heat exchanger (34) and the first intermediate portion (P1), and the fifth intermediate portion (P5) is a portion of the heat-source-side liquid refrigerant pipe (53) between the liquid end of the heat-source-side heat exchanger (33) and the third intermediate portion (P3).

<<Heat-Source-Side Expansion Valve>>

[0046] The heat-source-side expansion valve (38) is provided on the second connection pipe (56). The heat-source-side expansion valve (38) has an adjustable degree of opening. The heat-source-side expansion valve (38) is configured as, for example, an electronic expansion valve (motor-operated valve).

<<Check Valves>>

[0047] The first check valve (CV1) is provided on a portion of the heat-source-side liquid refrigerant pipe (53) between the third and fifth intermediate portions (P3, P5), and is configured to allow a refrigerant to flow only in a direction from the fifth intermediate portion (P5) toward the third intermediate portion (P3). The second check valve (CV2) is provided on a portion of the heat-source-side liquid refrigerant pipe (53) between the first and second intermediate portions (P1, P2), and is configured to allow a refrigerant to flow only in a direction from the first intermediate portion (P1) toward the second intermediate portion (P2). The third check valve (CV3) is provided on the first connection pipe (55), and is configured to allow a refrigerant to flow only in a direction from the second intermediate portion (P2) toward the third intermediate portion (P3) of the heat-source-side liquid refrigerant pipe (53).

<<Oil Separator>>

[0048] The oil separator (41) is provided on the discharge refrigerant pipe (51) (in this example, the discharge collection pipe (51d)), and is capable of separating refrigerating machine oil from a refrigerant discharged from the compressors (31 a, 31b, 31c) and storing therein the refrigerating machine oil.

<<Oil Return Pipe>>

[0049] The oil return pipe (57) is used to supply the refrigerating machine oil (relatively high-temperature refrigerating machine oil) stored in the oil separator (41) to the injection pipe (54), and has two ends respectively connected to the oil separator (41) and an intermediate portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) (in this example, an intermediate portion of the second main injection pipe (54n)).

<<Oil Return Expansion Valve>>

[0050] The oil return expansion valve (42) is provided on the oil return pipe (57). The oil return expansion valve (42) has an adjustable degree of opening. The oil return expansion valve (42) is configured as, for example, an electronic expansion valve (motor-operated valve).

<Utilization-Side Circuits>

[0051] Each utilization-side circuit (23) includes a utilization-side heat exchanger (61), a utilization-side open/close valve (62), and a utilization-side expansion valve (63). The utilization-side circuit (23) is provided with a utilization-side liquid refrigerant pipe (71) and a utilization-side gaseous refrigerant pipe (72).

<<Utilization-Side Heat Exchanger>>

[0052] The utilization-side heat exchanger (61) has its liquid end connected to the liquid interconnecting pipe (14) through the utilization-side liquid refrigerant pipe (71), and has its gas end connected to the gas interconnecting pipe (15) through the utilization-side gaseous refrigerant pipe (72). The utilization-side fan (24) is disposed near the utilization-side heat exchanger (61). The utilization-side heat exchanger (61) is configured to exchange heat between a refrigerant and utilization-side air (e.g., inside air) transferred by the utilization-side fan (24). The utilization-side heat exchanger (61) is configured as, for example, a cross-fin, fin-and-tube heat exchanger.

<<Utilization-Side Liquid Refrigerant Pipe, Utilization-Side Gaseous Refrigerant Pipe>>

[0053] One end of the utilization-side liquid refrigerant pipe (71) is connected to the liquid interconnecting pipe (14), and the other end thereof is connected to the liquid end of the utilization-side heat exchanger (61). In this example, the utilization-side liquid refrigerant pipe (71) includes a first utilization-side liquid pipe (71a) one end of which is connected to the liquid interconnecting pipe (14), a drain pan pipe (71b) one end of which is connected to the other end of the first utilization-side liquid pipe (71a), and a second utilization-side liquid pipe (71c) connecting the other end of the drain pan pipe (71b) to the liquid end of the utilization-side heat exchanger (61). One end of the utilization-side gaseous refrigerant pipe (72) is connected to the gas end of the utilization-side heat exchanger (61), and the other end thereof is connected to the gas interconnecting pipe (15).

<<Utilization-Side Open/Close Valve, Utilization-Side Expansion Valve>>

[0054] The utilization-side open/close valve (62) and the utilization-side expansion valve (63) are arranged in series on the utilization-side liquid refrigerant pipe (71) (in this example, the second utilization-side liquid pipe (71c)).

[0055] The utilization-side open/close valve (62) is switchable between an open state and a closed state. The utilization-side open/close valve (62) is configured as, for example, a solenoid valve. The utilization-side expansion valve (63) has an adjustable degree of opening.

In this example, the utilization-side expansion valve (63) is configured as an externally equalized thermostatic expansion valve. Specifically, the utilization-side expansion valve (63) includes a feeler bulb (63a) provided on the utilization-side gaseous refrigerant pipe (72), and an equalizer (63b) connected to an intermediate portion of the utilization-side gaseous refrigerant pipe (72), and has its degree of opening adjusted in accordance with the temperature of the feeler bulb (63a) and the pressure of a refrigerant in the equalizer (63b).

<Drain Pan>

[0056] The drain pan (25) is disposed below the utilization-side heat exchanger (61), and is configured to collect frost and condensed water dropped from the surface of the utilization-side heat exchanger (61). The drain pan pipe (71b) that is a portion of the utilization-side liquid refrigerant pipe (71) is disposed in the drain pan (25).

<Liquid Refrigerant Pipe>

[0057] In the refrigerant circuit (20), the heat-source-side liquid refrigerant pipe (53) and the liquid interconnecting pipe (14) form a liquid refrigerant pipe (50). That is to say, the liquid end of the heat-source-side heat exchanger (33) is connected to the liquid refrigerant pipe (50). The utilization-side liquid refrigerant pipe (71) connects the liquid end of the utilization-side heat exchanger (61) to the liquid refrigerant pipe (50). The injection pipe (54) connects an intermediate portion (the first intermediate portion (P1)) of the liquid refrigerant pipe (50) to the intermediate ports of the compressors (31a, 31b, 31c). The supercooling heat exchanger (34) is connected to the liquid refrigerant pipe (50) and the injection pipe (54), and is configured to exchange heat between a refrigerant flowing through the liquid refrigerant pipe (50) and a refrigerant flowing through the injection pipe (54).

<<Various Sensors>>

[0058] The refrigeration apparatus (10) is provided with various sensors such as first through third discharged refrigerant temperature sensors (81a-81c) and an injection refrigerant temperature sensor (82). In the following description, the first through third discharged refrigerant temperature sensors (81a-81c) are collectively referred to as "the discharged refrigerant temperature sensor (81a, 81b, 81c)."

[0059] The discharged refrigerant temperature sensor (81a, 81b, 81c) is configured to sense the temperature of a refrigerant discharged from the compressor (31 a, 31b, 31 c) (hereinafter referred to as the discharged refrigerant temperature (Td)). In this example, the first, second, and third discharged refrigerant temperature sensors (81 a, 81b, 81c) are respectively associated with the first, second, and third intermediate expansion valves (36a, 36b, 36c) and installed near the discharge ports of the first, second, and third compressors (31a, 31b, 31c), and sense the temperatures of refrigerants at their respective installation sites as the discharged refrigerant temperatures (Td).

[0060] The injection refrigerant temperature sensor (82) is configured to sense the temperature of a refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) (beneficially, between a junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valves (36a, 36b, 36c)). In this example, the injection refrigerant temperature sensor (82) is installed on a portion of the second main injection pipe (54n) between the junction (P6) and the intermediate expansion valves (36a, 36b, 36c) to sense the temperature of a refrigerant at its installation site as the temperature of a refrigerant flowing through a portion of the second main injection pipe (54n) between the junction (P6) and the intermediate expansion valves (36a, 36b, 36c) (hereinafter referred to as the injection refrigerant temperature (Tinj)).

<Controller (Control Section)>

[0061] The controller (13) controls components of the refrigeration apparatus (10) to control operations of the refrigeration apparatus (10). Specifically, the controller (13) controls the compressors (31a, 31b, 31c), the various fans (the heat-source-side fan (22), and the utilization-side fans (24)), and the various valves (the four-way valve (32), the supercooling expansion valve (35), the intermediate expansion valves (36a, 36b, 36c), the heat-source-side expansion valve (38), the oil return expansion valve (42), and the utilization-side open/close valves (62)), based on values sensed by the various sensors (the discharged refrigerant temperature sensors (81a, 81b, 81c), the injection refrigerant temperature sensor (82), and other sensors). Note that the refrigeration apparatus (10) operates in a cooling mode in which inside air is cooled, or in a defrosting mode in which the utilization-side heat exchangers (61) are defrosted.

<Cooling Mode>

[0062] Next, an operation in a cooling mode will be described with reference to FIG. 2. In the cooling mode, the refrigerant circuit (20) performs a refrigeration cycle in which the heat-source-side heat exchanger (33) functions as a condenser, the supercooling heat exchanger (34) functions as a supercooler, and the utilization-side heat exchangers (61) function as evaporators.

[0063] Specifically, the four-way valve (32) is placed in the first state. This allows the discharge ports of the compressors (31a, 31b, 31c) to communicate with the gas end of the heat-source-side heat exchanger (33), and allows the suction ports of the compressors (31a, 31b, 31c) to communicate with the gas interconnecting pipe (15). The compressors (31a, 31b, 31c), the heat-source-side fan (22), and the utilization-side fans (24) are placed in operation. Furthermore, the degrees of opening of the supercooling expansion valve (35) and the intermediate expansion valves (36a, 36b, 36c) are adjusted, the heat-source-side expansion valve (38) is placed in a fully-closed state, and the oil return expansion valve (42) is intermittently placed in an open state. In each utilization-side unit (12), the utilization-side open/close valve (62) is placed in either an open state or a closed state, in accordance with the load required to cool inside air, and the degree of opening of the utilization-side expansion valve (63) is adjusted in accordance with the temperature of the feeler bulb (63a) and the pressure of a refrigerant in the equalizer (63b), such that the degree of superheat of a refrigerant at an outlet of the utilization-side heat exchanger (61) is equal to a predetermined degree of superheat. Note that FIG. 2 shows a situation where the utilization-side open/close valves (62) of all of the utilization-side units (12) are placed in the open state.

[0064] A refrigerant discharged from the compressors (31 a, 31b, 31 c) passes through the oil separator (41) in the discharge refrigerant pipe (51), then flows through the four-way valve (32) into the heat-source-side heat exchanger (33), dissipates heat to the heat-source-side air (e.g., outdoor air) in the heat-source-side heat exchanger (33), and condenses. The refrigerant (high-pressure refrigerant) that has flowed out of the heat-source-side heat exchanger (33) passes through the first check valve (CV1) in the first heat-source-side liquid pipe (53a), then passes through the receiver (37) and the second heat-source-side liquid pipe (53b) in this order, flows into the first channels (34a) of the supercooling heat exchanger (34), and is supercooled by having its heat absorbed by a refrigerant (intermediate-pressure refrigerant) flowing through the second channels (34b) of the supercooling heat exchanger (34). The refrigerant that has flowed out of the first channels (34a) of the supercooling heat exchanger (34) flows into the third heat-source-side liquid pipe (53c). Part of the refrigerant that has flowed into the third heat-source-side liquid pipe (53c) flows into the first main injection pipe (54m). The remaining part passes through the second check valve (CV2) in the third heat-source-side liquid pipe (53c), and then flows through the liquid stop valve (V1) into the liquid interconnecting pipe (14).

[0065] The refrigerant that has flowed into the first main injection pipe (54m) is decompressed in the supercooling expansion valve (35), flows into the second channels (34b) of the supercooling heat exchanger (34), and absorbs heat from the refrigerant (high-pressure refrigerant) flowing through the first channels (34a) of the supercooling heat exchanger (34). The refrigerant that has flowed out of the second channels (34b) of the supercooling heat exchanger (34) flows through the second main injection pipe (54n) into the injection branch pipes (54a, 54b, 54c). The refrigerant that has flowed into each injection branch pipe (54a, 54b, 54c) is decompressed in an associated one of the intermediate expansion valves (36a, 36b, 36c), and flows into the intermediate port of an associated one of the compressors (31a, 31b, 31c). The refrigerant that has flowed through the intermediate port into the compressor (31a, 31b, 31c) is mixed with a refrigerant in the compressor (31a, 31b, 31c) (specifically, a refrigerant in the compression chamber). That is to say, the refrigerant in the compressor (31a, 31b, 31c) is compressed while being cooled.

[0066] Meanwhile, the refrigerant that has flowed into the liquid interconnecting pipe (14) flows into the first utilization-side liquid pipe (71 a) of the utilization-side unit (12) that has its utilization-side open/close valve (62) placed in the open state. In the utilization-side unit (12) having its utilization-side open/close valve (62) placed in the open state, the refrigerant that has flowed into the first utilization-side liquid pipe (71a) flows through the drain pan pipe (71b) into the second utilization-side liquid pipe (71c). The refrigerant that has flowed into the second utilization-side liquid pipe (71c) passes through the open utilization-side open/close valve (62), and is then decompressed in the utilization-side expansion valve (63). The decompressed refrigerant flows into the utilization-side heat exchanger (61), and absorbs heat from the utilization-side air (e.g., inside air) in the utilization-side heat exchanger (61) to evaporate. Thus, the utilization-side air is cooled. The refrigerant that has flowed out of the utilization-side heat exchanger (61) passes through the utilization-side gaseous refrigerant pipe (72), the gas interconnecting pipe (15), the gas stop valve (V2), the four-way valve (32), and the suction refrigerant pipe (52) in this order, and is sucked into the suction ports of the compressors (31a, 31b, 31c).

[0067] The oil separator (41) separates refrigerating machine oil from the refrigerant (i.e., the refrigerant discharged from the compressors (31a, 31b, 31c)), and stores therein the refrigerating machine oil. Then, if the oil return expansion valve (42) is placed in the open state, the refrigerating machine oil (relatively high-temperature refrigerating machine oil) stored in the oil separator (41) flows through the oil return pipe (57) into the second main injection pipe (54n). The flow of the refrigerating machine oil that has flowed into the second main injection pipe (54n) merges with the flow of a refrigerant flowing through the second main injection pipe (54n). Then, the merged refrigerant flows through the intermediate expansion valves (36a, 36b, 36c) in the injection branch pipes (54a, 54b, 54c) into the intermediate ports of the compressors (31a, 31b, 31c).

[0068] In the cooling mode, the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31a, 31b, 31c) can be adjusted by adjusting the degree of opening of the intermediate expansion valve (36a, 36b, 36c). Thus, how much the temperature of a refrigerant in the compressor (31a, 31b, 31c) is to decrease can be adjusted. As a result, the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c) (i.e., the discharged refrigerant temperature (Td)) can be adjusted. How the degree of opening of the intermediate expansion valve (36a, 36b, 36c) is adjusted in the cooling mode will be described in detail below.

[0069] In the cooling mode, the pressure of the refrigerant flowing through the supercooling expansion valve (35) into the second channels (34b) of the supercooling heat exchanger (34) in the injection pipe (54) can be adjusted by adjusting the degree of opening of the supercooling expansion valve (35). This allows the adjustment of the degree of supercooling of the refrigerant in the supercooling heat exchanger (34) (specifically, the degree of supercooling of the refrigerant flowing out of the first channels (34a) of the supercooling heat exchanger (34)) and the temperature of the refrigerant flowing between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) in the injection pipe (54). The flow rate of the refrigerant flowing through the supercooling expansion valve (35) into the second channels (34b) of the supercooling heat exchanger (34) in the injection pipe (54) can be adjusted by adjusting the degree of opening of the supercooling expansion valve (35). This allows the flow rates (injection amounts) of the refrigerant flowing from the second channels (34b) of the supercooling heat exchanger (34) through the intermediate expansion valves (36a, 36b, 36c) into the intermediate ports of the compressors (31a, 31b, 31c) to be adjusted. How the degree of opening of the supercooling expansion valve (35) is adjusted in the cooling mode will be described in detail below.

[0070] In the cooling mode, intermittently placing the oil return expansion valve (42) in the open state allows the refrigerating machine oil stored in the oil separator (41) to intermittently flow into the oil return pipe (57). Thus, the refrigerating machine oil can be effectively returned into the compressors (31a, 31b, 31c). How the degree of opening of the oil return expansion valve (42) is adjusted in the cooling mode will be described in detail below.

<Defrosting Mode>

[0071] Next, an operation in a defrosting mode will be described with reference to FIG. 3. In the defrosting mode, the refrigerant circuit (20) performs a refrigeration cycle in which the utilization-side heat exchangers (61) function as condensers and the heat-source-side heat exchanger (33) functions as an evaporator.

[0072] Specifically, the four-way valve (32) is placed in the second state. This allows the discharge ports of the compressors (31a, 31b, 31c) to communicate with the gas interconnecting pipe (15), and allows the suction ports of the compressors (31a, 31b, 31c) to communicate with the gas end of the heat-source-side heat exchanger (33). The compressors (31a, 31b, 31c) and the heat-source-side fan (22) are placed in operation, and the utilization-side fan (24) is placed at rest. Furthermore, the supercooling expansion valve (35) is placed in a fully-closed state. The intermediate expansion valves (36a, 36b, 36c) are placed in a fully-closed state. The degree of opening of the heat-source-side expansion valve (38) is adjusted such that the degree of superheat of the refrigerant at the outlet of the heat-source-side heat exchanger (33) is equal to a predetermined target degree of superheat. The oil return expansion valve (42) is placed in a fully-closed state. In each utilization-side unit (12), the utilization-side open/close valve (62) is placed in the open state, and the utilization-side expansion valve (63) is placed in the fully-open state.

[0073] The refrigerant discharged from the compressors (31 a, 31b, 31 c) passes through the oil separator (41) in the discharge refrigerant pipe (51), then passes through the four-way valve (32) and the gas stop valve (V2) in this order, and flows into the gas interconnecting pipe (15). The refrigerant that has flowed into the gas interconnecting pipe (15) flows into the utilization-side gaseous refrigerant pipes (72) of the utilization-side units (12). In each utilization-side unit (12), the refrigerant that has flowed into the utilization-side gaseous refrigerant pipe (72) flows into the utilization-side heat exchanger (61), and dissipates heat in the utilization-side heat exchanger (61) to condense. Thus, frost formed on the utilization-side heat exchanger (61) is heated to melt. The refrigerant that has flowed out of the utilization-side heat exchanger (61) flows into the second utilization-side liquid pipe (71c), passes through the fully open utilization-side expansion valve (63) and the open utilization-side open/close valve (62) in this order, passes through the drain pan pipe (71b) and the first utilization-side liquid pipe (71a) in this order, and flows into the liquid interconnecting pipe (14).

[0074] The refrigerant that has flowed into the liquid interconnecting pipe (14) flows through the liquid stop valve (V1) into the third heat-source-side liquid pipe (53c). The refrigerant that has flowed into the third heat-source-side liquid pipe (53c) flows into the first connection pipe (55), passes through the third check valve (CV3) in the first connection pipe (55), and flows into the first heat-source-side liquid pipe (53a). The refrigerant that has flowed into the first heat-source-side liquid pipe (53a) passes through the receiver (37), the second heat-source-side liquid pipe (53b), the first channels (34a) of the supercooling heat exchanger (34) in this order, and flows into the third heat-source-side liquid pipe (53c). The refrigerant that has flowed into the third heat-source-side liquid pipe (53c) flows into the second connection pipe (56). The refrigerant that has flowed into the second connection pipe (56) is decompressed in the heat-source-side expansion valve (38), and flows into the first heat-source-side liquid pipe (53a). The refrigerant that has flowed into the first heat-source-side liquid pipe (53a) flows into the heat-source-side heat exchanger (33), and absorbs heat from the heat-source-side air (e.g., outdoor air) in the heat-source-side heat exchanger (33) to evaporate. The refrigerant that has flowed out of the heat-source-side heat exchanger (33) passes through the four-way valve (32) and the suction refrigerant pipe (52) in this order, and is sucked into the suction ports of the compressors (31 a, 31b, 31 c).

[0075] In the defrosting mode, a refrigerant (high-temperature refrigerant) that has flowed out of the utilization-side heat exchanger (61) functioning as the condenser flows through the drain pan pipe (71b). This allows the refrigerant flowing through the drain pan pipe (71b) to heat, and melt, frost remaining in the drain pan (25) (i.e., frost collected in the drain pan (25) and ice blocks resulting from freezing of condensed water). Note that water resulting from melting of the remaining frost is discharged through a drainage pipe (not shown).

[Adjustment of Degrees of Opening of Intermediate Expansion Valves]

[0076] Next, how the degree of opening of the intermediate expansion valve (36a, 36b, 36c) is adjusted in the cooling mode will be described with reference to FIG. 4. The controller (13) performs a first degree-of-opening adjusting operation (steps (ST11-ST13)) every time a predetermined operating time elapses in the cooling mode. In the first degree-of-opening adjusting operation, the controller (13) adjusts the degree of opening of the intermediate expansion valve (36a, 36b, 36c) such that the discharged refrigerant temperature (Td) is below a predetermined higher discharged refrigerant temperature threshold (Tdth). In this example, the controller (13) performs the first degree-of-opening adjusting operation for each of the first through third intermediate expansion valves (36a-36c). For example, the controller (13) performs the first degree-of-opening adjusting operation for the first intermediate expansion valve (36a) associated with the first compressor (31a), based on the value sensed by the first discharged refrigerant temperature sensor (81a). In the first degree-of-opening adjusting operation, processes indicated below are performed.

<Step (ST11)>

[0077] First, the controller (13) determines whether or not the discharged refrigerant temperature (Td) is below the higher discharged refrigerant temperature threshold (Tdth) (step (ST11)). The higher discharged refrigerant temperature threshold (Tdth) is set to be, for example, the threshold (highest value such as 105°C) of the discharged refrigerant temperature (Td) which may be considered not to cause the compressor (31a, 31b, 31c) to have an abnormally high temperature. If the discharged refrigerant temperature (Td) is below the higher discharged refrigerant temperature threshold (Tdth), the process proceeds to step (ST12). If not, the process proceeds to step (ST13).

<Step (ST12): Control of Degree of Superheat of Discharged Refrigerant>

[0078] If the discharged refrigerant temperature (Td) is below the higher discharged refrigerant temperature threshold (Tdth), the controller (13) adjusts the degree of opening of the intermediate expansion valve (36a, 36b, 36c) such that the degree of superheat of the refrigerant discharged from the compressor (31a, 31b, 31c) (hereinafter referred to as the degree of discharged superheat) is equal to a predetermined target degree of superheat (e.g., 15°C).

[0079] Specifically, if the degree of discharged superheat is above the target degree of superheat, the controller (13) increases the degree of opening of the intermediate expansion valve (36a, 36b, 36c). This increases the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31 a, 31b, 31c), thereby increasing how much the temperature of the refrigerant in the compressor (31a, 31b, 31c) is to decrease. As a result, the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c) (i.e., the discharged refrigerant temperature (Td)) can be reduced, thus reducing the degree of discharged superheat.

[0080] On the other hand, if the degree of discharged superheat is below the target degree of superheat, the controller (13) reduces the degree of opening of the intermediate expansion valve (36a, 36b, 36c). This increases the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31 a, 31b, 31c), thereby reducing how much the temperature of the refrigerant in the compressor (31a, 31b, 31c) is to decrease. As a result, the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c) (i.e., the discharged refrigerant temperature (Td)) can be increased, thus increasing the degree of discharged superheat.

[0081] If, in this manner, the degree of opening of the intermediate expansion valve (36a, 36b, 36c) is adjusted such that the degree of superheat of the refrigerant discharged from the compressor (31 a, 31b, 31 c) is equal to the predetermined target degree of superheat, the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31a, 31b, 31c) can be appropriately adjusted.

<Step (ST13)>

[0082] If the discharged refrigerant temperature (Td) is not below the higher discharged refrigerant temperature threshold (Tdth) (NO in step (ST11)), the controller (13) increases the degree of opening of the intermediate expansion valve (36a, 36b, 36c) by a predetermined amount. This increases the flow rate (injection amount) of the refrigerant flowing into the intermediate port of the compressor (31a, 31b, 31c), thereby increasing how much the temperature of the refrigerant in the compressor (31a, 31b, 31c) is to decrease. As a result, the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c) (i.e., the discharged refrigerant temperature (Td)) can be reduced.

[0083] If, in step (ST13), the intermediate expansion valve (36a, 36b, 36c) has a maximum degree of opening (e.g., a fully-open state), the controller (13) keeps the degree of opening of the intermediate expansion valve (36a, 36b, 36c) at the maximum degree of opening.

[Adjustment of Degree of Opening of Supercooling Expansion Valve]

[0084] Next, how the degree of opening of the supercooling expansion valve (35) is adjusted in the cooling mode will be described with reference to FIG. 5. The controller (13) performs the process shown in FIG. 5 (steps (ST20-ST24)) every time a predetermined operating time elapses in the cooling mode.

<Step (ST20)>

[0085] First, the controller (13) determines whether or not the discharged refrigerant temperature (Td) is below the higher discharged refrigerant temperature threshold (Tdth). If the discharged refrigerant temperature (Td) is below the higher discharged refrigerant temperature threshold (Tdth), the process proceeds to step (ST21). If not, the process proceeds to step (ST24).

<Steps (ST21-ST23): Second Degree-of-Opening Adjusting Operation>

[0086] If the discharged refrigerant temperature (Td) is below the higher discharged refrigerant temperature threshold (Tdth), the controller (13) performs a second degree-of-opening adjusting operation. In the second degree-of-opening adjusting operation, the controller (13) adjusts the degree of opening of the supercooling expansion valve (35) such that the temperature of a refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) (in this example, the injection refrigerant temperature (Tinj)) is above a predetermined freezing temperature threshold (Tfth). The freezing temperature threshold (Tfth) is set to be, for example, the threshold (lowest value such as 0°C) of the injection refrigerant temperature (Tinj) which may be considered not to cause the injection pipe (54) to be frozen. In the second degree-of-opening adjusting operation, processes indicated below are performed.

<<Step (ST21)>>

[0087] Specifically, the controller (13) determines whether or not the injection refrigerant temperature (Tinj) is above the freezing temperature threshold (Tfth). If the injection refrigerant temperature (Tinj) is above the freezing temperature threshold (Tfth), the process proceeds to step (ST22). If not, the process proceeds to step (ST23).

<<Step (ST22)>>

[0088] If the injection refrigerant temperature (Tinj) is above the freezing temperature threshold (Tfth), the controller (13) reduces the degree of opening of the supercooling expansion valve (35) by a predetermined amount (step (ST22)). This can reduce the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the second channels (34b) of the supercooling heat exchanger (34) in the injection pipe (54). As a result, the degree of subcooling of the refrigerant in the supercooling heat exchanger (34) can be increased.

<<Step (ST23)>>

[0089] On the other hand, if the injection refrigerant temperature (Tinj) is not above the freezing temperature threshold (Tfth), the controller (13) increases the degree of opening of the supercooling expansion valve (35) by a predetermined amount (step (ST23)). This can increase the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the second channels (34b) of the supercooling heat exchanger (34) in the injection pipe (54). As a result, the temperature of the refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) (in this example, the injection refrigerant temperature (Tinj)) can be increased.

<Step (ST24)>

[0090] If the discharged refrigerant temperature (Td) is not above the higher discharged refrigerant temperature threshold (Tdth) (NO in step (ST20)), the controller (13) increases the degree of opening of the supercooling expansion valve (35) by a predetermined amount without performing the second degree-of-opening adjusting operation (steps (ST21-ST23)). This can increase the flow rate of the refrigerant flowing from the supercooling expansion valve (35) into the second channels (34b) of the supercooling heat exchanger (34) in the injection pipe (54), and can increase the flow rate (injection amount) of the refrigerant flowing through each intermediate expansion valve (36a, 36b, 36c) into the intermediate port of an associated one of the compressors (31a, 31b, 31c). As a result, how much the temperature of the refrigerant in each compressor (31a, 31b, 31c) is to decrease can be increased, and the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c) (i.e., the discharged refrigerant temperature (Td)) can be reduced. Increasing the degree of opening of the supercooling expansion valve (35) can increase the pressure of the refrigerant flowing from the supercooling expansion valve (35) into the second channels (34b) of the supercooling heat exchanger (34) in the injection pipe (54). As a result, the temperature of the refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) (in this example, the injection refrigerant temperature (Tinj)) can be increased.

[0091] If, in step (ST22), the supercooling expansion valve (35) has a minimum degree of opening (e.g., a fully-closed state), the controller (13) keeps the degree of opening of the supercooling expansion valve (35) at the minimum degree of opening. If, in steps (ST23, ST24), the supercooling expansion valve (35) has a maximum degree of opening (e.g., a fully-open state), the controller (13) keeps the degree of opening of the supercooling expansion valve (35) at the maximum degree of opening.

[Adjustment of Degree of Opening of Oil Return Expansion Valve]

[0092] Next, how the degree of opening of the oil return expansion valve (42) is adjusted in the cooling mode will be described with reference to FIG. 6. The controller (13) performs a third degree-of-opening adjusting operation (steps (ST31-ST33)) every time a predetermined operating time elapses in the cooling mode. In the third degree-of-opening adjusting operation, the controller (13) adjusts the degree of opening of the oil return expansion valve (42) such that the temperature of the refrigerant flowing through a portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valves (36a, 36b, 36c) (in this example, the injection refrigerant temperature (Tinj)) is above the freezing temperature threshold (Tfth). In the third degree-of-opening adjusting operation, processes indicated below are performed.

<Step (ST31)>

[0093] First, the controller (13) determines whether or not the injection refrigerant temperature (Tinj) is above the freezing temperature threshold (Tfth). If the injection refrigerant temperature (Tinj) is above the freezing temperature threshold (Tfth), the process proceeds to step (ST32). If not, the process proceeds to step (ST33).

<Step (ST32)>

[0094] If the injection refrigerant temperature (Tinj) is above the freezing temperature threshold (Tfth), the controller (13) intermittently places the oil return expansion valve (42) in an open state so that the flow rate of refrigerating machine oil passing through the oil return pipe (57) within a predetermined unit period of time (i.e., the oil return amount) is equal to a predetermined flow rate (a normal flow rate). Specifically, the controller (13) intermittently places the oil return expansion valve (42) in the open state so that the period of time during which the oil return expansion valve (42) is placed in the open state within a predetermined period of time is equal to a predetermined period of time (a normal period of time). Alternatively, the controller (13) sets the degree of opening of the open oil return expansion valve (42) to be a predetermined degree of opening (a normal degree of opening).

<Step (ST33)>

[0095] If the injection refrigerant temperature (Tinj) is not above the freezing temperature threshold (Tfth), the controller (13) intermittently places the oil return expansion valve (42) in an open state, so that the flow rate of refrigerating machine oil passing through the oil return pipe (57) within a predetermined unit period of time (i.e., the oil return amount) increases by a predetermined rate (step (ST33)). Specifically, the controller (13) intermittently places the oil return expansion valve (42) in the open state so that the period of time during which the oil return expansion valve (42) is placed in the open state within a predetermined period of time increases. Alternatively, the controller (13) may increase the degree of opening of the open oil return expansion valve (42). Increasing the flow rate of the refrigerating machine oil (relatively high-temperature refrigerating machine oil) passing through the oil return pipe (57) within a predetermined unit period of time can increase the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valves (36a, 36b, 36c) (in this example, the injection refrigerant temperature (Tinj)).

[0096] If, in step (ST33), the flow rate of the refrigerating machine oil passing through the oil return pipe (57) within a predetermined unit period of time (i.e., the oil return amount) is highest, the controller (13) controls the opening/closing of the oil return expansion valve (42) to keep the oil return amount at the highest flow rate. Specifically, if a period of time during which the oil return expansion valve (42) is in the open state within a predetermined unit period of time is longest (e.g., equal to the unit period of time), the controller (13) controls the opening/closing of the oil return expansion valve (42) to keep the period of time during which the valve is in the open state at the longest period of time. Alternatively, if the degree of opening of the open oil return expansion valve (42) is highest (e.g., in the fully-open state), the controller (13) may control the opening/closing of the oil return expansion valve (42) to keep the degree of opening of the open oil return expansion valve (42) at the highest degree of opening.

[Advantages of Embodiment]

[0097] As can be seen from the foregoing description, adjusting the degree of opening of the intermediate expansion valve (36a, 36b, 36c) in the first degree-of-opening adjusting operation allows the temperature (Td) of the refrigerant discharged from the compressor (31 a, 31b, 31c) to be adjusted to be below the higher discharged refrigerant temperature threshold (Tdth). Thus, the compressor (31a, 31b, 31c) can be protected from abnormally high temperatures. Adjusting the degree of opening of the supercooling expansion valve (35) in the second degree-of-opening adjusting operation allows the temperature of the refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) to be adjusted to be above the freezing temperature threshold (Tfth). This can reduce the degree to which the injection pipe (54) is frozen (specifically, the degree to which freezing progresses).

[0098] If the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is not below the higher discharged refrigerant temperature threshold (Tdth), increasing the degree of opening of the supercooling expansion valve (35) can reduce the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c), and can increase the temperature of the refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c). This allows the compressors (31a, 31b, 31c) to be protected from abnormally high temperatures, and reduces the degree to which the injection pipe (54) is frozen.

[0099] In the first degree-of-opening adjusting operation, if the temperature (Td) of the refrigerant discharged from the compressor (31 a, 31 b, 31 c) is not below the higher discharged refrigerant temperature threshold (Tdth), increasing the degree of opening of the intermediate expansion valve (36a, 36b, 36c) can reduce the temperature of the refrigerant discharged from the compressor (31a, 31b, 31c). Thus, the compressor (31a, 31b, 31c) can be protected from abnormally high temperatures.

[0100] In the second degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) is above the freezing temperature threshold (Tfth), reducing the degree of opening of the supercooling expansion valve (35) increases the degree of subcooling of the refrigerant in the supercooling heat exchanger (34). This can enhance the cooling capability of the utilization-side heat exchanger (61). On the other hand, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), increasing the degree of opening of the supercooling expansion valve (35) can increase the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valves (36a, 36b, 36c). This can reduce the degree to which the injection pipe (54) is frozen.

[0101] Adjusting the degree of opening of the oil return expansion valve (42) in the third degree-of-opening adjusting operation allows the flow rate of refrigerating machine oil (relatively high-temperature refrigerating machine oil) flowing from the oil separator (41) through the oil return pipe (57) into the injection pipe (54) to be adjusted. Thus, the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valves (36a, 36b, 36c) can be adjusted.

[0102] In the third degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valves (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), increasing the flow rate of the refrigerating machine oil (relatively high-temperature refrigerating machine oil) passing through the oil return pipe (57) within a predetermined unit period of time triggers an increase in the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valves (36a, 36b, 36c). This can reduce the degree to which the injection pipe (54) is frozen.

(Other Embodiments)

[0103] In the foregoing description, an exemplary refrigeration apparatus (10) includes two utilization-side units (12). However, the number of utilization-side units (12) may be one, three, or more.

[0104] The exemplary refrigerant circuit (20) includes three compressors (first through third compressors (31a-31c)). However, the number of compressors may be one, two, four, or more.

[0105] Note that the foregoing description of the embodiment is a merely beneficial example in nature, and is not intended to limit the scope, application, or uses of the present disclosure.

INDUSTRIAL APPLICABILITY

[0106] As can be seen from the foregoing description, the above-mentioned refrigeration apparatus is useful as a refrigeration apparatus which cools an internal space, etc.

DESCRIPTION OF REFERENCE CHARACTERS

[0107]

10 Refrigeration Apparatus
11 Heat-Source-Side Unit

12	Utilization-Side Unit
13	Controller (Control Section)
20	Refrigerant Circuit
21	Heat-Source-Side Circuit
22	Heat-Source-Side Fan
23	Utilization-Side Circuit
24	Utilization-Side Fan
25	Drain Pan
31 a	First Compressor
31b	Second Compressor
31 c	Third Compressor
32	Four-Way Valve
33	Heat-Source-Side Heat Exchanger
34	Supercooling Heat Exchanger
35	Supercooling Expansion Valve
36a	First Intermediate Expansion Valve
36b	Second Intermediate Expansion Valve
36c	Third Intermediate Expansion Valve
37	Receiver
38	Heat-Source-Side Expansion Valve
41	Oil Separator
42	Oil Return Expansion Valve
50	Liquid Refrigerant Pipe
51	Discharge Refrigerant Pipe
52	Suction Refrigerant Pipe
53	Heat-Source-Side Liquid Refrigerant Pipe
54	Injection Pipe
55	First Connection Pipe
56	Second Connection Pipe
57	Oil Return Pipe
61	Utilization-Side Heat Exchanger
62	Utilization-Side Open/Close valve
63	Utilization-Side Expansion Valve
71	Utilization-Side Liquid Refrigerant Pipe
72	Utilization-Side Gaseous Refrigerant Pipe

Claims

1. A refrigeration apparatus comprising:

a refrigerant circuit (20) including a compressor (31 a, 31b, 31c), a heat-source-side heat exchanger (33), a utilization-side heat exchanger (61), a liquid refrigerant pipe (50) connecting a liquid end of the heat-source-side heat exchanger (33) to a liquid end of the utilization-side heat exchanger (61), an injection pipe (54) connecting an intermediate portion (P1) of the liquid refrigerant pipe (50) to an intermediate port of the compressor (31a, 31b, 31c), a supercooling heat exchanger (34) connected to the liquid refrigerant pipe (50) and the injection pipe (54) to exchange heat between a refrigerant flowing through the liquid refrigerant pipe (50) and a refrigerant flowing through the injection pipe (54), a supercooling expansion valve (35) provided on a portion of the injection pipe (54) between the intermediate portion (P1) of the liquid refrigerant pipe (50) and the supercooling heat exchanger (34), and an intermediate expansion valve (36a, 36b, 36c) provided on a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate port of the compressor (31 a, 31 b, 31 c); and

a control section (13) configured to perform first and second degree-of-opening adjusting operations in a cooling mode in which the refrigerant circuit (20) performs a refrigeration cycle where the heat-source-side heat exchanger (33) functions as a condenser, the supercooling heat exchanger (34) functions as a supercooler, and the utilization-side heat exchanger (61) functions as an evaporator, a degree of opening of the intermediate expansion valve (36a, 36b, 36c) being adjusted in the first degree-of-opening adjusting operation such that a temperature (Td) of a refrigerant discharged from the compressor (31a, 31b, 31c) is below a predetermined higher discharged refrigerant temperature threshold (Tdth), a degree of opening of the supercooling expansion valve (35) being adjusted in the second degree-of-opening adjusting operation such that a temperature of a refrigerant flowing through a portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is above a predetermined freezing temperature threshold (Tfth).

2. The refrigeration apparatus of claim 1, wherein if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) performs the second degree-of-opening adjusting operation, and if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is not below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) increases the degree of opening of the supercooling expansion valve (35).

3. The refrigeration apparatus of claim 1 or 2, wherein in the first degree-of-opening adjusting operation, if the temperature (Td) of the refrigerant discharged from the compressor (31a, 31b, 31c) is below the higher discharged refrigerant temperature threshold (Tdth), the control section (13) adjusts the degree of opening of the intermediate expansion valve (36a, 36b, 36c) such that a degree of superheat of the refrigerant discharged from the compressor (31a, 31b, 31c) is equal to a predetermined target degree of superheat, and if the temperature (Td) of the refrigerant discharged from the compressor (31 a, 31b, 31c) is not below the higher discharged refrigerant temperature threshold (Tdth), the control section

(13) increases the degree of opening of the intermediate expansion valve (36a, 36b, 36c).

4. The refrigeration apparatus of any one of claims 1-3, wherein
in the second degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth), the control section (13) reduces the degree of opening of the supercooling expansion valve (35), and if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), the control section (13) increases the degree of opening of the supercooling expansion valve (35).

5. The refrigeration apparatus of any one of claims 1-4, wherein
the refrigerant circuit (20) includes an oil separator (41) configured to separate refrigerating machine oil from the refrigerant discharged from the compressor (31 a, 31b, 31 c), an oil return pipe (57) having two ends respectively connected to the oil separator (41) and an intermediate portion of the injection pipe (54) between the supercooling heat exchanger (34) and the intermediate expansion valve (36a, 36b, 36c), and an oil return expansion valve (42) provided on the oil return pipe (57), and
in the cooling mode, the control section (13) performs a third degree-of-opening adjusting operation in which a degree of opening of the oil return expansion valve (42) is adjusted such that a temperature of a refrigerant flowing through a portion of the injection pipe (54) between a junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth).

6. The refrigeration apparatus of claim 5, wherein
in the third degree-of-opening adjusting operation, if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is above the freezing temperature threshold (Tfth), the control section (13) intermittently places the oil return expansion valve (42) in an open state so that a flow rate of refrigerating machine oil passing through the oil return pipe (57) within a predetermined unit period of time is equal to a predetermined flow rate, and if the temperature of the refrigerant flowing through the portion of the injection pipe (54) between the junction (P6) of the injection pipe (54) and the oil return pipe (57) and the intermediate expansion valve (36a, 36b, 36c) is not above the freezing temperature threshold (Tfth), the control section (13) intermittently places the oil return expansion valve (42) in the open state so that the flow rate of the refrigerating machine oil passing through the oil return pipe (57) within the predetermined unit period of time increases.

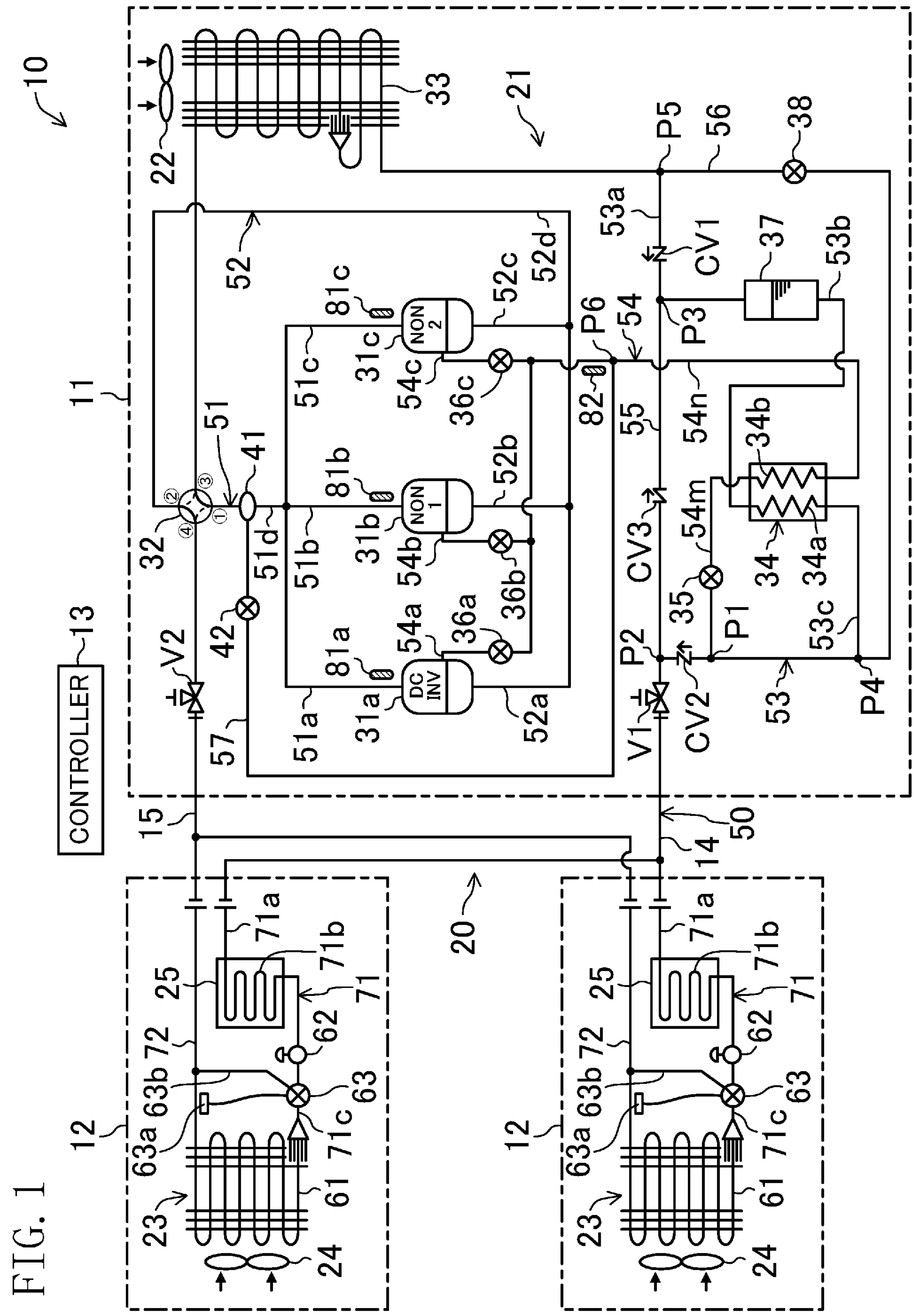


FIG. 1
10
11
12
13
CONTROLLER
14
15
20
21
22
23
24
25
31a
31b
31c
DC INV
NON 1
NON 2
32
33
34
34a
34b
35
36a
36b
36c
37
38
41
42
50
51
51a
51b
51c
51d
52
52a
52b
52c
52d
53
53a
53b
53c
54
54a
54b
54c
54m
54n
55
56
57
61
62
63
63a
63b
71
71a
71b
71c
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V1
V2
CV1
CV2
CV3

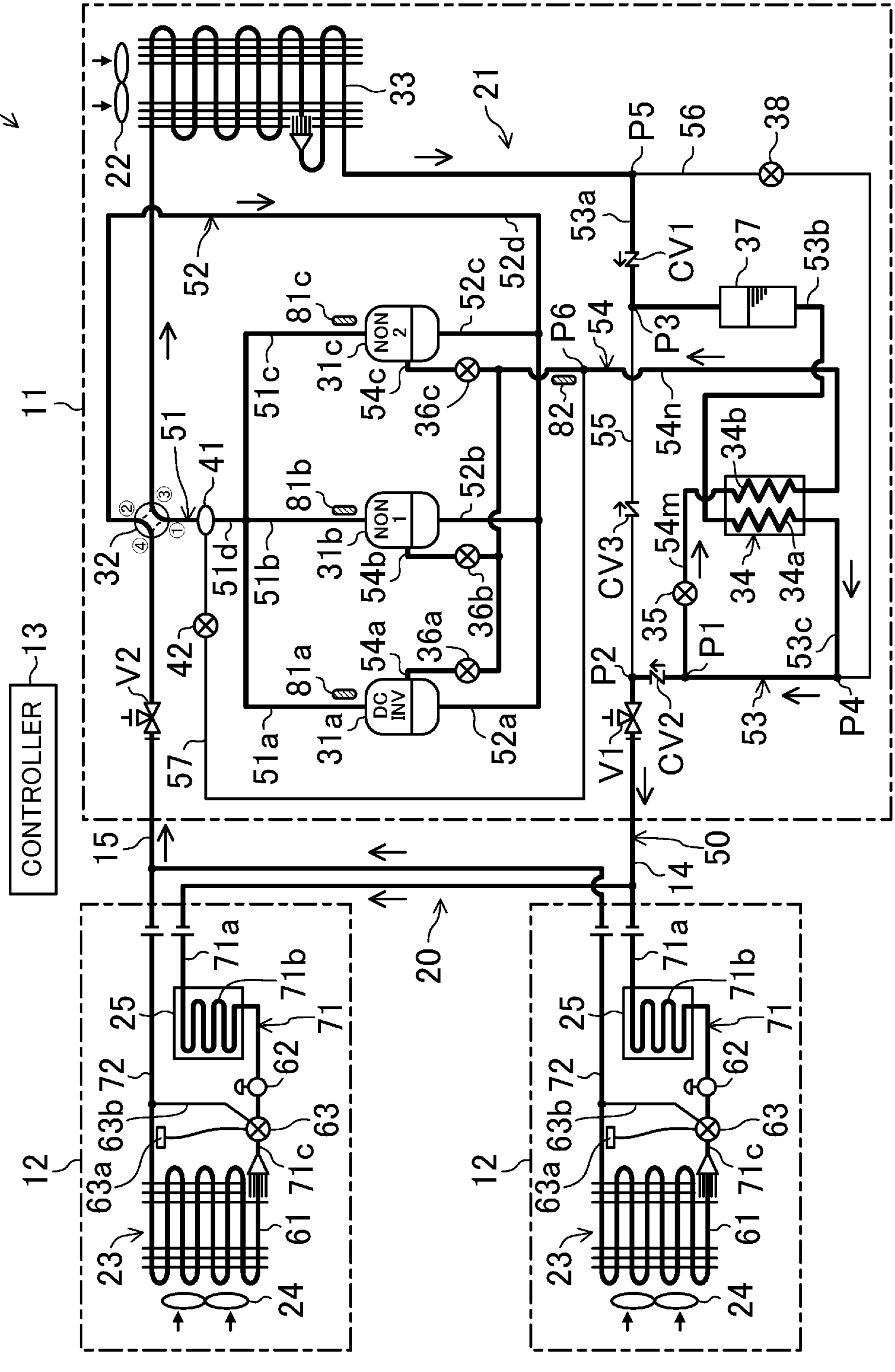


FIG. 2

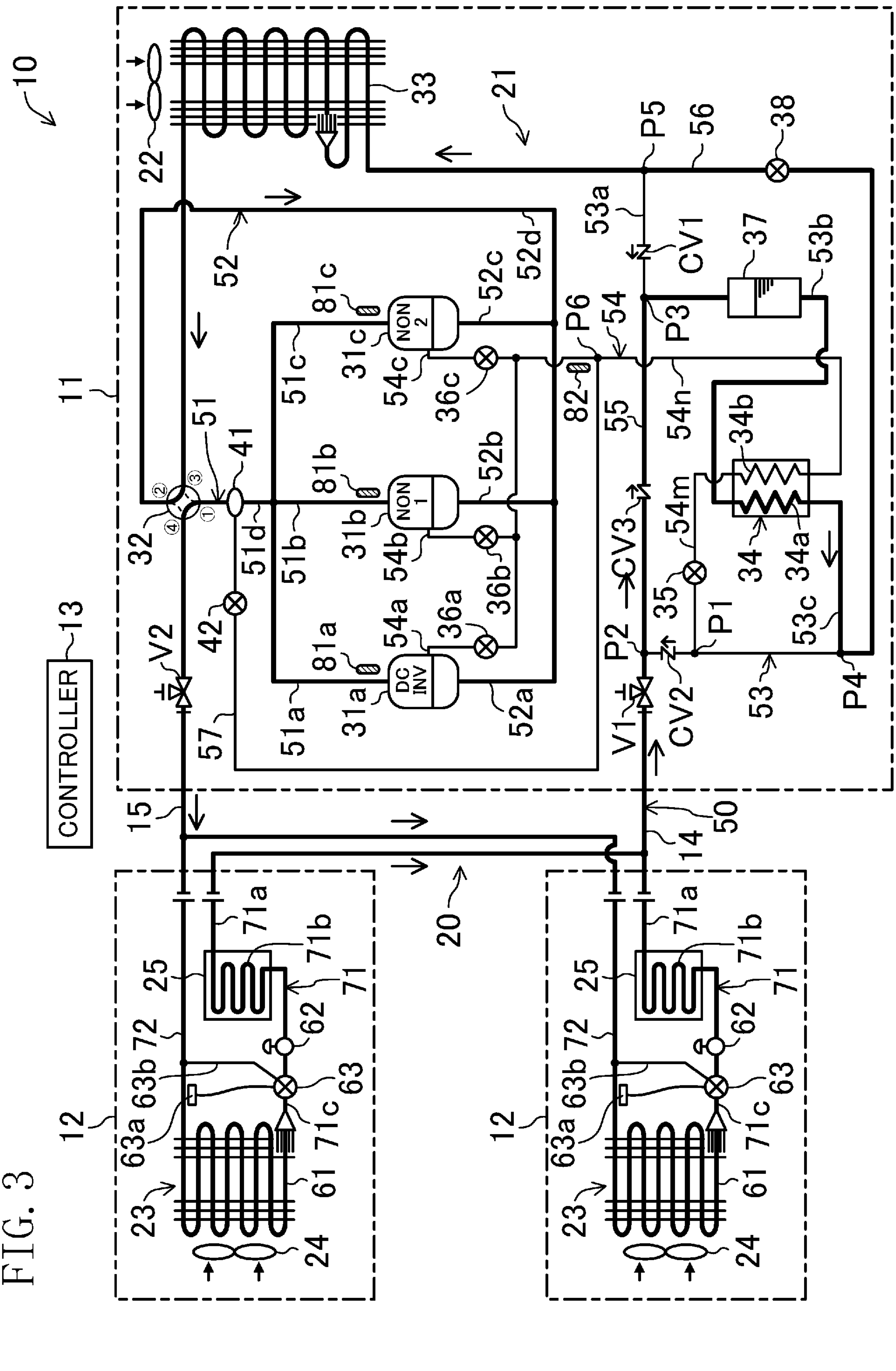


FIG. 3

FIG. 4

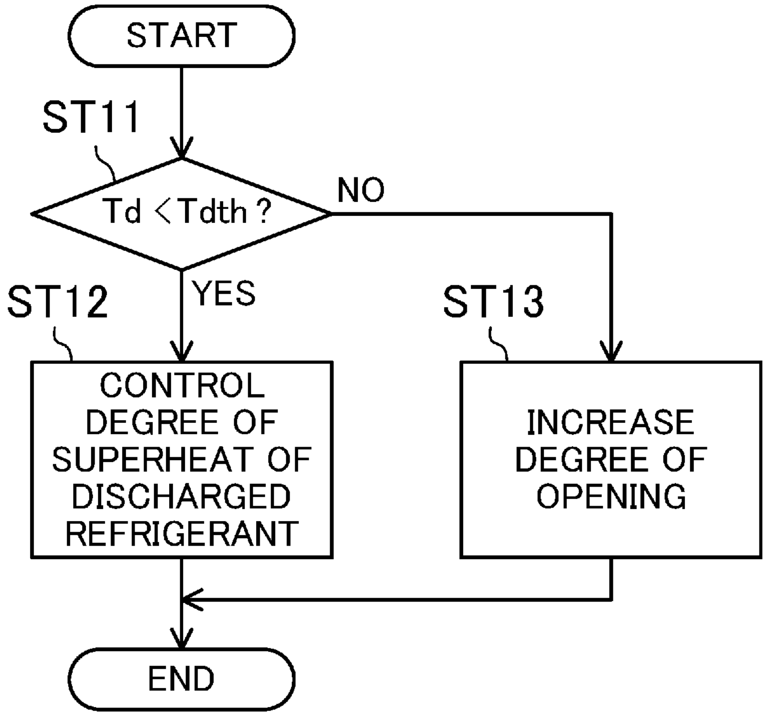

START
ST11
Td < Tdth ?
NO
YES
ST12
ST13
CONTROL DEGREE OF SUPERHEAT OF DISCHARGED REFRIGERANT
INCREASE DEGREE OF OPENING
END

FIG. 5

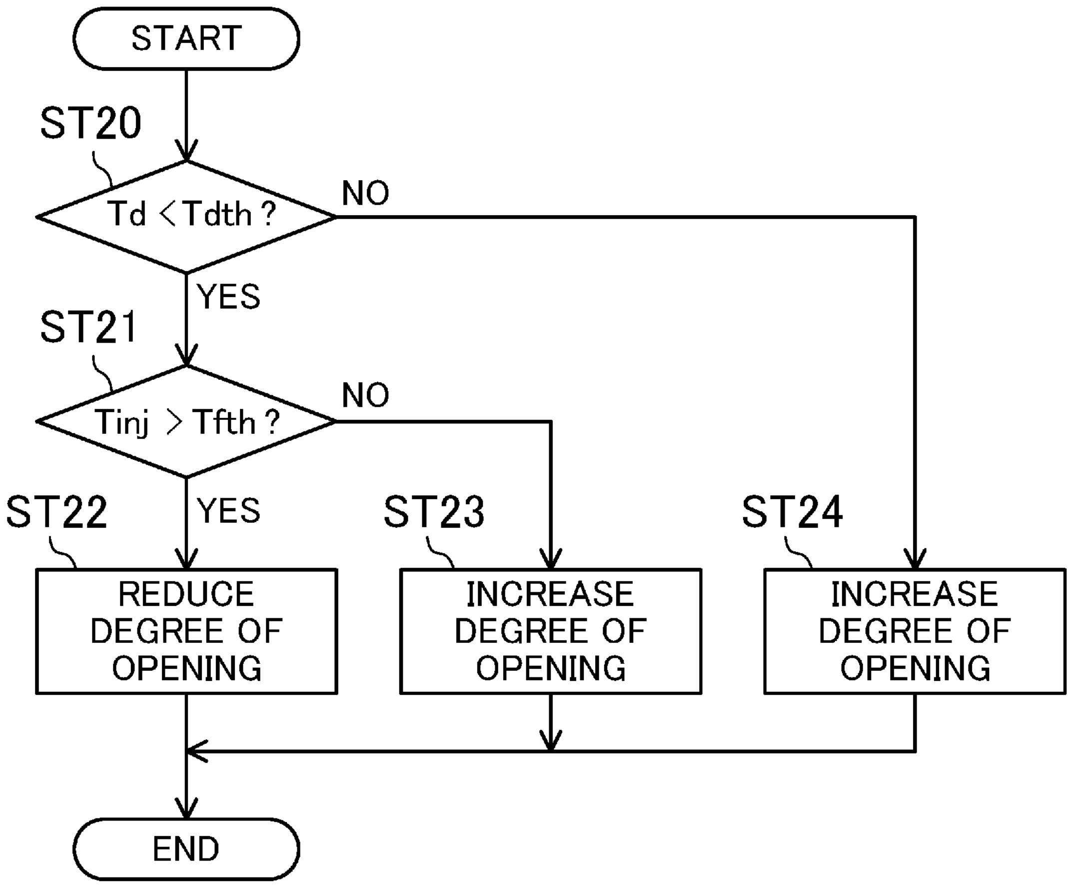
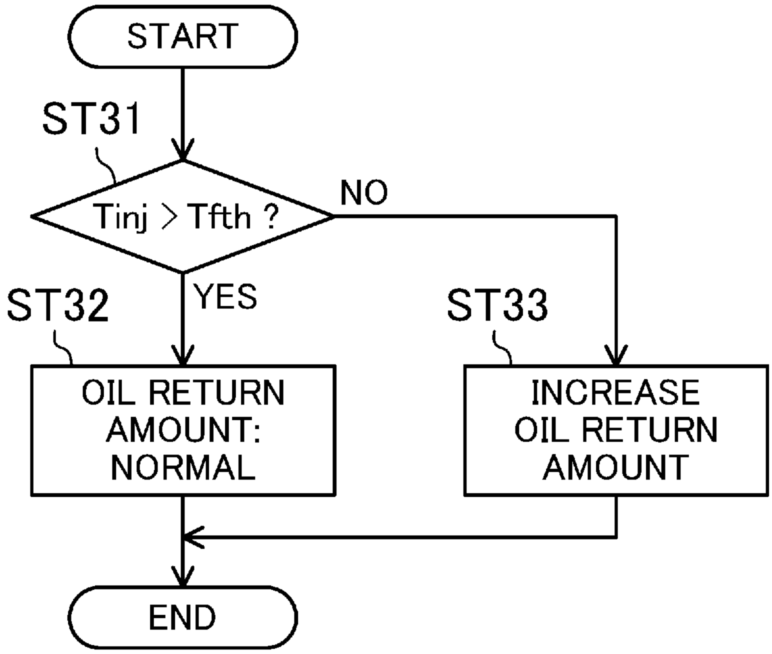

START
ST20
Td < Tdth ?
NO
YES
ST21
Tinj > Tfth ?
NO
YES
ST22
ST23
ST24
REDUCE DEGREE OF OPENING
INCREASE DEGREE OF OPENING
INCREASE DEGREE OF OPENING
END

FIG. 6


START
ST31
Tinj > Tfth ?
NO
YES
ST32
ST33
OIL RETURN AMOUNT: NORMAL
INCREASE OIL RETURN AMOUNT
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2016/001846

A. CLASSIFICATION OF SUBJECT MATTER
F25B1/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B1/00, F25B13/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2012-137207 A (Mitsubishi Electric Corp.), 19 July 2012 (19.07.2012), entire text; all drawings (Family: none)	1-6
A	JP 2014-16079 A (Daikin Industries, Ltd.), 30 January 2014 (30.01.2014), entire text; all drawings (Family: none)	1-6
A	JP 2007-127302 A (Daikin Industries, Ltd.), 24 May 2007 (24.05.2007), entire text; all drawings (Family: none)	1-6

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 June 2016 (03.06.16)	14 June 2016 (14.06.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 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/JP2016/001846

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-287800 A (Daikin Industries, Ltd.), 10 December 2009 (10.12.2009), entire text; all drawings (Family: none)	1-6

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009287800 A **[0003]**