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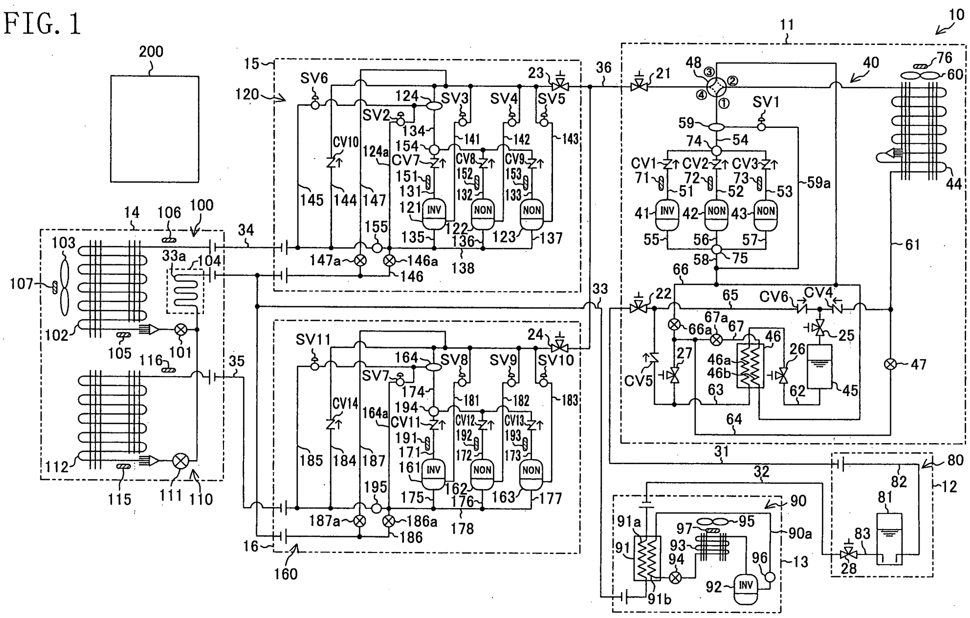
(54) **REFRIGERATING APPARATUS**

(57) In defrosting operation, a first individual defrosting process in which a first cooling heat exchanger (102) is defrosted and a second individual defrosting process in which a second cooling heat exchanger (112) is defrosted are alternately performed. The defrosting operation includes a discharge process in which refrigerant in one of the cooling heat exchangers (102, 112) which is not defrosted in the current individual defrosting process is sent to the other cooling heat exchanger (102, 112) which is to be defrosted.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to refrigeration systems each including a plurality of utilization side heat exchangers, more particularly to a refrigeration system capable of performing defrosting operation in a refrigeration cycle in order to defrost a plurality of utilization side heat exchangers.

BACKGROUND ART

[0002] Refrigeration systems including refrigerant circuits operating in refrigeration cycles are known, and are widely used in, for example, cooling machines such as chillers or freezers for storing food and other materials and air conditioners for cooling and heating the air in rooms.

[0003] For example, Patent Document 1 discloses an air conditioner capable of operating in a two-stage compression refrigeration cycle. The refrigerant circuit in this air conditioner includes a high-stage compressor, a low-stage compressor, an outdoor heat exchanger, and an indoor heat exchanger. During heating operation of the air conditioner, a two-stage compression refrigeration cycle in which the low-stage compressor and the high-stage compressor are operated, the indoor heat exchanger serves as a condenser, and the outdoor heat exchanger serves as an evaporator, is performed. The air conditioner described above is capable of performing defrosting operation of melting frost on the outdoor heat exchanger in winter. During this defrosting operation, only the high-stage compressor is operated, and a refrigeration cycle (i.e., so-called reverse cycle defrosting) in which the outdoor heat exchanger serves as a condenser and the indoor heat exchanger serves as an evaporator is performed.

[0004] Patent Document 2 discloses a refrigeration system for cooling the interior with a plurality of utilization side heat exchangers. In this refrigeration system, utilization side circuits each including a plurality of utilization side heat exchangers are connected in parallel to a heat-source side circuit including a heat-source side heat exchanger. During cooling operation of this refrigeration system, a refrigeration cycle in which the heat-source side heat exchanger serves as a condenser and the utilization side heat exchangers serve as evaporators is performed. Consequently, the air in the interior is cooled by each of the utilization side heat exchangers.

Patent Document 1: Japanese Laid-Open Patent Publication No. 2004-85047
Patent Document 2: Japanese Laid-Open Patent Publication No. 2002-228297

DISCLOSURE OF INVENTION

Problems that the Invention is to Solve

[0005] In a refrigeration system including a plurality of utilization side heat exchangers as disclosed in Patent Document 2, defrosting operation disclosed in Patent Document 1 is expected to be performed to defrost the utilization side heat exchangers at a time. However, in defrosting operation with such reverse cycle defrosting, condensed refrigerant may become liquid refrigerant and accumulate in the utilization side heat exchangers to cause so-called refrigerant stagnation. Such simultaneous defrosting of a plurality of utilization side heat exchangers as described above may increase the total amount of refrigerant which has accumulated in the utilization side heat exchangers, thus failing to keep a sufficient amount of refrigerant for defrosting. This results in the problem of inefficient defrosting of the utilization side heat exchangers.

[0006] In particular, in many refrigeration systems operating in a two-stage compression refrigeration cycle as described above, the pressure at a low-pressure side is extremely low, and each of the utilization side heat exchangers has a large capacity. Accordingly, when a plurality of utilization side heat exchangers are defrosted in such a refrigeration system, a large amount of refrigerant accumulates in each of the utilization side heat exchangers, and thus it becomes more difficult to keep a sufficient amount of refrigerant for defrosting.

[0007] It is therefore an object of the present invention to increase, in a refrigeration system capable of performing defrosting operation to defrost a plurality of utilization side heat exchangers, the efficiency in the defrosting operation by keeping a sufficient amount of refrigerant for defrosting.

Means of Solving the Problems

[0008] A first aspect of the present invention is directed to a refrigeration system including: a heat-source side circuit (40) including a compressor (41, 42, 43) and a heat-source side heat exchanger (44); and a plurality of utilization side circuits (100, 120; 110, 160) respectively including utilization side heat exchangers (102, 112) and connected in parallel to the heat-source side circuit (40). This refrigeration system is switchable between cooling operation performed in a refrigeration cycle in which the heat-source side heat exchanger (44) serves as a condenser and the utilization side heat exchangers (102, 112) serve as evaporators, and defrosting operation performed in a refrigeration cycle in which the utilization side heat exchangers (102, 112) serve as condensers and the heat-source side heat exchanger (44) serves as an evaporator. In the refrigeration system, the defrosting operation includes an individual defrosting process in which part of the utilization side heat exchangers (102, 112) is operated as a condenser and the other part of the utilization side heat exchangers (102, 112) is stopped, the individual defrosting process being performed a plurality of times in such a manner that each of the utilization side heat exchangers (102, 112) serves as a condenser at least once in the defrosting operation by switching the part of the utilization side heat exchangers (102, 112) serving as a condenser every time, and a discharge process in which refrigerant is discharged from the part of the utilization side heat exchangers (102, 112) stopped in the individual defrosting process.

[0009] In the refrigeration system of the first aspect, the plurality of utilization side circuits (100, 120; 110, 160) are connected in parallel to the heat-source side circuit (40), thereby forming a refrigerant circuit. This refrigeration system is capable of performing cooling operation for cooling, for example, the inside of a freezer case with the utilization side heat exchanger (102, 112) and defrosting operation for melting frost on the surface of the utilization side heat exchanger (102, 112).

[0010] Specifically, in the cooling operation, refrigerant compressed by the compressor (41, 42, 43) condenses in the heat-source side heat exchanger (44), is subjected to pressure reduction at, for example, an expansion valve, and then is sent to each of the utilization side heat exchangers (102, 112). In each of the utilization side heat exchangers (102, 112), the refrigerant takes heat from the air, and evaporates. Consequently, the air in the freezer case, for example, is cooled. The refrigerant that has evaporated in the utilization side heat exchanger (102, 112) is sucked into the compressor (41, 42, 43), and is compressed again.

[0011] On the other hand, in the defrosting operation, the individual defrosting process in which only part of the utilization side heat exchangers (102, 112) to be defrosted serves as a condenser and the other utilization side heat exchangers (102, 112) not to be defrosted is stopped, is performed. This individual defrosting process is now described based on a specific example.

[0012] It is assumed that the first utilization side heat exchanger (102) is defrosted and the second utilization side heat exchanger (112) is not defrosted in the individual defrosting process, for example. In this case, refrigerant compressed by the compressor (41, 42, 43) is sent only to the first utilization side heat exchanger (102), and is not sent to the second utilization side heat exchanger (112). In the first utilization side heat exchanger (102), the refrigerant dissipates heat to frost on the surface of a heat exchanger pipe. Consequently, in the first utilization side heat exchanger (102), the refrigerant condenses, and the frost on the surface of the heat exchanger tube gradually melts to be removed. The refrigerant condensed in the first utilization side heat exchanger (102) is subjected to pressure reduction at, for example, an expansion valve, and then evaporates in the heat-source side heat exchanger (44). The refrigerant that has evaporated in the heat-source side heat exchanger (44) is sucked into the compressor (41, 42, 43), and is compressed again.

[0013] In the defrosting operation, the individual defrosting process as described above is repeated in such a manner that the target of defrosting is sequentially switched in a given order. Specifically, after completion of the individual defrosting process in the above example, an individual defrosting process in which the second utilization side heat exchanger (112) is defrosted (i.e., serves as a condenser) and the first utilization side heat exchanger (102) is not defrosted (i.e., is stopped), is performed. Accordingly, in this aspect of the present invention, a larger amount of refrigerant is sent to each of the utilization side heat exchangers (102, 112) than in a case where refrigerant is split into the utilization side heat exchangers (102, 112) and the utilization side heat exchangers (102, 112) are defrosted at a time. Therefore, even when refrigerant stagnates in the utilization side heat exchanger (102, 112) in the individual defrosting process, no shortage of refrigerant for use in defrosting of the utilization side heat exchangers (102, 112) occurs.

[0014] In addition, the defrosting operation includes the discharge process for discharging refrigerant from part of the utilization side heat exchangers (102, 112) not to be defrosted. Specifically, in the individual defrosting process, refrigerant may remain in the part of the utilization side heat exchangers (102, 112) which is stopped. However, in this aspect of the present invention, this refrigerant is discharged in the discharge process. As a result, in the individual defrosting process, the amount of refrigerant capable of being sent to part of the utilization side heat exchangers (102, 112) to be defrosted can further increase.

[0015] In a second aspect of the present invention, in the refrigeration system of the first aspect, the heat-source side circuit (40) includes the high-stage compressor (41, 42, 43), whereas the utilization side circuits (100, 120; 110, 160) respectively include low-stage compressors (121, 122, 123; 161, 162, 163). In the cooling operation, the high-stage compressor (41, 42, 43) and the low-stage compressors (121, 122, 123; 161, 162, 163) are driven to perform a two-stage compression refrigeration cycle, whereas in the defrosting operation, the high-stage compressor (41, 42, 43) is driven to perform a refrigeration cycle. In the discharge process, part of the low-stage compressors (121, 122, 123; 161, 162, 163) of the utilization side circuits (100, 120; 110, 160) associated with part of the utilization side heat exchangers (102, 112) not to be defrosted is driven to send refrigerant remaining in the part of the utilization side heat exchangers (102, 112) not to be defrosted to the part of the utilization side heat exchangers (102, 112) to be defrosted.

[0016] The refrigeration system of the second aspect is configured to be capable of operating in a two-stage compression refrigeration cycle. Specifically, the refrigerant circuit of this refrigeration system includes the high-stage compressor (41, 42, 43) and the low-stage compressors (121, 122, 123; 161, 162, 163). In the cooling operation of this refrigeration system, refrigerant compressed in the high-stage compressor (41, 42, 43) condenses in the heat-source side heat exchanger (44), is subjected to pressure reduction at, for example, a pressure-reducing valve, and then is sent to each of the utilization side heat exchangers (102, 112). The refrigerant that has evaporated in the utilization side heat exchangers (102, 112) is compressed in the low-stage compressors (121, 122, 123; 161, 162, 163), and is sucked into the high-stage compressor (41, 42, 43) to be further compressed.

[0017] On the other hand, in the defrosting operation of this refrigeration system, the individual defrosting process is performed with the high-stage compressor (41, 42, 43) operated. Specifically, in the individual defrosting process, refrigerant compressed in the high-stage compressor (41, 42, 43) is sent to, for example, the first utilization side heat exchanger (102) to be defrosted, and is not sent to the second utilization side heat exchanger (112) not to be defrosted. Refrigerant used for defrosting of the first utilization side heat exchanger (102) is subjected to pressure reduction at, for example, an expansion valve, condenses in the heat-source side heat exchanger (44), and then is sucked into the high-stage compressor (41, 42, 43) to be compressed again.

[0018] In the discharge process in this aspect, refrigerant is sent to part of the utilization side heat exchangers (102, 112) to be defrosted by operating part of the low-stage compressors (121, 122, 123; 161, 162, 163) of the utilization side circuits (100, 120; 110, 160) associated with part of the utilization side heat exchangers (102, 112) not to be defrosted in the individual defrosting process. Specifically, in the individual defrosting process, for example, in a case where the second utilization side heat exchanger (112) is stopped, the second low-stage compressor (161, 162, 163) of the second utilization side circuit (110, 160) associated with the second utilization side heat exchanger (112) is operated. Consequently, refrigerant in the second utilization side heat exchanger (112) is sucked into the second low-stage compressor (161, 162, 163) to be compressed, and then is sent to the first utilization side heat exchanger (102) to be defrosted. At this time, in the second utilization side circuit (110, 160), refrigerant in, for example, the pipe of the suction side of the second low-stage compressor (161, 162, 163) is also sent to the first utilization side heat exchanger (102). Accordingly, in the individual defrosting process, the amount of refrigerant capable of being sent to the utilization side heat exchanger (102, 112) to be defrosted further increases.

[0019] In a third aspect of the present invention, in the refrigeration system of the second aspect, the utilization side circuits (100, 120; 110, 160) respectively include expansion valves (101, 111) for reducing pressures of refrigerant at inflow ends of the utilization side heat exchangers (102, 112) in the cooling operation, and in the individual defrosting process, part of the expansion valves (101, 111) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) to be defrosted is opened, whereas part of the expansion valves (101, 111) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is fully closed.

[0020] In the third aspect, the utilization side circuits (100, 120; 110, 160) respectively include the expansion valves (101, 111). In the cooling operation, refrigerant condensed in the heat-source side heat exchanger (44) is subjected to pressure reduction at the expansion valves (101, 111), and then is sent to the utilization side heat exchangers (102, 112) to evaporate.

[0021] On the other hand, in the individual defrosting process, the expansion valve (101, 111) is opened in the utilization side circuit (100, 120; 110, 160) associated with the utilization side heat exchanger (102, 112) to be defrosted. In the utilization side circuit (100, 120; 110, 160) not to be defrosted, the expansion valve (101, 111) is fully closed. In this state, when the high-stage compressor (41, 42, 43) is operated, refrigerant expelled from the high-stage compressor (41, 42, 43) flows into the utilization side heat exchanger (102, 112) to be defrosted. On the other hand, the fully-closed expansion valve (101, 111) prevents this refrigerant from flowing in the utilization side heat exchanger (102, 112) not to be defrosted. Accordingly, in the individual defrosting process, a larger amount of refrigerant can be sent to the utilization side heat exchanger (102, 112) to be defrosted.

[0022] In a fourth aspect of the present invention, in the refrigeration system of the third aspect, in the discharge process, the part of the expansion valves (101, 111) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted in the individual defrosting process is fully closed.

[0023] In the discharge process in the fourth aspect, the expansion valve (101, 111) is fully closed in the utilization side circuit (100, 120; 110, 160) associated with the utilization side heat exchanger (102, 112) not to be defrosted, and the low-stage compressor (121, 122, 123; 161, 162, 163) is operated. Specifically, for example, in the stopped second utilization side circuit (110, 160), the second expansion valve (111) is fully closed, and the second low-stage compressor (161, 162, 163) is operated. Consequently, in the second utilization side circuit (110, 160), refrigerant remaining from the fully-closed second expansion valve (111) to the suction port of the second low-stage compressor (161, 162, 163) is sucked into the second low-stage compressor (161, 162, 163) to be compressed, and is sent to the first utilization side heat exchanger (102) to be defrosted. Accordingly, in the individual defrosting process, the amount of refrigerant capable of being sent to the utilization side heat exchanger (102, 112) to be defrosted can further increase.

[0024] In addition, fully-closing the expansion valve (101, 111) in the manner described above causes a rapid decrease in pressure at the suction side of the operating low-stage compressor (121, 122, 123; 161, 162, 163). Accordingly, even if liquid refrigerant has accumulated in the utilization side heat exchanger (102, 112) not to be defrosted and pipes before and after this part, the pressure of this liquid refrigerant rapidly decreases, and thus the liquid refrigerant is likely to evaporate. This can prevent refrigerant in the liquid state from being sucked into the low-stage compressors (121, 122, 123; 161, 162, 163), thus avoiding a so-called liquid compression phenomenon in the low-stage compressors (121, 122, 123; 161, 162, 163).

[0025] In a fifth aspect of the present invention, in the refrigeration system of one of the second through fourth aspects, the utilization side circuits (100, 120; 110, 160) respectively include bypass pipes (145, 185) connecting suction sides and discharge sides of the low-stage compressors (121, 122, 123; 161, 162, 163) and provided with shut-off valves (SV6, SV11) which are closed during the cooling operation, and in the individual defrosting process, part of the shut-off valves (SV6, SV11) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) to be defrosted is opened, whereas part of the shut-off valves (SV6, SV11) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is closed.

[0026] In the fifth aspect, the utilization side circuits (100, 120; 110, 160) respectively include the bypass pipes (145, 185). During the cooling operation, the shut-off valves (SV6, SV11) of the bypass pipes (145, 185) are closed. Accordingly, refrigerant that has evaporated in the utilization side heat exchangers (102, 112) does not flow in the bypass pipes (145, 185), but is compressed in the low-stage compressors (121, 122, 123; 161, 162, 163), and then is further compressed in the high-stage compressor (41, 42, 43).

[0027] On the other hand, in the individual defrosting process, the shut-off valve (SV6, SV 11) of the utilization side circuit (100, 120; 110, 160) associated with the utilization side heat exchanger (102, 112) not to be defrosted is closed. Accordingly, this closed shut-off valve (SV6, SV11) prevents refrigerant compressed in the high-stage compressor (41, 42, 43) from being sent to the utilization side heat exchanger (101, 112) not to be defrosted through the bypass pipe (145, 185). As a result, in the individual defrosting process, a larger amount of refrigerant can be sent to the utilization side heat exchanger (102, 112) to be defrosted.

[0028] In a sixth aspect of the present invention, in the refrigeration system of the fifth aspect, in the discharge process, the part of the shut-off valves (SV6, SV11) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is closed.

[0029] In the discharge process in the sixth aspect, the shut-off valve (SV6, SV11) of the utilization side circuit (100, 120; 110, 160) associated with the utilization side heat exchanger (102, 112) not to be defrosted is closed, and the low-stage compressor (121, 122, 123; 161, 162, 163) is operated. Specifically, for example, in the second utilization side circuit (110, 160) associated with the stopped second utilization side heat exchanger (112), the shut-off valve (SV 11) is closed, and the second low-stage compressor (161, 162, 163) is operated. This prevents refrigerant expelled from the second low-stage compressor (161, 162, 163) from returning to the suction side of the second low-stage compressor (161, 162, 163) through the second bypass pipe (185) in the second utilization side circuit (110, 160). Accordingly, refrigerant in the second utilization side circuit (110, 160) can be quickly discharged, thus further increasing the amount of refrigerant capable of being sent to the utilization side heat exchanger (102, 112) to be defrosted in the individual defrosting process.

[0030] In a seventh aspect of the present invention, in the refrigeration system of the fifth aspect, the utilization side circuits (100, 120; 110, 160) respectively include vessel-like oil separators (124, 164) for causing oil in refrigerant expelled from the low-stage compressors (121, 122, 123; 161, 162, 163) to be sucked in the low-stage compressors (121, 122, 123; 161, 162, 163), and an end of each of the bypass pipes (145, 185) is connected to an associated one of the oil separators (124, 164).

[0031] In the seventh aspect, the oil separators (124, 164) are respectively provided at the discharge sides of the low-stage compressors (121, 122, 123; 161, 162, 163). This oil separator (124, 164) separates oil from refrigerant expelled from the low-stage compressor (121, 122, 123; 161, 162, 163) during, for example, the cooling operation. The oil separated by the oil separator (124, 164) is sucked into the low-stage compressor (121, 122, 123; 161, 162, 163) through, for example, an oil return pipe, and is used for lubricating a compression mechanism, for example.

[0032] In a case where the oil separator (124, 164) is provided in the utilization side circuit (100, 120; 110, 160), refrigerant may also accumulate in the oil separator (124, 164) during the defrosting operation. Specifically, in the defrosting operation, the high-stage compressor (41, 42, 43) communicates with a pipe through which refrigerant flows in the oil separator (124, 164), and thus refrigerant expelled from the high-stage compressor (41, 42, 43) accumulates in the oil separator (124, 164) in some cases. This may cause shortage of refrigerant capable of being sent to the utilization side heat exchanger (102, 112) in the defrosting operation, thus reducing the capacity of defrosting the utilization side heat exchanger (102, 112).

[0033] To prevent this problem, according to this aspect, an end of the bypass pipe (145, 185) is connected to the oil separator (124, 164) in order to avoid accumulation of refrigerant in the oil separator (124, 164). With this configuration, in the defrosting operation, refrigerant expelled from the high-stage compressor (41, 42, 43) flows into the bypass pipe (145, 185) through the oil separator (124, 164), and is sent to the utilization side heat exchanger (102, 112) to be defrosted. Specifically, in the defrosting operation, refrigerant in the oil separator (124, 164) is always pushed to the bypass pipe (145, 185), and thus accumulation of refrigerant in the oil separator (124, 164) is prevented. As a result, the amount of refrigerant capable of being sent to the utilization side heat exchanger (102, 112) to be defrosted can further increase.

[0034] An eighth aspect of the present invention, in the refrigeration system of the seventh aspect, an end of each of the bypass pipes (145, 185) is connected to a bottom of an associated one of the oil separators (124, 164).

[0035] In the eighth aspect, an end of the bypass pipe (145, 185) is connected to the bottom of the oil separator (124, 164). This configuration allows refrigerant which has accumulated in the oil separator (124, 164) during the defrosting operation to easily flow into the bypass pipe (145, 185). Even if refrigerant in the oil separator (124, 164) condenses and liquid refrigerant accumulates in the bottom of the oil separator (124, 164), this liquid refrigerant quickly flows into the bypass pipe (145, 185).

[0036] In a ninth aspect of the present invention, in the refrigeration system of one of the first through eighth aspects, the utilization side heat exchangers (102, 112) are placed in a case, and share a fin (102a).

[0037] In the ninth aspect, the utilization side heat exchangers (102, 112) are placed in the same case. In addition, the utilization side heat exchangers (102, 112) share the same fin (102a). Accordingly, in the individual defrosting process, when the utilization side heat exchanger (102, 112) to be defrosted serves as a condenser, heat of refrigerant in this utilization side heat exchanger (102, 112) is transmitted to the other utilization side heat exchanger (102, 112) by way of the fin (102a). Consequently, in the individual defrosting process, frost on the surface of the utilization side heat exchanger (102, 112) which is stopped can be melted by utilizing heat of the utilization side heat exchanger (102, 112) serving as a condenser.

[0038] In a tenth aspect of the present invention, in the refrigeration system of one of the first through ninth aspects, in the defrosting operation, when a degree of supercooling of refrigerant flowing from part of the utilization side heat exchangers (102, 112) to be defrosted reaches a given temperature or more, a target of defrosting in the individual defrosting process is switched.

[0039] In the defrosting operation in the tenth aspect, when condensed liquid refrigerant accumulates in the utilization side heat exchanger (102, 112) to be defrosted and the degree of supercooling of this liquid refrigerant reaches a given temperature or more, the target of defrosting in the individual defrosting process is switched. Consequently, even if the individual defrosting process is repeated with the target of defrosting appropriately switched between the utilization side heat exchangers (102, 112), it is possible to prevent liquid refrigerant from accumulating in the utilization side heat exchanger (102, 112). This further ensures prevention of shortage of refrigerant for use in defrosting of the utilization side heat exchanger (102, 112).

[0040] In an eleventh aspect of the present invention, in the refrigeration system of one of the first through ninth aspects, in the defrosting operation, when a temperature of refrigerant flowing from part of the utilization side heat exchangers (102, 112) to be defrosted reaches a given temperature or more, a target of defrosting in the individual defrosting process is switched.

[0041] In the defrosting operation in the eleventh aspect, when condensed liquid refrigerant accumulates in the utilization side heat exchanger (102, 112) to be defrosted and the temperature of the refrigerant in the utilization side heat exchanger (102, 112) reaches a given temperature or more, the target of defrosting in the individual defrosting process is switched. Consequently, even if the individual defrosting process is repeated with the target of defrosting appropriately switched between the utilization side heat exchangers (102, 112), it is possible to prevent liquid refrigerant from accumulating in the utilization side heat exchanger (102, 112). This further ensures prevention of shortage of refrigerant for use in defrosting of the utilization side heat exchanger (102, 112).

EFFECTS OF THE INVENTION

[0042] According to the present invention, in the defrosting operation, the individual defrosting process is performed with the target of defrosting appropriately switched among the plurality of utilization side heat exchangers (102, 112). Accordingly, a smaller amount of refrigerant accumulates in the utilization side heat exchangers (102, 112) than a case where defrosting is performed with all the utilization side heat exchangers (102, 112) used as condensers. Accordingly, in this individual defrosting process, a sufficient amount of refrigerant can be used for defrosting of the utilization side heat exchangers (102, 112), thus increasing the efficiency in defrosting operation.

[0043] In addition, according to the present invention, the discharge process in which refrigerant in the utilization side heat exchanger (102, 112) not to be defrosted in the individual defrosting process is sent to the utilization side heat exchanger (102, 112) to be defrosted, is performed. Accordingly, refrigerant in the utilization side heat exchanger (102, 112) which is stopped can be used for defrosting of the utilization side heat exchanger (102, 112) to be defrosted, thus further ensuring that a sufficient amount of refrigerant is kept for defrosting of the utilization side heat exchanger (102, 112).

[0044] In the second aspect of the present invention, in the refrigeration system capable of operating in a two-stage compression refrigeration cycle in which the utilization side heat exchangers (102, 112) tend to have large capacities, the individual defrosting process is performed with the target of defrosting switched. Accordingly, in this aspect, even if a large amount of liquid refrigerant accumulates in the utilization side heat exchanger (102, 112), a sufficient amount of refrigerant can be kept for defrosting of the utilization side heat exchanger (102, 112).

[0045] In the discharge process of this aspect, refrigerant compressed in the low-stage compressor (121, 122, 123; 161, 162, 163) is sent to part of the utilization side heat exchanger (102, 112) to be defrosted. This configuration allows heat input to the low-stage compressor (121, 122, 123; 161, 162, 163) to be used for defrosting of the utilization side heat exchanger (102, 112) to be defrosted.

[0046] In the individual defrosting process in the third aspect of the present invention, the expansion valve (101, 111) associated with the utilization side heat exchanger (102, 112) not to be defrosted is fully closed. This ensures that flowing of refrigerant in the utilization side heat exchanger (102, 112) not to be defrosted is prevented. Accordingly, a larger amount of refrigerant can be sent to the utilization side heat exchanger (102, 112) to be defrosted.

[0047] In particular, in the discharge process in the fourth aspect of the present invention, the expansion valve (101, 111) associated with the utilization side heat exchanger (102, 112) not to be defrosted is fully closed. Accordingly, refrigerant that has accumulated between the expansion valve (101, 111) and the suction port of the low-stage compressor (121, 122, 123; 161, 162, 163) can be sent to the utilization side heat exchanger (102, 112) to be defrosted. This ensures that a sufficient amount of refrigerant is used for defrosting of the utilization side heat exchanger (102, 112) to be defrosted. In addition, fully closing the expansion valve (101, 111) changes the refrigerant at the suction side of the low-stage compressor (121, 122, 123; 161, 162, 163) into gas, thus preventing a liquid compression phenomenon in the low-stage compressor (121, 122, 123; 161, 162, 163).

[0048] In the fifth aspect of the present invention, the utilization side circuits (100, 120; 110, 160) respectively include bypass pipes (145, 185) connecting the suction sides and the discharge sides of the low-stage compressors (121, 122, 123; 161, 162, 163). Accordingly, in the individual defrosting process, refrigerant expelled from the high-stage compressor (41, 42, 43) can be sent to the utilization side heat exchanger (102, 112) to be defrosted by way of the bypass pipe (145, 185).

[0049] In particular, in the discharge process in the sixth aspect of the present invention, the shut-off valve (SV6, SV11) associated with the utilization side heat exchanger (102, 112) not to be defrosted is closed. This allows refrigerant compressed in the low-stage compressor (121, 122, 123; 161, 162, 163) to be quickly sent to the utilization side heat exchanger (102, 112) to be defrosted in the discharge process. Accordingly, a sufficient amount of refrigerant can be used for defrosting of the utilization side heat exchanger (102, 112) to be defrosted.

[0050] In the seventh aspect of the present invention, an end of the bypass pipes (145, 185) is connected to an associated one of the oil separators (124, 164). This ensures that refrigerant in the oil separator (124, 164) is sent to the utilization side heat exchanger (102, 112) to be defrosted by way of the bypass pipe (145, 185) in the defrosting operation. Accordingly, a sufficient amount of refrigerant can be used for defrosting of the utilization side heat exchanger (102, 112).

[0051] In particular, in the eighth aspect of the present invention, an end of each of the bypass pipes (145, 185) is connected to the bottom of an associated one of the oil separators (124, 164). Accordingly, liquid refrigerant, for example, in the oil separator (124, 164) quickly flows into the bypass pipe (145, 185), and is sent to the utilization side heat exchanger (102, 112) to be defrosted.

[0052] In the ninth aspect of the present invention, the plurality of utilization side heat exchangers (102, 112) share the fin (102a). Accordingly, in the individual defrosting process, the utilization side heat exchanger (102, 112) which is stopped can be defrosted by utilizing heat of refrigerant in the utilization side heat exchanger (102, 112) serving as a condenser. This can reduce the time for defrosting the utilization side heat exchanger (102, 112).

[0053] Further, in the defrosting operation in the tenth aspect of the present invention, when the degree of supercooling of refrigerant flowing from the utilization side heat exchanger (102, 112) to be defrosted reaches to a given temperature or more, the target of defrosting is switched. This can prevent refrigerant stagnation in the utilization side heat exchanger (102, 112). As a result, a sufficient amount of refrigerant can be used for defrosting of the utilization side heat exchanger (102, 112).

[0054] In the defrosting operation in the eleventh aspect of the present invention, when the temperature of refrigerant flowing from part of the utilization side heat exchangers (102, 112) to be defrosted reaches to a given temperature or more, the target of defrosting is switched. This can prevent refrigerant stagnation in the utilization side heat exchanger (102, 112). As a result, a sufficient amount of refrigerant can be used for defrosting of the utilization side heat exchanger (102, 112).

BRIEF DESCRIPTION OF DRAWINGS

[0055]

[FIG. 1] FIG. 1 is a piping diagram showing a schematic configuration of a refrigeration system according to an embodiment.

[FIG. 2] FIG. 2 is a view schematically illustrating a configuration of a cooling heat exchanger in the refrigeration system of the embodiment.

[FIG. 3] FIG. 3 is a piping diagram showing the vicinity of a low-stage oil separator in the refrigeration system of the embodiment.

[FIG. 4] FIG. 4 is a piping diagram showing a flow of refrigerant in cooling operation of the refrigeration system of the embodiment.

[FIG. 5] FIG. 5 is a piping diagram showing a flow of refrigerant in a pre-discharge process of the refrigeration system of the embodiment.

[FIG. 6] FIG. 6 is a piping diagram showing a flow of refrigerant in a first individual defrosting process of the refrigeration system of the embodiment.

[FIG. 7] FIG. 7 is a piping diagram showing a flow of refrigerant in a first discharge process of the refrigeration system of the embodiment.

[FIG. 8] FIG. 8 is a piping diagram showing a flow of refrigerant in a second individual defrosting process of the refrigeration system of the embodiment.

[FIG. 9] FIG. 9 is a piping diagram showing a flow of refrigerant in a second discharge process of the refrigeration system of the embodiment.

Description of Symbols

[0056]

10	refrigeration system
40	outdoor circuit (heat-source side circuit)
41, 42, 43	high-stage compressor (compressor)
44	heat-source side heat exchanger (outdoor heat exchanger)
100, 120	first freezing circuit, first booster circuit (first utilization side circuit)
110, 160	second freezing circuit, second booster circuit (second utilization side circuit)
101, 111	indoor expansion valve (expansion valve)
102, 112	cooling heat exchanger (utilization side heat exchanger)
121, 161	low-stage compressor
124, 164	low-stage oil separator (oil separator)
145, 185	bypass pipe
SV6, SV11	solenoid valve (shut-off valve)

BEST MODE FOR CARRYING OUT THE INVENTION

[0057] Hereinafter, an embodiment of the present invention will be described in detail with reference to the drawings.

[0058] A refrigeration system (10) according to this embodiment is placed in, for example, a convenience store, and is used to cool the interior of a freezer.

[0059] As shown in FIG. 1, the refrigeration system (10) of this embodiment includes an outdoor unit (11), an extension unit (12), a supercooling unit (13), a freezer display case (14), a first booster unit (15), and a second booster unit (16). The outdoor unit (11), the extension unit (12), and the supercooling unit (13) are placed outdoors. On the other hand, the other units (14, 15, 16) are placed in a store such as a convenience store.

[0060] The outdoor unit (11) includes an outdoor circuit (40). The extension unit (12) includes an extension circuit (80). The supercooling unit (13) includes a supercooling circuit (90). The outdoor circuit (40), the extension circuit (80), and the supercooling circuit (90) are connected in series to form a heat-source side circuit. The freezer display case (14) includes a first freezing circuit (100) and a second freezing circuit (110). The first booster unit (15) includes a first booster circuit (120). The second booster unit (16) includes a second booster circuit (160). The first freezing circuit (100) and the first booster circuit (120) are connected in series to form a first utilization side circuit. The second freezing circuit (110) and the second booster circuit (160) are connected in series to form a second utilization side circuit.

[0061] In this refrigeration system (10), the first utilization side circuit (100, 120) and the second utilization side circuit (110, 160) are connected in parallel to the heat-source side circuit (40, 80, 90) to form a refrigerant circuit in which refrigerant circulates in a vapor compression refrigeration cycle.

[0062] Specifically, the ends of the outdoor circuit (40) are provided with a first shut-off valve (21) and a second shut-off valve (22), respectively. The second shut-off valve (22) is connected to an end of the extension circuit (80) through a first connection pipe (31). The other end of the extension circuit (80) is connected to an end of the supercooling circuit (90) through a second connection pipe (32). The other end of the supercooling circuit (90) is connected to an end of each of the first freezing circuit (100) and the second freezing circuit (110) through a third connection pipe (33). The other end of the first freezing circuit (100) is connected to an end of the first booster circuit (120) through a fourth connection pipe (34). The other end of the second freezing circuit (110) is connected to an end of the second booster circuit (160) through a fifth connection pipe (35). The other end of the first booster circuit (120) is provided with a third shut-off valve (23). The other end of the second booster circuit (160) is provided with a fourth shut-off valve (24). The third shut-off valve (23) and the fourth shut-off valve (24) are connected to the first shut-off valve (21) through a sixth connection pipe (36).

<<Outdoor Unit>>

[0063] The outdoor circuit (40) of the outdoor unit (11) includes a first high-stage compressor (41), a second high-stage compressor (42), a third high-stage compressor (43), an outdoor heat exchanger (44), a receiver (45), an internal heat exchanger (46), an outdoor expansion valve (47), and a four-way selector valve (48).

[0064] Each of the high-stage compressors (41, 42, 43) is fully-enclosed, and is a high-pressure domed scroll compressor. The first high-stage compressor (41) is a variable displacement compressor which is supplied with electric power through an inverter. Specifically, the first high-stage compressor (41) is configured to be changeable in displacement by changing the output frequency of the inverter to change the rotational speed of a motor for the compressor. On the other hand, the second high-stage compressor (42) and the third high-stage compressor (43) are fixed displacement compressors. Specifically, the second high-stage compressor (42) and the third high-stage compressor (43) have their respective motors always operated at constant rotational speeds, and are not changeable in displacement.

[0065] The discharge side of the first high-stage compressor (41) is connected to an end of a first discharge pipe (51). The discharge side of the second high-stage compressor (42) is connected to an end of a second discharge pipe (52). The discharge side of the third high-stage compressor (43) is connected to an end of a third discharge pipe (53). The other ends of these discharge pipes (51, 52, 53) are connected to the four-way selector valve (48) through a high-stage discharge pipe (54). The suction side of the first high-stage compressor (41) is connected to an end of a first suction pipe (55). The suction side of the second high-stage compressor (42) is connected to an end of a second suction pipe (56). The suction side of the third high-stage compressor (43) is connected to an end of a third suction pipe (57). The other ends of these suction pipes (55, 56, 57) are connected to the four-way selector valve (48) through a high-stage suction pipe (58).

[0066] The high-stage discharge pipe (54) is provided with a high-stage oil separator (59). An end of a high-stage oil return pipe (59a) is connected to the bottom of the high-stage oil separator (59). The other end of the high-stage oil return pipe (59a) is connected to the high-stage suction pipe (58). The high-stage oil return pipe (59a) is provided with a first solenoid valve (SV1) which can be appropriately opened and closed. The high-stage oil separator (59) separates oil (i.e., refrigerating machine oil) from the refrigerant expelled from the high-stage compressors (41, 42, 43). The oil obtained by the high-stage oil separator (59) is sucked into the high-stage compressors (41, 42, 43) by way of the high-stage oil return pipe (59a) with the first solenoid valve (SV1) opened.

[0067] The outdoor heat exchanger (44) is a cross-fin type fin-and-tube heat exchanger, and is a heat-source side heat exchanger. An outdoor fan (60) is provided near the outdoor heat exchange (44). This outdoor heat exchanger (44) performs heat exchange between outdoor air blown from the outdoor fan (60) and the refrigerant. An end of the outdoor heat exchanger (44) is connected to the four-way selector valve (48), whereas the other end of the outdoor heat exchanger (44) is connected to the top of the receiver (45) through a first liquid pipe (61).

[0068] The receiver (45) stores redundant refrigerant in a vessel. The receiver (45) has an internal volume of about 10 L (liters). The top of the receiver (45) is connected to the first liquid pipe (61), and the bottom of the receiver (45) is connected to a second liquid pipe (62).

[0069] The internal heat exchanger (46) includes a first heat exchanger tube (46a) and a second heat exchanger tube (46b), and performs heat exchange between the refrigerant flowing in the heat exchanger tube (46a) and the refrigerant flowing in the heat exchanger tube (46b). This internal heat exchanger (46) is, for example, a plate heat exchanger.

[0070] An end of the first heat exchanger tube (46a) is connected to the second liquid pipe (62), and the other end of the first heat exchanger tube (46a) is connected to the second shut-off valve (22) through a third liquid pipe (63). An end of a first branch pipe (64) and an end of the second branch pipe (65) are connected to midpoints of the third liquid pipe (63). The other ends of the first and second branch pipes (64, 65) are connected to midpoints of the first liquid pipe (61). The first branch pipe (64) is provided with the outdoor expansion valve (47). The outdoor expansion valve (47) is an electronic expansion valve controllable in opening, and is a heat-source side expansion valve. An end of a first injection pipe (66) is connected to a midpoint of the first branch pipe (64). The other end of the first injection pipe (66) is connected to the high-stage suction pipe (58). The first injection pipe (66) is provided with a first motor-operated valve (66a) which is a motor-operated valve.

[0071] An end of the second heat exchanger tube (46b) is connected to a midpoint of the first branch pipe (64) through a second injection pipe (67), and the other end of the second heat exchanger tube (46b) is connected to the high-stage suction pipe (58). The second injection pipe (67) is provided with a second motor-operated valve (67a) which is a motor-operated valve.

[0072] The four-way selector valve (48) includes first through fourth ports. In the four-way selector valve (48), the first port is connected to the high-stage discharge pipe (54), the second port is connected to the outdoor heat exchanger (44), the third port is connected to the high-stage suction pipe (58), and the fourth port is connected to the first shut-off valve (21). The four-way selector valve (48) is switchable between a first position (i.e., the position indicated by the solid lines in FIG. 1) in which the first and second ports communicate with each other and the third and fourth ports communicate with each other, and a second position (i.e., the position indicated by the broken lines in FIG. 1) in which the first and fourth ports communicate with each other and the second and third ports communicate with each other.

[0073] The outdoor circuit (40) includes various sensors. Specifically, the first discharge pipe (51) is provided with a first discharge temperature sensor (71), the second discharge pipe (52) is provided with a second discharge temperature sensor (72), and the third discharge pipe (53) is provided with a third discharge temperature sensor (73). The discharge temperature sensors (71, 72, 73) respectively detect the temperatures of the refrigerant discharged from the high-stage compressors (41, 42, 43). The high-stage discharge pipe (54) is provided with a high-stage high-pressure pressure sensor (74). The high-stage suction pipe (58) is provided with a high-stage low-pressure pressure sensor (75). The high-stage high-pressure pressure sensor (74) detects the pressure of the refrigerant at a high-pressure side of the outdoor circuit (40). The high-stage low-pressure pressure sensor (75) detects the pressure of the refrigerant at a low-pressure side of the outdoor circuit (40). Near the outdoor fan (60), an outdoor temperature sensor (76) is provided.

The outdoor-temperature sensor (76) detects the temperature of outdoor air surrounding the outdoor heat exchanger (44).

[0074] The outdoor circuit (40) includes a plurality of check valves. Specifically, the first discharge pipe (51) is provided with a first check valve (CV1), the second discharge pipe (52) is provided with a second check valve (CV2), and the third discharge pipe (53) is provided with a third check valve (CV3). The first liquid pipe (61) is provided with a fourth check valve (CV4), the third liquid pipe (63) is provided with a fifth check valve (CV5), and the second branch pipe (65) is provided with a sixth check valve (CV6). These check valves and check valves which will be described later allow the refrigerant to flow only in the direction indicated by the arrows in FIG. 1, and prevent the refrigerant from flowing in the opposite direction.

[0075] In addition to the first shut-off valve (21) and the second shut-off valve (22), a plurality of shut-off valves are provided in the outdoor circuit (40). Specifically, the first liquid pipe (61) is provided with a fifth shut-off valve (25), the second liquid pipe (62) is provided with a sixth shut-off valve (26), and the first branch pipe (64) is provided with a seventh shut-off valve (27).

<<Extension Unit>>

[0076] The extension circuit (80) of the extension unit (12) includes a refrigerant reservoir (81). This refrigerant reservoir (81) is an elongated vessel in the shape of a sealed cylinder, and is configured to store the refrigerant. Specifically, the refrigerant reservoir (81) has an internal volume of about 10 L to about 15 L. An end of a fourth liquid pipe (82) and an end of a fifth liquid pipe (83) are connected to the circumferential surface of the refrigerant reservoir (81) near the bottom of the refrigerant reservoir (81). The other end of the fourth liquid pipe (82) is connected to the first connection pipe (31), and the other end of the fifth liquid pipe (83) is connected to the second connection pipe (32). In the extension circuit (80), the fifth liquid pipe (83) is provided with an eighth shut-off valve (28). The refrigerant reservoir (81) is configured to be filled with the refrigerant through this eighth shut-off valve (28).

<<Supercooling Unit>>

[0077] The supercooling circuit (90) of the supercooling unit (13) includes a supercooling heat exchanger (91), a supercooling side compressor (92), a supercooling side outdoor heat exchanger (93), and a supercooling side expansion valve (94). The supercooling heat exchanger (91) includes a high-pressure side heat exchanger tube (91a) and a low-pressure side heat exchanger tube (91b), and is configured to perform heat exchange between the refrigerant flowing in the heat exchanger tube (91 a) and the refrigerant flowing in the heat exchanger tube (91b). This supercooling heat exchanger (91) is, for example, a plate heat exchanger.

[0078] An end of the high-pressure side heat exchanger tube (91 a) is connected to the second connection pipe (32), and the other end of the high-pressure side heat exchanger tube (91a) is connected to the third connection pipe (33). The low-pressure side heat exchanger tube (91b) is located in a closed circuit (90a) in which the refrigerant circulates in a vapor compression refrigeration cycle. In this closed circuit (90a), the supercooling side compressor (92), the supercooling side outdoor heat exchanger (93), and the supercooling side expansion valve (94) are located in this order from the outflow end of the low-pressure side heat exchanger tube (91 b).

[0079] The supercooling side compressor (92) is a variable displacement compressor. The supercooling side outdoor heat exchanger (93) is a cross-fin type fin-and-tube heat exchanger. A supercooling side outdoor fan (95) is provided near the supercooling side outdoor heat exchanger (93). The supercooling side outdoor heat exchanger (93) performs heat exchange between outdoor air blown from the supercooling side outdoor fan (95) and the refrigerant. The supercooling side expansion valve (94) is an electronic expansion valve which is controllable in opening.

[0080] The closed circuit (90a) of the supercooling unit (13) includes a supercooling side low-pressure pressure sensor (96) provided on a suction pipe of the supercooling side compressor (92). The supercooling side low-pressure pressure sensor (96) detects the pressure of the refrigerant at a low-pressure side of the closed circuit (90a). A supercooling side outdoor-temperature sensor (97) is provided near the supercooling side outdoor fan (95). The supercooling side outdoor-temperature sensor (97) detects the temperature of outdoor air surrounding the supercooling side outdoor heat exchanger (93).

<<Freezer Display Case>>

[0081] In the freezer display case (14), the first freezing circuit (100) and the second freezing circuit (110) branch off from the third connection pipe (33), and are connected in parallel with each other. The first freezing circuit (100) includes a first indoor expansion valve (101) and a first cooling heat exchanger (102). The second freezing circuit (110) includes a second indoor expansion valve (111) and a second cooling heat exchanger (112). The indoor expansion valves (101, 111) are electronic expansion valves controllable in opening, and are utilization side expansion valves.

[0082] The cooling heat exchangers (102, 112) are cross-fin type fin-and-tube heat exchangers, and are utilization side heat exchangers. The first cooling heat exchanger (102) and the second cooling heat exchanger (112) are placed in the same case. As shown in FIG. 2, the cooling heat exchangers (102, 112) are close to each other in such a manner that heat exchanger tubes thereof penetrate the same fin (102a). That is, the cooling heat exchangers (102, 112) share the fin (102a). The heat exchanger tubes of the respective cooling heat exchangers (102, 112) may be in contact with each other, or may be spaced apart at a given distance. In FIG. 1, the cooling heat exchangers (102, 112) are separated from each other for convenience. Near the cooling heat exchangers (102, 112), an in-case fan (103) is provided. Each of the cooling heat exchangers (102, 112) performs heat exchange between in-case air blown from the in-case fan (103) and the refrigerant.

[0083] In the freezer display case (14), a drain pan (104) is placed under the cooling heat exchangers (102, 112). The drain pan (104) is an open vessel for recovering frost and dew condensation water which have dropped from the surfaces of the cooling heat exchangers (102, 112). A heating pipe part (33a) that is part of the third connection pipe (33) is provided inside the drain pan (104). The heating pipe part (33a) is formed along the bottom plate of the drain pan (104). The heating pipe part (33a) melts frost and ice blocks recovered in the drain pan (104) by utilizing heat of the refrigerant flowing in the heating pipe part (33a). In FIG. 1, the in-case fan (103), the drain pan (104), and the heating pipe part (33a) are illustrated at locations closer to the first cooling heat exchanger (102), for convenience.

[0084] The first freezing circuit (100) includes a first refrigerant-temperature sensor (105) and a second refrigerant-temperature sensor (106). The first refrigerant-temperature sensor (105) is located closer to the end of the first cooling heat exchanger (102) serving as the inflow end during cooling operation. The second refrigerant-temperature sensor (106) is located closer to the end of the first cooling heat exchanger (102) serving as the outflow end during cooling operation. The second freezing circuit (110) includes a third refrigerant-temperature sensor (115) and a fourth refrigerant-temperature sensor (116). The third refrigerant-temperature sensor (115) is located closer to the end of the second cooling heat exchanger (112) serving as the inflow end during cooling operation. The fourth refrigerant-temperature sensor (116) is located closer to the end of the second cooling heat exchanger (112) serving as the outflow end during cooling operation. Each of the temperature sensors (105, 106, 115, 116) detects the temperature of the refrigerant flowing in the associated portion. An in-case temperature sensor (107) is also provided near the in-case fan (103). The in-case temperature sensor (107) detects the temperature of in-case air in the freezer display case (14).

<<First Booster Unit>>

[0085] The first booster circuit (120) of the first booster unit (15) includes a first low-stage compressor (121), a second low-stage compressor (122), and a third low-stage compressor (123). Each of the low-stage compressors (121, 122, 123) is fully-enclosed, and is a high-pressure domed scroll compressor. The first low-stage compressor (121) is a variable displacement compressor which is supplied with electric power through an inverter. Specifically, the first low-stage compressor (121) is configured to be changeable in displacement by changing the output frequency of the inverter to change the rotational speed of a motor for the compressor. The second low-stage compressor (122) and the third low-stage compressor (123) are fixed displacement compressors. Specifically, the second and third low-stage compressors (122, 123) have their respective motors always operated at constant rotational speeds, and are not changeable in displacement.

[0086] The discharge side of the first low-stage compressor (121) is connected to an end of a fourth discharge pipe (131). The discharge side of the second low-stage compressor (122) is connected to an end of a fifth discharge pipe (132). The discharge side of the third low-stage compressor (123) is connected to an end of a sixth discharge pipe (133). The other ends of these discharge pipes (131, 132, 133) are connected to the third shut-off valve (23) through a first low-stage discharge pipe (134). The suction side of the first low-stage compressor (121) is connected to a fourth suction pipe (135). The suction side of the second low-stage compressor (122) is connected to a fifth suction pipe (136). The suction side of the third low-stage compressor (123) is connected to a sixth suction pipe (137). The other ends of these suction pipes (135, 136, 137) are connected to the fourth connection pipe (34) through a first low-stage suction pipe (138).

[0087] The first low-stage discharge pipe (134) is provided with a first low-stage oil separator (124). The first low-stage oil separator (124) is in the shape of a sealed cylinder. An end of a first low-stage oil return pipe (124a) is connected to the bottom of the first low-stage oil separator (124). The other end of the first low-stage oil return pipe (124a) is connected to the first low-stage suction pipe (138). The first low-stage oil return pipe (124a) is provided with a second solenoid valve (SV2). The first low-stage oil separator (124) separates oil (i.e., refrigerating machine oil) from the refrigerant expelled from the first through third low-stage compressors (121, 122, 123). The oil obtained by the first low-stage oil separator (124) is sucked into the low-stage compressors (121, 122, 123) by way of a low-stage oil return pipe (124a) with the second solenoid valve (SV2) opened.

[0088] First through third oil discharge pipes (141, 142, 143) are respectively connected to the low-stage compressors (121, 122, 123) of the first booster circuit (120). An end of each of the oil discharge pipes (141, 142, 143) opens into an oil sump in a casing of an associated one of the low-stage compressors (121, 122, 123). The other end of each of the oil discharge pipes (141, 142, 143) is connected to the first low-stage discharge pipe (134). The first through third oil discharge pipes (141, 142, 143) are provided with a third solenoid valve (SV3), a fourth solenoid valve (SV4), and a fifth solenoid valve (SV5), respectively. In the oil discharge pipes (141, 142, 143), when the solenoid valves (SV3, SV4, SV5) are opened, redundant oil that has accumulated in the low-stage compressors (121, 122, 123) is sent to the high-stage compressors (41, 42, 43) in the outdoor circuit (40).

[0089] The first booster circuit (120) includes a first escape pipe (144), a first bypass pipe (145), a first suction side injection pipe (146), and a first discharge side injection pipe (147).

[0090] When the low-stage compressors (121, 122, 123) are stopped because of failures or the like during cooling operation which will be described later, the first escape pipe (144) allows the refrigerant in the suction sides of the low-stage compressors (121, 122, 123) to be sent to the high-stage compressors (41, 42, 43) in the outdoor circuit (40). An end of the first escape pipe (144) is connected to the suction sides of the low-stage compressors (121, 122, 123), and the other end of the first escape pipe (144) is connected to a point between the first low-stage oil separator (124) and the third shut-off valve (23).

[0091] The first bypass pipe (145) allows the refrigerant to bypass the low-stage compressors (121, 122, 123). The first bypass pipe (145) connects the suction sides and the discharge sides of the low-stage compressors (121, 122, 123). Specifically, an end of the first bypass pipe (145) is connected to the first low-stage suction pipe (138). On the other hand, as illustrated in FIG. 3, the other end of the first bypass pipe (145) is connected to the first low-stage oil return pipe (124a) so as to be connected to the bottom of the first low-stage oil separator (124). The first bypass pipe (145) is provided with a sixth solenoid valve (SV6).

[0092] The first suction side injection pipe (146) is configured to send liquid refrigerant to the suction sides of the low-stage compressors (121, 122, 123). During cooling operation, the liquid refrigerant is sucked into the low-stage compressors (121, 122, 123) as appropriate, thus adjusting the temperature of the refrigerant expelled from the low-stage compressors (121, 122, 123). An end of the first suction side injection pipe (146) is connected to the third connection pipe (33), and the other end of the first suction side injection pipe (146) is connected to the first low-stage suction pipe (138). The first suction side injection pipe (146) is provided with a third motor-operated valve (146a) controllable in opening.

[0093] The first discharge side injection pipe (147) sends the liquid refrigerant to the discharge sides of the low-stage compressors (121, 122, 123). During cooling operation, the liquid refrigerant is mixed with the refrigerant expelled from the low-stage compressors (121, 122, 123), and thus oil remaining in the expelled refrigerant can be easily transmitted with the refrigerant. Specifically, when the refrigerant expelled from the low-stage compressors (121, 122, 123) is excessively dried, oil in the refrigerant is likely to stagnate in, for example, the connection pipes. However, the mixing of the liquid refrigerant in the expelled refrigerant facilitates transmission of the oil to the high-stage compressors (41, 42, 43) in the outdoor circuit (40). An end of the first discharge side injection pipe (147) is connected to the third connection pipe (33), and the other end of the first discharge side injection pipe (147) is connected to the first low-stage discharge pipe (134). The first discharge side injection pipe (147) is provided with a fourth motor-operated valve (147a) controllable in opening.

[0094] The first booster circuit (120) includes various sensors. Specifically, the fourth discharge pipe (131) is provided with a fourth discharge temperature sensor (151), the fifth discharge pipe (132) is provided with a fifth discharge temperature sensor (152), and the sixth discharge pipe (133) is provided with a sixth discharge temperature sensor (153). The discharge temperature sensors (151, 152, 153) respectively detect the temperatures of the refrigerant expelled from the low-stage compressors (121, 122, 123). The first low-stage discharge pipe (134) is provided with a first low-stage high-pressure pressure sensor (154). The first low-stage suction pipe (138) is provided with a first low-stage low-pressure pressure sensor (155). The first low-stage high-pressure pressure sensor (154) detects the pressure of the refrigerant at the discharge side of the first booster circuit (120). The first low-stage low-pressure pressure sensor (155) detects the pressure of the refrigerant at the suction side of the first booster circuit (120).

[0095] The first booster circuit (120) includes a plurality of check valves. Specifically, the fourth discharge pipe (131) is provided with a seventh check valve (CV7), the fifth discharge pipe (132) is provided with an eighth check valve (CV8), and the sixth discharge pipe (133) is provided with a ninth check valve (CV9). The first escape pipe (144) is provided with a tenth check valve (CV 10).

<<Second Booster Unit>>

[0096] The second booster circuit (160) of the second booster unit (16) has a configuration similar to that of the first booster circuit (120) described above, and thus detailed description thereof is omitted. That is, the second booster circuit (160) includes a fourth low-stage compressor (161), a fifth low-stage compressor (162), and a sixth low-stage compressor (163). The second booster circuit (160) includes seventh through ninth discharge pipes (171, 172, 173), a second low-stage discharge pipe (174), seventh through ninth suction pipes (175, 176, 177), and a second low-stage suction pipe (178).

[0097] The second booster circuit (160) includes a second low-stage oil separator (164), a second low-stage oil return pipe (164a), and fourth through sixth oil discharge pipes (181, 182, 183). The second low-stage oil return pipe (164a) is provided with a seventh solenoid valve (SV7). The oil discharge pipes (181, 182, 183) are respectively provided with eighth through tenth solenoid valves (SV8, SV9, SV 10). The second booster circuit (160) includes a second escape pipe (184), a second bypass pipe (185), a second suction side injection pipe (186), and a second discharge side injection pipe (187). The second bypass pipe (185) is provided with an eleventh solenoid valve (SV11), the second suction side injection pipe (186) is provided with a fifth motor-operated valve (186a), and the second discharge side injection pipe (187) is provided with a sixth motor-operated valve (187a). The second booster circuit (160) further includes seventh through ninth discharge temperature sensors (191, 192, 193), a second low-stage high-pressure pressure sensor (194), a second low-stage low-pressure pressure sensor (195), and eleventh through fourteenth check valves (CV 11, CV 12, CV13, CV 14).

<<Control Unit>>

[0098] The refrigeration system (10) of this embodiment includes a controller (200) as a control unit. This controller (200) is configured to receive detection signals obtained by, for example, the sensors in the outdoor unit (11), the supercooling unit (13), the freezer display case (14), the first booster unit (15), and the second booster unit (16), and to output control signals to components in these units (11, 13, 14, 15, 16).

-Operation-

[0099] Operation of the refrigeration system (10) of this embodiment is now described. This refrigeration system (10) is capable of performing cooling operation for cooling the inside of the freezer display case (14) and also performing defrosting operation for defrosting the cooling heat exchangers (102, 112) in the freezer display case (14).

<Cooling Operation>

[0100] In the cooling operation shown in FIG. 4, the four-way selector valve (48) is set at the first position. The outdoor expansion valve (47) is fully closed. The opening of each of the supercooling side expansion valve (94), the first indoor expansion valve (101), and the second indoor expansion valve (111) is adjusted, as appropriate. The sixth solenoid valve (SV6) and the eleventh solenoid valve (SV11) are closed, and the other solenoid valves are also closed in principle.

[0101] In the cooling operation, the outdoor fan (60), the supercooling side outdoor fan (95), and the in-case fan (103) are driven. The high-stage compressors (41, 42, 43) in the outdoor circuit (40), the low-stage compressors (121, 122, 123) in the first booster circuit (120), the low-stage compressors (161, 162, 163) in the second booster circuit (160) are also driven. Consequently, the refrigerant circuit in the cooling operation operates in a two-stage compression refrigeration cycle in which the outdoor heat exchanger (44) serves as a condenser and the cooling heat exchangers (102, 112) serve as evaporators.

[0102] Specifically, the refrigerant expelled from the high-stage compressors (41, 42, 43) passes through the high-stage discharge pipe (54) and the four-way selector valve (48), and flows into the outdoor heat exchanger (44). In the outdoor heat exchanger (44), the refrigerant dissipates heat to the outdoor air, and condenses. The refrigerant condensed in the outdoor heat exchanger (44) passes through the receiver (45) and the first heat exchanger tube (46a) of the internal heat exchanger (46), and flows into the third liquid pipe (63). Part of the refrigerant flowing in the third liquid pipe (63) is subjected to pressure reduction at the second motor-operated valve (67a) when flowing in the second injection pipe (67), and then flows into the second heat exchanger tube (46b) of the internal heat exchanger (46). In the internal heat exchanger (46), heat is exchanged between the high-pressure refrigerant flowing in the first heat exchanger tube (46a) and the low-pressure refrigerant flowing in the second heat exchanger tube (46b). Consequently, heat of the refrigerant in the first heat exchanger tube (46a) is taken as heat of evaporation of the refrigerant flowing in the second heat exchanger tube (46b). That is, in the internal heat exchanger (46), the refrigerant flowing in the first heat exchanger tube (46a) is cooled. The refrigerant evaporated in the second heat exchanger tube (46b) flows into the high-stage suction pipe (58).

[0103] The refrigerant that has flown from the third liquid pipe (63) passes through the refrigerant reservoir (81), and then flows into the high-pressure side heat exchanger tube (91 a) of the supercooling heat exchanger (91). On the other hand, in the closed circuit (90a) of the supercooling unit (13), a vapor compression refrigeration cycle is performed. Specifically, in the closed circuit (90a), the refrigerant compressed in the supercooling side compressor (92) condenses in the supercooling side outdoor heat exchanger (93), then is subjected to pressure reduction in the supercooling side expansion valve (94), and then flows into the low-pressure side heat exchanger tube (91b) of the supercooling heat exchanger (91). In the supercooling heat exchanger (91), heat of the refrigerant in the high-pressure side heat exchanger tube (91 a) is taken as heat of evaporation of the refrigerant in the low-pressure side heat exchanger tube (91b). That is, in the supercooling heat exchanger (91), the refrigerant flowing in the high-pressure side heat exchanger tube (91a) is further cooled.

[0104] The refrigerant that has flown from the high-pressure side heat exchanger tube (91a) of the supercooling heat exchanger (91) flows through the third connection pipe (33), and then flows into the heating pipe part (33a). At this time, frost that has dropped from the surfaces of the cooling heat exchangers (102, 112) and ice blocks produced by freezing of dew condensation water has accumulated in the drain pan (104). Accordingly, when the drain pan (104) is heated with the refrigerant flowing in the heating pipe part (33a), frost and ice blocks in the drain pan (104) melt. Water produced by the melting in the drain pan (104) is drained from the drain pan (104) through, for example, the drain pipe. On the other hand, the refrigerant flowing in the heating pipe part (33a) gives heat of melting to the frost and ice blocks in the drain pan (104), and thus is further cooled. The refrigerant that has flown from the heating pipe part (33a) is distributed to the first freezing circuit (100) and the second freezing circuit (110).

[0105] The refrigerant that has flown into the first freezing circuit (100) is subjected to pressure reduction when passing through the first indoor expansion valve (101), and then flows into the first cooling heat exchanger (102). In the first cooling heat exchanger (102), the refrigerant takes heat from the in-case air, and evaporates. Consequently, the air in the freezer display case (14) is cooled. The refrigerant that has evaporated in the first cooling heat exchanger (102) flows into the first booster circuit (120).

[0106] In the same manner, the refrigerant that has flown into the second freezing circuit (110) is subjected to pressure reduction when passing through the second indoor expansion valve (111), and then flows into the second cooling heat exchanger (112). In the second cooling heat exchanger (112), the refrigerant takes heat from the in-case air, and evaporates. The refrigerant that has evaporated in the second cooling heat exchanger (112) flows into the second booster circuit (160). In this manner, the air in the freezer display case (14) is kept at, for example, -30°C.

[0107] The refrigerant that has flown into the first booster circuit (120) is sucked into the low-stage compressors (121, 122, 123). The refrigerant compressed in the low-stage compressors (121, 122, 123) passes through the first low-stage oil separator (124), and flows into the sixth connection pipe (36). In the first low-stage oil separator (124), oil is separated from the refrigerant expelled from the low-stage compressors (121, 122, 123). The oil obtained by the separation is sucked into the low-stage compressors (121, 122, 123) through the first low-stage oil return pipe (124a) by appropriately opening the second solenoid valve (SV2).

[0108] In the same manner, the refrigerant that has flown into the second booster circuit (160) is sucked into the low-stage compressors (161, 162, 163). The refrigerant compressed by the low-stage compressors (161, 162, 163) passes through the second low-stage oil separator (164), and flows into the sixth connection pipe (36). In the second low-stage oil separator (164), oil is separated from the refrigerant expelled from the low-stage compressors (161, 162, 163). The oil obtained by the separation is sucked into the low-stage compressors (161, 162, 163) through the second low-stage oil return pipe (164a) by appropriately opening the seventh solenoid valve (SV7).

[0109] The refrigerant merged in the sixth connection pipe (36) passes through the four-way selector valve (48), and flows into the high-stage suction pipe (58). This refrigerant is mixed with the refrigerant which has flown from the second heat exchanger tube (46b) of the internal heat exchanger (46) described above, and is sucked into the high-stage compressors (121, 122, 123) to be compressed.

<Defrosting Operation>

[0110] In defrosting operation of the refrigeration system (10), a first individual defrosting process for defrosting the first cooling heat exchanger (102) and a second individual defrosting process for defrosting the second cooling heat exchanger (112) are repeated.

[0111] In the refrigeration system (10), when the cooling operation described above is continuously performed for a given period of time or longer, the cooling operation shifts to defrosting operation. Specifically, when a timer provided in the controller (200) indicates a given set period, it is determined that an increasing amount of frost has accumulated in the cooling heat exchangers (102, 112), thus performing defrosting operation.

[0112] In this defrosting operation, a first individual defrosting process is performed first. The first individual defrosting process is aimed at defrosting the first cooling heat exchanger (102). Before starting the defrosting operation, a pre-discharge process for recovering refrigerant in the second cooling heat exchanger (112) not to be defrosted in the first individual defrosting process, which is performed first in the subsequent operation, is performed.

<<Pre-discharge Operation>>

[0113] In the pre-discharge process shown in FIG. 5, the four-way selector valve (48) is set at the first position, and the high-stage compressors (41, 42, 43) operate. The outdoor expansion valve (47) is fully closed. The opening of the supercooling side expansion valve (94) is adjusted. In the first utilization side circuit (100, 120) associated with the first cooling heat exchanger (102) to be defrosted in the first individual defrosting process, which will be described later, the opening of each of the first indoor expansion valve (101), the third motor-operated valve (146a), and the fourth motor-operated valve (147a) is adjusted as appropriate, and the sixth solenoid valve (SV6) is closed. In the first utilization side circuit (100, 120), the low-stage compressors (121, 122, 123) are operated. On the other hand, in the second utilization side circuit (110, 160) associated with the second cooling heat exchanger (112) not to be defrosted in the first individual defrosting process, each of the second indoor expansion valve (111), the fifth motor-operated valve (186a), and the sixth motor-operated valve (187a) is fully closed, and the eleventh solenoid valve (SV11) is also closed. In the second utilization side circuit (110, 160), the fourth low-stage compressor (161) which is a variable displacement compressor is operated.

[0114] In this pre-discharge process, the refrigerant compressed in the high-stage compressors (41, 42, 43) condenses in the outdoor heat exchanger (44), and then is sent only to the first utilization side circuit (100, 120). In the first utilization side circuit (100, 120), the refrigerant subjected to pressure reduction at the first indoor expansion valve (101) evaporates in the first cooling heat exchanger (102). Accordingly, in this pre-discharge process, cooling of the air in the freezer display case (14) is still continued. The refrigerant that has evaporated in the first cooling heat exchanger (102) is compressed in the low-stage compressors (121, 122, 123) in the first booster circuit (120), and flows into the sixth connection pipe (36).

[0115] On the other hand, in the second utilization side circuit (110, 160), the refrigerant is sealed in between the second indoor expansion valve (111) and the suction ports of the low-stage compressors (161, 162, 163). When the fourth low-stage compressor (161) is driven in this state, the refrigerant that has accumulated in the second cooling heat exchanger (112) and the refrigerant sealed in the other pipes are sucked into the fourth low-stage compressor (161) to be compressed. This causes a rapid decrease in the pressure at the suction side of the fourth low-stage compressor (161). Accordingly, even if the temporarily sealed refrigerant condenses and becomes liquid, the pressure of this refrigerant is reduced, and the refrigerant becomes gas. This can avoid a so-called liquid compression phenomenon in which the liquid refrigerant is sucked into the fourth low-stage compressor (161).

[0116] The refrigerant expelled from the fourth low-stage compressor (161) passes through the second low-stage oil separator (164), and flows into the sixth connection pipe (36). In this manner, in the second utilization side circuit (110, 160) not to be defrosted in the first individual defrosting process, the refrigerant is discharged outside the system with operation of the low-stage compressor (161), and is recovered to the outdoor circuit (40). During the pre-discharge process, this refrigerant is sent to the first cooling heat exchanger (102), and is used for cooling of the freezer display case (14).

[0117] In addition, in the pre-discharge process, the seventh solenoid valve (SV7) is opened as appropriate, thereby returning oil recovered in the second low-stage oil separator (164) to the second low-stage oil return pipe (164a). Further, at this time, the eighth solenoid valve (SV8) is opened. This causes redundant oil in the fourth low-stage compressor (161) to be sent to the sixth connection pipe (36) by way of the fourth oil discharge pipe (181), and is finally sucked into the high-stage compressors (41, 42, 43). As described above, in this pre-discharge process, oil recovery operation in which oil in the low-stage compressor (161) in the second utilization side circuit (110, 160) not to be defrosted in the first individual defrosting process is sent to the high-stage compressors (41, 42, 43) is also performed.

[0118] In the pre-discharge process, operation capacity of the fourth low-stage compressor (161) is controlled according to the refrigerant temperatures at the discharge sides of the low-stage compressors (161, 162, 163) in the second utilization side circuit (110, 160). Specifically, the fourth low-stage compressor (161) is controlled in such a manner that the operation frequency decreases as the temperature of the expelled refrigerant detected by the seventh discharge temperature sensor (191).

[0119] In the pre-discharge process, when the temperature detected by the seventh discharge temperature sensor (191) reaches a given temperature or more, the fourth low-stage compressor (161) is stopped. Consequently, the pre-discharge process is completed, and the first individual defrosting process is performed.

<<First Individual Defrosting Process>>

[0120] In the first individual defrosting process shown in FIG. 6, the four-way selector valve (48) is set at the second position, and the high-stage compressors (41, 42, 43). The opening of each of the outdoor expansion valve (47) and the supercooling side expansion valve (94) is adjusted. In the first utilization side circuit (100, 120) associated with the first cooling heat exchanger (102) to be defrosted in the first individual defrosting process, the first indoor expansion valve (101) is fully opened, each of the third motor-operated valve (146a) and the fourth motor-operated valve (147a) is fully closed, and the sixth solenoid valve (SV6) is opened. In the first utilization side circuit (100, 120), the low-stage compressors (121, 122, 123) are stopped.

[0121] On the other hand, in the second utilization side circuit (110, 160) associated with the second cooling heat exchanger (112) not to be defrosted in the first individual defrosting process, each of the second indoor expansion valve (111), the fifth motor-operated valve (186a), and the sixth motor-operated valve (187a) is fully closed, and the eleventh solenoid valve (SV11) is closed. In the second utilization side circuit (110, 160), the low-stage compressors (161, 162, 163) are stopped.

[0122] In the first individual defrosting process, the refrigerant compressed in the high-stage compressors (41, 42, 43) flows into the sixth connection pipe (36). The refrigerant that has flown into the sixth connection pipe (36) passes through the first booster circuit (120), and flows into the first low-stage oil separator (124). In the first low-stage oil separator (124), the refrigerant that has accumulated therein is pushed out, and flows into the first bypass pipe (145). The refrigerant flowing in the first bypass pipe (145) flows into the first freezing circuit (100) by way of the first low-stage suction pipe (138).

[0123] The refrigerant that has flown into the first freezing circuit (100) flows in the first cooling heat exchanger (102). In the first cooling heat exchanger (102), frost on the surface of the first cooling heat exchanger (102) is heated from the inside thereof to be melted, whereas the refrigerant gives heat of melting to the frost to condense. The refrigerant condensed in the first cooling heat exchanger (102) passes through the fully-open first indoor expansion valve (101), and then flows in the heating pipe part (33a) of the third connection pipe (33). Consequently, this refrigerant heats the inside of the drain pan (104), thereby melting the frost and ice blocks in the drain pan (104). The refrigerant that has passed through the third connection pipe (33) is cooled in the supercooling heat exchanger (91), and then flows into the refrigerant reservoir (81).

[0124] In this case, the refrigerant reservoir (81) stores refrigerant for increasing the amount of refrigerant for use in defrosting the cooling heat exchangers (102, 112) during defrosting operation. Specifically, the refrigerant may stagnate in the cooling heat exchangers (102, 112) during defrosting operation, resulting in a deficiency of the refrigerant for use in defrosting. However, the refrigerant reservoir (81) stores the refrigerant in an amount enough to compensate for the deficiency. Accordingly, when refrigerant stagnation occurs in the cooling heat exchangers (102, 112), refrigerant in an amount corresponding to the amount of the stagnating refrigerant flows from the refrigerant reservoir (81) into the fourth liquid pipe (82) as appropriate, thereby adding the refrigerant in the refrigerant circuit.

[0125] The refrigerant that has flown from the refrigerant reservoir (81) is further cooled in the internal heat exchanger (46), and then is subjected to pressure reduction in the outdoor expansion valve (47). The refrigerant whose pressure has been reduced in the outdoor expansion valve (47) condenses in the outdoor heat exchanger (44), and is sucked into the high-stage compressors (41, 42, 43).

[0126] On the other hand, in the second utilization side circuit (110, 160), the second indoor expansion valve (111), the eleventh solenoid valve (SV11), the fifth motor-operated valve (186a), and the sixth motor-operated valve (187a) are closed. Accordingly, no refrigerant is sent to the second utilization side circuit (110, 160), and thus the second cooling heat exchanger (112) not to be defrosted in the first individual defrosting process is stopped.

[0127] The first individual defrosting process as described above is completed before a given amount of liquid refrigerant accumulates in the first cooling heat exchanger (102). Specifically, as the first individual defrosting process continues, liquid refrigerant accumulates in the first cooling heat exchanger (102), and thus the degree of supercooling of the refrigerant which has flown from the first cooling heat exchanger (102) increases. In the first individual defrosting process, the degree of supercooling is calculated from the difference between the condensation temperature of the first cooling heat exchanger (102) obtained from the values detected by the high-stage high-pressure pressure sensor (74) and the first refrigerant-temperature sensor (105) and the temperature of the refrigerant detected by the second refrigerant-temperature sensor (106). When the obtained degree of supercooling reaches a given temperature (e.g., 5°C) or more, the first individual defrosting process is completed.

[0128] After the completion of the first individual defrosting process, the next individual defrosting process is performed so as to switch the cooling heat exchanger (102, 112) to be defrosted. Specifically, after the completion of the first individual defrosting process, the defrosting target is changed from the first cooling heat exchanger (102) to the second cooling heat exchanger (112), and then a second individual defrosting process is performed.

[0129] After the first individual defrosting process described above, the refrigerant remains in the first cooling heat exchanger (102) and the pipes located before and after the first cooling heat exchanger (102). If the second individual defrosting process was immediately performed after this state, an insufficient amount of refrigerant might be kept for defrosting of the second cooling heat exchanger. To prevent this, in the refrigeration system (10) of this embodiment, before the second individual defrosting process, a discharge process (i.e., a first discharge process) for discharging refrigerant in the first cooling heat exchanger (102) not to be defrosted in the second individual defrosting process is performed, in the same manner as in the pre-discharge process described above.

<<First Discharge Process>>

[0130] In the first discharge process shown in FIG. 7, the four-way selector valve (48) is set at the second position, and the high-stage compressors (41, 42, 43) operate. In addition, the opening of each of the outdoor expansion valve (47) and the supercooling side expansion valve (94) is adjusted. In the second utilization side circuit (110, 160) associated with the second cooling heat exchanger (112) to be defrosted in the second individual defrosting process, the second indoor expansion valve (111) is fully opened, the fifth motor-operated valve (186a) and the sixth motor-operated valve (187a) are closed, and the eleventh solenoid valve (SV11) is opened. In the second utilization side circuit (110, 160), the low-stage compressors (161, 162, 163) are stopped.

[0131] On the other hand, in the first utilization side circuit (100, 120) associated with the first cooling heat exchanger (102) not to be defrosted in the second individual defrosting process, each of the first indoor expansion valve (101), the third motor-operated valve (146a), and the fourth motor-operated valve (147a) is fully closed, and the sixth solenoid valve (SV6) is also closed. In the first utilization side circuit (100, 120), the first low-stage compressor (121) which is a variable displacement compressor is operated.

[0132] In the first discharge process, the refrigerant compressed in the high-stage compressors (41, 42, 43) flows into the sixth connection pipe (36). The refrigerant flowing in the sixth connection pipe (36) passes through the second booster circuit (160), and then flows into the second low-stage oil separator (164). In the second low-stage oil separator (164), the refrigerant that has accumulated therein is pushed out, and flows into the second bypass pipe (185). The refrigerant flowing in the second bypass pipe (185) flows into the second freezing circuit (110) by way of the second low-stage suction pipe (178).

[0133] The refrigerant that has flown into the second freezing circuit (110) flows into the second cooling heat exchanger (112). In the second cooling heat exchanger (112), frost on the surface of the second cooling heat exchanger (112) is heated from the inside thereof to be melted, whereas the refrigerant gives heat of melting to the frost to condense. The refrigerant condensed in the second cooling heat exchanger (112) passes through the fully-open second indoor expansion valve (111), and flows into the heating pipe part (33a) of the third connection pipe (33). Consequently, this refrigerant heats the inside of the drain pan (104), thereby melting the frost and ice blocks in the drain pan (104). The subsequent flow of the refrigerant is the same as in the first individual defrosting process described above, and thus description thereof is omitted.

[0134] On the other hand, in the first utilization side circuit (100, 120), the refrigerant is sealed in between the first indoor expansion valve (101) and the suction ports of the low-stage compressors (141, 142, 143). When the first low-stage compressor (121) is driven in this state, the refrigerant that has accumulated in the first cooling heat exchanger (102) and the refrigerant sealed in the other pipes are sucked into the first low-stage compressor (141) to be compressed. This causes a rapid decrease in the pressure at the suction side of the first low-stage compressor (121), and the refrigerant becomes gas. Accordingly, it is possible to avoid a liquid compression phenomenon in the first low-stage compressor (121).

[0135] The refrigerant compressed in the first low-stage compressor (121) passes through the first low-stage oil separator (124), and flows into the sixth connection pipe (36). This refrigerant is mixed with the refrigerant expelled from the high-stage compressors (41, 42, 43), and is sent to the second utilization side circuit (110, 160). That is, the refrigerant discharged from the first utilization side circuit (100, 120) is used for defrosting the second cooling heat exchanger (112). In this case, the refrigerant discharged from the first utilization side circuit (100, 120) is provided with heat input from the first low-stage compressor (121). Accordingly, the capacity to defrost the second cooling heat exchanger (112) is enhanced.

[0136] In the first discharge process, the second solenoid valve (SV2) and the third solenoid valve (SV3) are opened as appropriate, in the same manner as in the pre-discharge process described above. Consequently, oil recovery operation in which redundant oil in the first low-stage compressor (121) is sent to the high-stage compressors (41, 42, 43) is performed.

[0137] As the pre-discharge process described above, the first discharge process is completed when the temperature detected by the fourth discharge temperature sensor (151) reaches a given temperature or more, and then the second individual defrosting process is performed.

<<Second Individual Defrosting Process>>

[0138] In the second individual defrosting process shown in FIG. 8, the four-way selector valve (48) is set at the second position, and the high-stage compressors (41, 42, 43) operate. In addition, the opening of each of the outdoor expansion valve (47) and the supercooling side expansion valve (94) is adjusted. In the second utilization side circuit (110, 160) associated with the second cooling heat exchanger (112) to be defrosted in the second individual defrosting process, the second indoor expansion valve (111) is fully opened, each of the fifth motor-operated valve (186a) and the sixth motor-operated valve (187a) is fully closed, and the eleventh solenoid valve (SV11) is opened. In the second utilization side circuit (110, 160), the low-stage compressors (161, 162, 163) are stopped.

[0139] On the other hand, in the first utilization side circuit (100, 120) associated with the first cooling heat exchanger (102) not to be defrosted in the second individual defrosting process, each of the first indoor expansion valve (101), the third motor-operated valve (146a), and the fourth motor-operated valve (147a) is fully closed, and the sixth solenoid valve (SV6) is also closed. In the first utilization side circuit (100, 120), the low-stage compressors (121, 122, 123) are stopped.

[0140] In the second individual defrosting process, the refrigerant compressed in the high-stage compressors (41, 42, 43) flows into the sixth connection pipe (36). The refrigerant that has flown into the sixth connection pipe (36) passes through the second booster circuit (160), and then flows into the second low-stage oil separator (164). In the second low-stage oil separator (164), the refrigerant that has accumulated therein is pushed out, and flows into the second bypass pipe (185). The refrigerant that has flown into the second bypass pipe (185) flows into the second freezing circuit (110) by way of the second low-stage suction pipe (178).

[0141] The second freezing circuit (110) defrosts the second cooling heat exchanger (112), in the same manner as in the first individual defrosting process described above. The refrigerant that has flown from the second cooling heat exchanger (112) is also used for heating the inside of the drain pan (104). The subsequent flow of the refrigerant is the same as in the first individual defrosting process described above, and thus description thereof is omitted.

[0142] The second individual defrosting process described above is completed before a given amount of liquid refrigerant accumulates in the second cooling heat exchanger (112). Specifically, in the second individual defrosting process, the degree of supercooling is calculated from the difference between the refrigerant temperature detected by the third refrigerant-temperature sensor (115) and the refrigerant temperature detected by the fourth refrigerant-temperature sensor (116), for example. When the obtained degree of supercooling reaches a given temperature (e.g., 5°C) or more, the second individual defrosting process is completed.

[0143] After the completion of the second individual defrosting process, the first individual defrosting process is performed again. Before this first individual defrosting process, a process (i.e., a second discharge process) for discharging the refrigerant in the second cooling heat exchanger (112) is performed, in the same manner as in the first discharge process described above.

<<Second Discharge Process>>

[0144] In the second discharge process shown in FIG. 9, the four-way selector valve (48) is set at the second position, and the high-stage compressors (41, 42, 43) operate. In addition, the opening of each of the outdoor expansion valve (47) and the supercooling side expansion valve (94) is adjusted. In the first utilization side circuit (100, 120) associated with the first cooling heat exchanger (102) to be defrosted in the first individual defrosting process, the first indoor expansion valve (101) is fully opened, the third motor-operated valve (146a) and the fourth motor-operated valve (147a) are closed, and the sixth solenoid valve (SV6) is opened. In the first utilization side circuit (100, 120), the low-stage compressors (121, 122, 123) are stopped.

[0145] On the other hand, in the second utilization side circuit (110, 160) associated with the second cooling heat exchanger (112) not to be defrosted in the first individual defrosting process, each of the second indoor expansion valve (111), the fifth motor-operated valve (186a), and the sixth motor-operated valve (187a) is fully closed, and the eleventh solenoid valve (SV11) is also closed. In the second utilization side circuit (110, 160), the fourth low-stage compressor (161) which is a variable displacement compressor is operated.

[0146] In the second discharge process, the refrigerant in the second utilization side circuit (110, 160) is discharged to outside the system, as in the first discharge process described above. This refrigerant is sent to the first cooling heat exchanger (102), and is used for defrosting, together with the refrigerant expelled from the high-stage compressors (41, 42, 43).

[0147] As described above, in defrosting operation, a series of a first individual defrosting process→a first discharge process→a second individual defrosting process→a second discharge process→a first individual defrosting process→... is repeated after the pre-discharge process. This defrosting operation is completed when a timer provided in the controller (200) indicates a given set period, and then the cooling operation starts again.

-Advantages of Embodiment-

[0148] In the above embodiment, the first individual defrosting process and the second individual defrosting process are sequentially performed in the defrosting operation in such a manner that the cooling heat exchangers (102, 112) are alternately defrosted. Accordingly, in this embodiment, the amount of refrigerant that accumulates in the cooling heat exchangers (102, 112) is smaller than in a case where the two cooling heat exchangers (102, 112) are defrosted as condensers at a time. Consequently, in the individual defrosting processes, it is possible to keep a sufficient amount of refrigerant for defrosting of the cooling heat exchangers (102, 112), and thus enhancing the efficiency in defrosting operation.

[0149] In addition, in the above embodiment, before the individual defrosting processes, discharge operation for sending refrigerant in the cooling heat exchanger (102, 112) not to be defrosted to the cooling heat exchanger (102, 112) to be defrosted. Accordingly, in this embodiment, the refrigerant in the cooling heat exchanger (102, 112) to be stopped in the subsequent individual defrosting process can be used for defrosting of the cooling heat exchanger (102, 112) to be defrosted, thus ensuring that shortage of the refrigerant caused by refrigerant stagnation is avoided.

[0150] Further, in the first discharge process and the second discharge process of this embodiment, refrigerant compressed by the low-stage compressors (121, 161) is sent to the cooling heat exchanger (102, 112) to be defrosted. Accordingly, heat input from the low-stage compressors (121, 161) can be used for defrosting of the cooling heat exchangers (102, 112), thus enhancing the capacity to defrost the cooling heat exchangers (102, 112).

[0151] In the discharge processes, the indoor expansion valve (101, 111) in the utilization side circuit (100, 120; 110, 160) not to be defrosted is fully closed. Accordingly, the refrigerant is sealed in between the indoor expansion valve (101, 111) and the suction ports of the low-stage compressors (121, 122, 123; 161, 162, 163), and this refrigerant is sent to the cooling heat exchanger (102, 112) to be defrosted. When the low-stage compressor (121, 161) is operated in this manner, the refrigerant at the suction side is subjected to pressure reduction, and becomes gas. Accordingly, it is also possible to avoid a liquid compression phenomenon in the low-stage compressor (121, 161).

[0152] In addition, in the embodiment, an end of each of the bypass pipes (145, 185) is connected to an associated one of the low-stage oil separators (124, 164). Accordingly, in the defrosting operation, the refrigerant that has accumulated in the low-stage oil separators (124, 164) can be sent to the cooling heat exchanger (102, 112) to be defrosted by way of the bypass pipes (145, 185). Consequently, a sufficient amount of refrigerant can be kept for defrosting of the cooling heat exchangers (102, 112). In particular, since an end of each of the bypass pipes (145, 185) is connected to the bottom of an associated one of the low-stage oil separators (124, 164), liquid refrigerant that has accumulated in the low-stage oil separators (124, 164), for example, can also quickly flow into the bypass pipes (145, 185).

[0153] Moreover, in the embodiment, the cooling heat exchangers (102, 112) share a fin. Accordingly, in the individual defrosting processes, one of the cooling heat exchangers (102, 112) which is stopped is defrosted by utilizing heat of refrigerant in the other cooling heat exchanger (102, 112) serving as a condenser. This results in reduction of time necessary for defrosting the cooling heat exchanger (102, 112).

[0154] Furthermore, in the defrosting operation of the embodiment, when the degree of supercooling of the refrigerant that has flown from the cooling heat exchanger (102, 112) to be defrosted reaches a given temperature or more, the target of defrosting is switched. This can avoid refrigerant stagnation in the cooling heat exchangers (102, 112). As a result, a sufficient amount of refrigerant can be kept for defrosting of the cooling heat exchangers (102, 112).

<<Other Embodiments>>

[0155] The above embodiment may have the following configurations.

[0156] In the above embodiment, the individual defrosting processes are performed in the refrigeration system which can operate in a two-stage compression refrigeration cycle. Alternatively, the individual defrosting processes may be performed on a cooling heat exchanger in a refrigeration system operating in a single-stage compression refrigeration cycle.

[0157] In the above embodiment, two cooling heat exchangers (102, 112) are provided, and these cooling heat exchangers (102, 112) are alternately subjected to individual defrosting processes. However, three or more cooling heat exchangers may be provided in such a manner that each individual defrosting process is performed on at least one of these cooling heat exchangers selected in a given order.

[0158] In the above embodiment, the cooling heat exchangers (102, 112) are placed in the same case. Alternatively, the cooling heat exchangers (102, 112) may be placed in different freezer display cases in such a manner that individual defrosting processes are respectively performed on the cooling heat exchangers (102, 112).

[0159] In the discharge processes of the above embodiment, when the temperature of the refrigerant expelled from the low-stage compressor (121, 161) reaches a given temperature or more, the low-stage compressor (121, 161) is stopped. Alternatively, the low-stage compressor (121, 161) may stopped, when the pressure at the suction side of the low-stage compressor (121, 161) decreases to a given pressure or less, for example.

[0160] In the above embodiment, when the degree of supercooling of the cooling heat exchanger (102, 112) to be defrosted reaches a give temperature or more, the target of defrosting is switched, and the process proceeds to the next individual defrosting process. Alternatively, the temperature of the refrigerant flowing from the cooling heat exchanger (102, 112) may be detected by the refrigerant temperature sensor (105, 115) such that when this temperature reaches a given temperature or more, the target of defrosting is switched and the next individual defrosting operation is performed. The pressure at the high-pressure side of the outdoor circuit (40), for example, may also be detected by the high-stage high-pressure pressure sensor (74) such that when this pressure reaches a given pressure or more, the process shifts to the next individual defrosting process.

[0161] The foregoing embodiments are merely preferred examples in nature, and are not intended to limit the scope, applications, and use of the invention.

INDUSTRIAL APPLICABILITY

[0162] As can be seen from the above description, the present invention relates to refrigeration systems each including a plurality of utilization side heat exchangers, and is particularly useful for a refrigeration system capable of performing defrosting operation in a refrigeration cycle in which a plurality of utilization side heat exchangers are defrosted.

Claims

1. A refrigeration system including: a heat-source side circuit (40) including a compressor (41, 42, 43) and a heat-source side heat exchanger (44); and a plurality of utilization side circuits (100, 120; 110, 160) respectively including utilization side heat exchangers (102, 112) and connected in parallel to the heat-source side circuit (40),
   the refrigeration system being switchable between cooling operation performed in a refrigeration cycle in which the heat-source side heat exchanger (44) serves as a condenser and the utilization side heat exchangers (102, 112) serve as evaporators, and defrosting operation performed in a refrigeration cycle in which the utilization side heat exchangers (102, 112) serve as condensers and the heat-source side heat exchanger (44) serves as an evaporator, wherein
   the defrosting operation includes
   an individual defrosting process in which part of the utilization side heat exchangers (102, 112) is operated as a condenser and the other part of the utilization side heat exchangers (102, 112) is stopped, the individual defrosting process being performed a plurality of times in such a manner that each of the utilization side heat exchangers (102, 112) serves as a condenser at least once in the defrosting operation by switching the part of the utilization side heat exchangers (102, 112) serving as a condenser every time, and
   a discharge process in which refrigerant is discharged from the part of the utilization side heat exchangers (102, 112) stopped in the individual defrosting process.

2. The refrigeration system of claim 1, wherein the heat-source side circuit (40) includes the high-stage compressor (41, 42, 43), whereas the utilization side circuits (100, 120; 110, 160) respectively include low-stage compressors (121, 122, 123; 161, 162, 163), in the cooling operation, the high-stage compressor (41, 42, 43) and the low-stage compressors (121, 122, 123; 161, 162, 163) are driven to perform a two-stage compression refrigeration cycle, whereas in the defrosting operation, the high-stage compressor (41, 42, 43) is driven to perform a refrigeration cycle in which only part of the utilization side heat exchangers (102, 112) to be defrosted serves as a condenser, and
in the discharge process, part of the low-stage compressors (121, 122, 123; 161, 162, 163) of the utilization side circuits (100, 120; 110, 160) associated with part of the utilization side heat exchangers (102, 112) not to be defrosted is driven to send refrigerant remaining in the part of the utilization side heat exchangers (102, 112) not to be defrosted to the part of the utilization side heat exchangers (102, 112) to be defrosted.

3. The refrigeration system of claim 2, wherein the utilization side circuits (100, 120; 110, 160) respectively include expansion valves (101, 111) for reducing pressures of refrigerant at inflow ends of the utilization side heat exchangers (102, 112) in the cooling operation, and
in the individual defrosting process, part of the expansion valves (101, 111) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) to be defrosted is opened, whereas part of the expansion valves (101, 111) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is fully closed.

4. The refrigeration system of claim 3, wherein in the discharge process, the part of the expansion valves (101, 111) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is fully closed.

5. The refrigeration system of claim 2, wherein the utilization side circuits (100, 120; 110, 160) respectively include bypass pipes (145, 185) connecting suction sides and discharge sides of the low-stage compressors (121, 122, 123; 161, 162, 163) and provided with shut-off valves (SV6, SV11) which are closed during the cooling operation, and
in the individual defrosting process, part of the shut-off valves (SV6, SV11) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) to be defrosted is opened, whereas part of the shut-off valves (SV6, SV11) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is closed.

6. The refrigeration system of claim 5, wherein in the discharge process, the part of the shut-off valves (SV6, SV11) of the utilization side circuits (100, 120; 110, 160) associated with the part of the utilization side heat exchangers (102, 112) not to be defrosted is closed.

7. The refrigeration system of claim 5, wherein the utilization side circuits (100, 120; 110, 160) respectively include vessel-like oil separators (124, 164) for causing oil in refrigerant expelled from the low-stage compressors (121, 122, 123; 161, 162, 163) to be sucked in the low-stage compressors (121, 122, 123; 161, 162, 163), and
an end of each of the bypass pipes (145, 185) is connected to an associated one of the oil separators (124, 164).

8. The refrigeration system of claim 7, wherein an end of each of the bypass pipes (145, 185) is connected to a bottom of an associated one of the oil separators (124, 164).

9. The refrigeration system of claim 1, wherein the utilization side heat exchangers (102, 112) are placed in a case, and share a fin (102a).

10. The refrigeration system of claim 1, wherein in the defrosting operation, when a degree of supercooling of refrigerant flowing from part of the utilization side heat exchangers (102, 112) to be defrosted reaches a given temperature or more, a target of defrosting in the individual defrosting process is switched.

11. The refrigeration system of claim 1, wherein in the defrosting operation, when a temperature of refrigerant flowing from part of the utilization side heat exchangers (102, 112) to be defrosted reaches a given temperature or more, a target of defrosting in the individual defrosting process is switched.

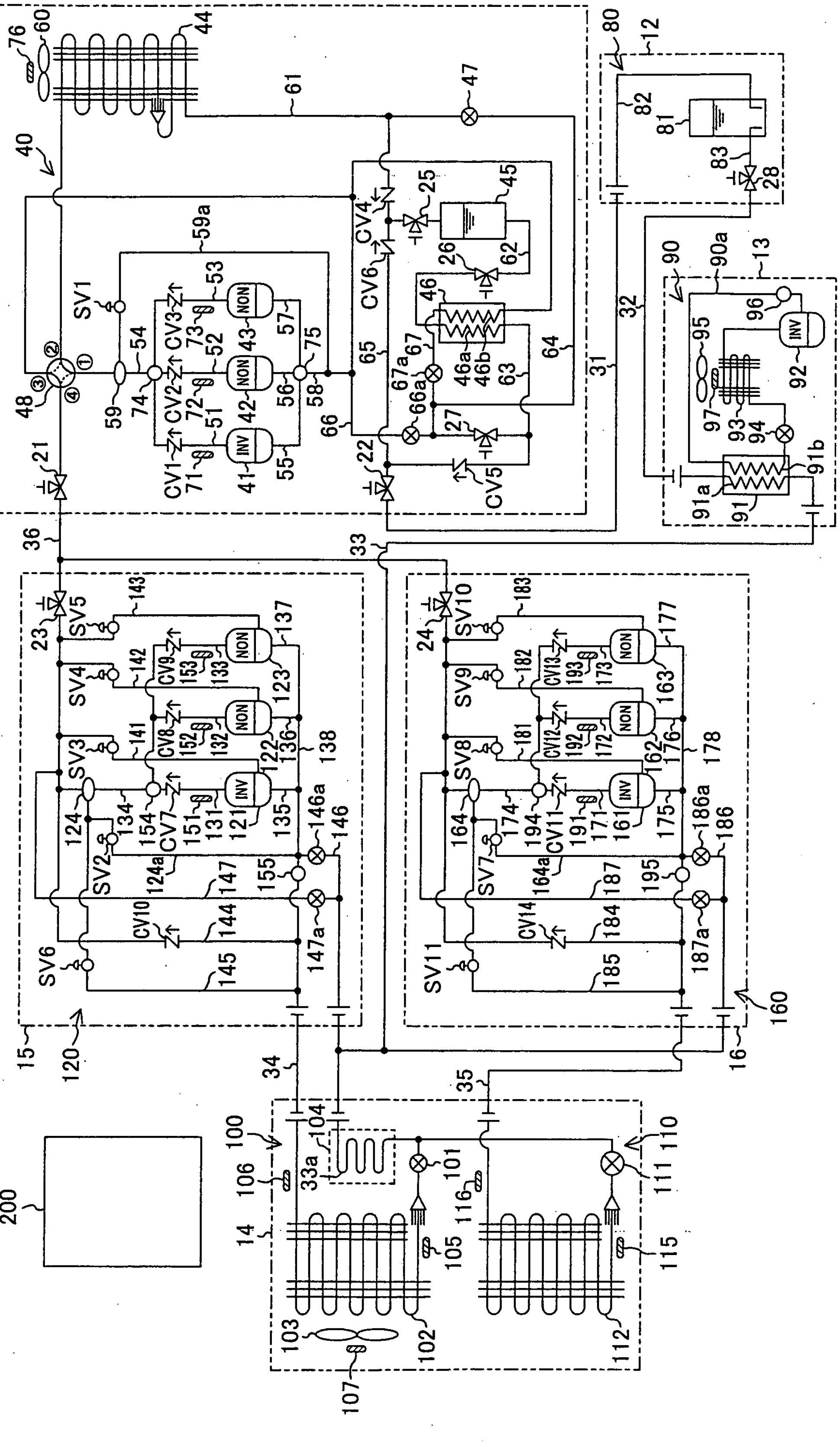
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FIG. 1

FIG. 2

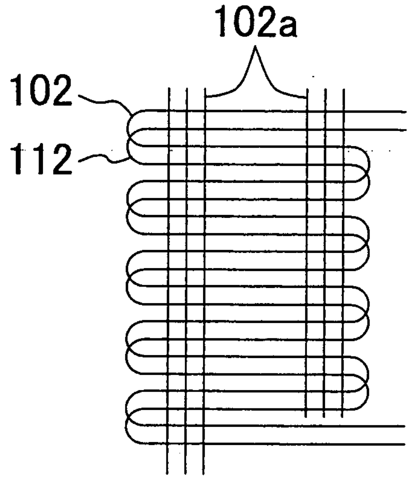
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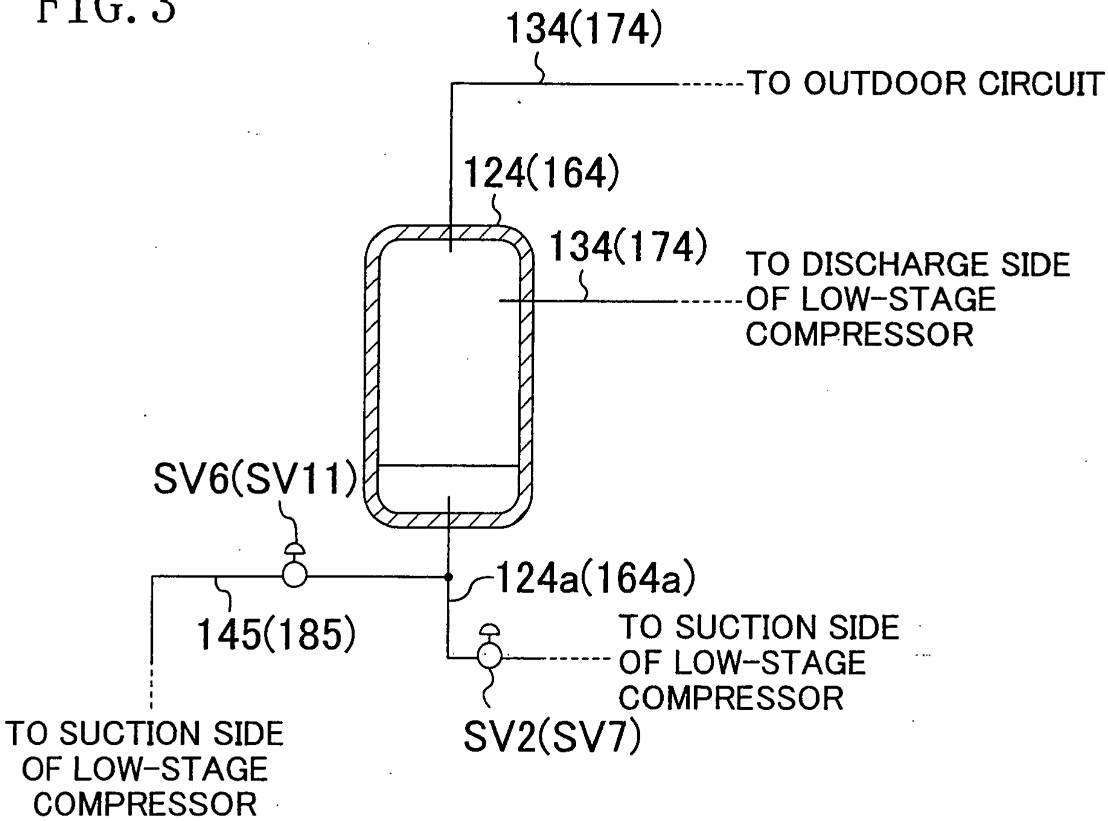
FIG. 3


134(174)
TO OUTDOOR CIRCUIT
124(164)
134(174)
TO DISCHARGE SIDE OF LOW-STAGE COMPRESSOR
SV6(SV11)
124a(164a)
145(185)
TO SUCTION SIDE OF LOW-STAGE COMPRESSOR
SV2(SV7)
TO SUCTION SIDE OF LOW-STAGE COMPRESSOR

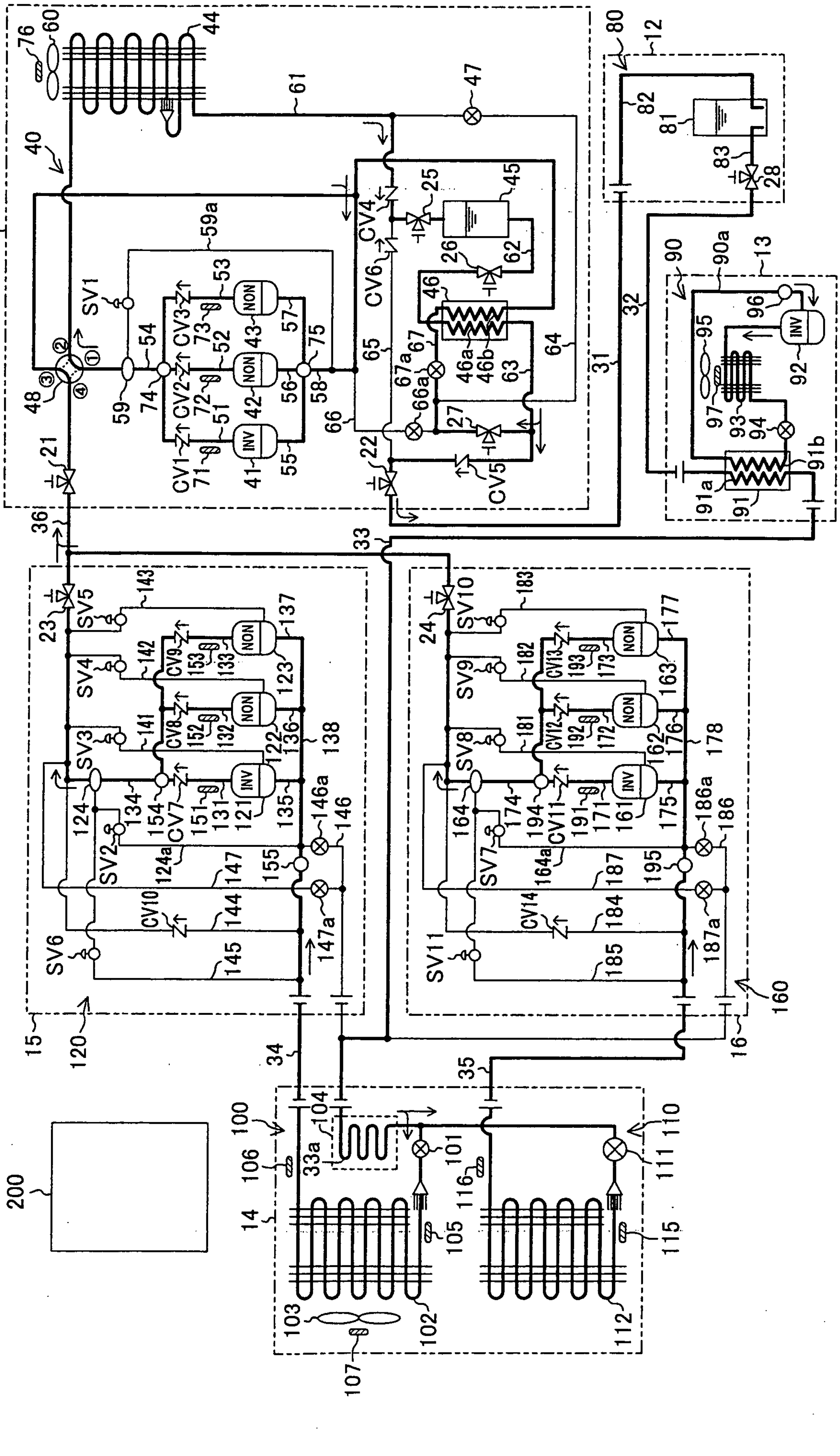

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FIG. 4

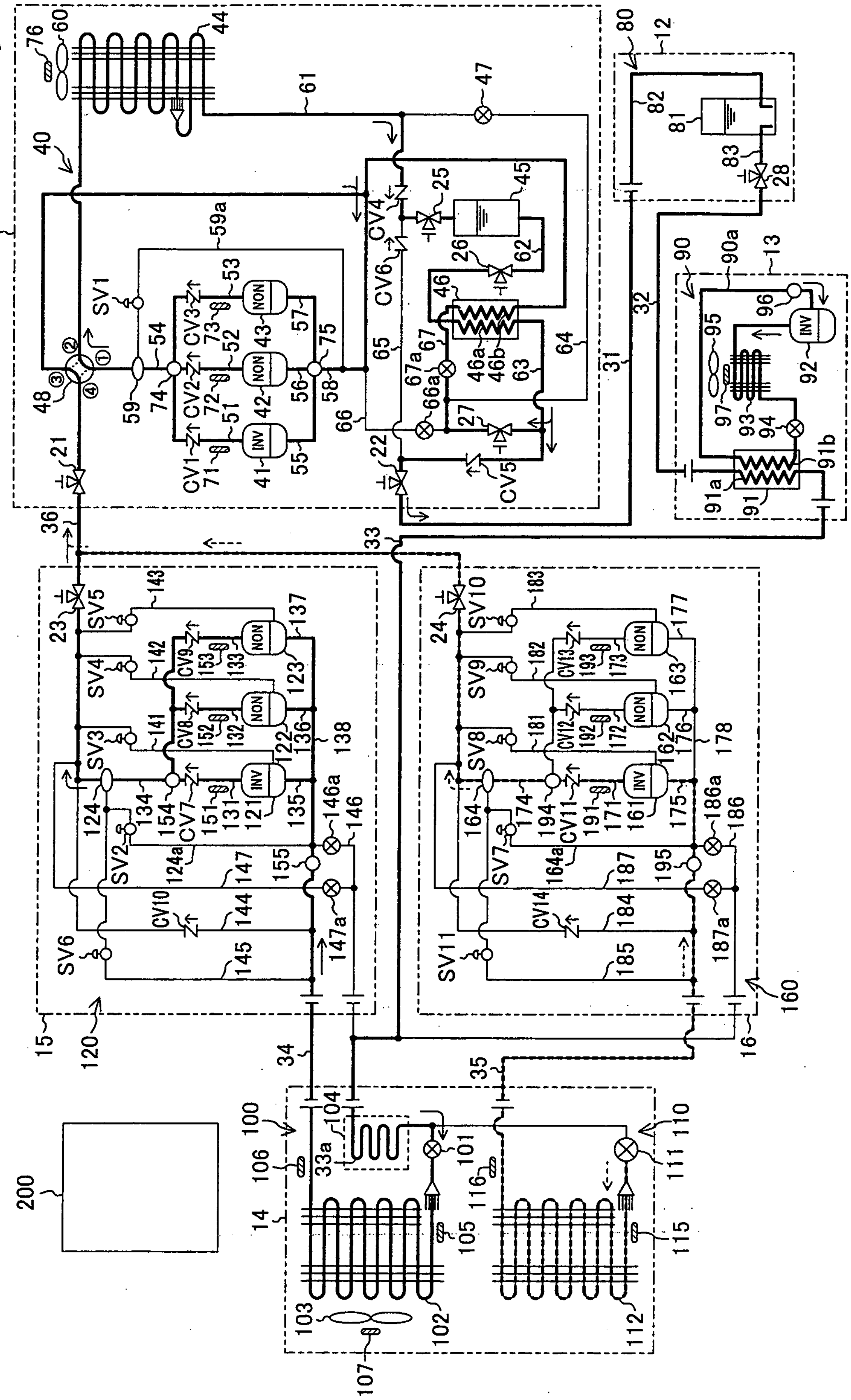
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FIG. 5

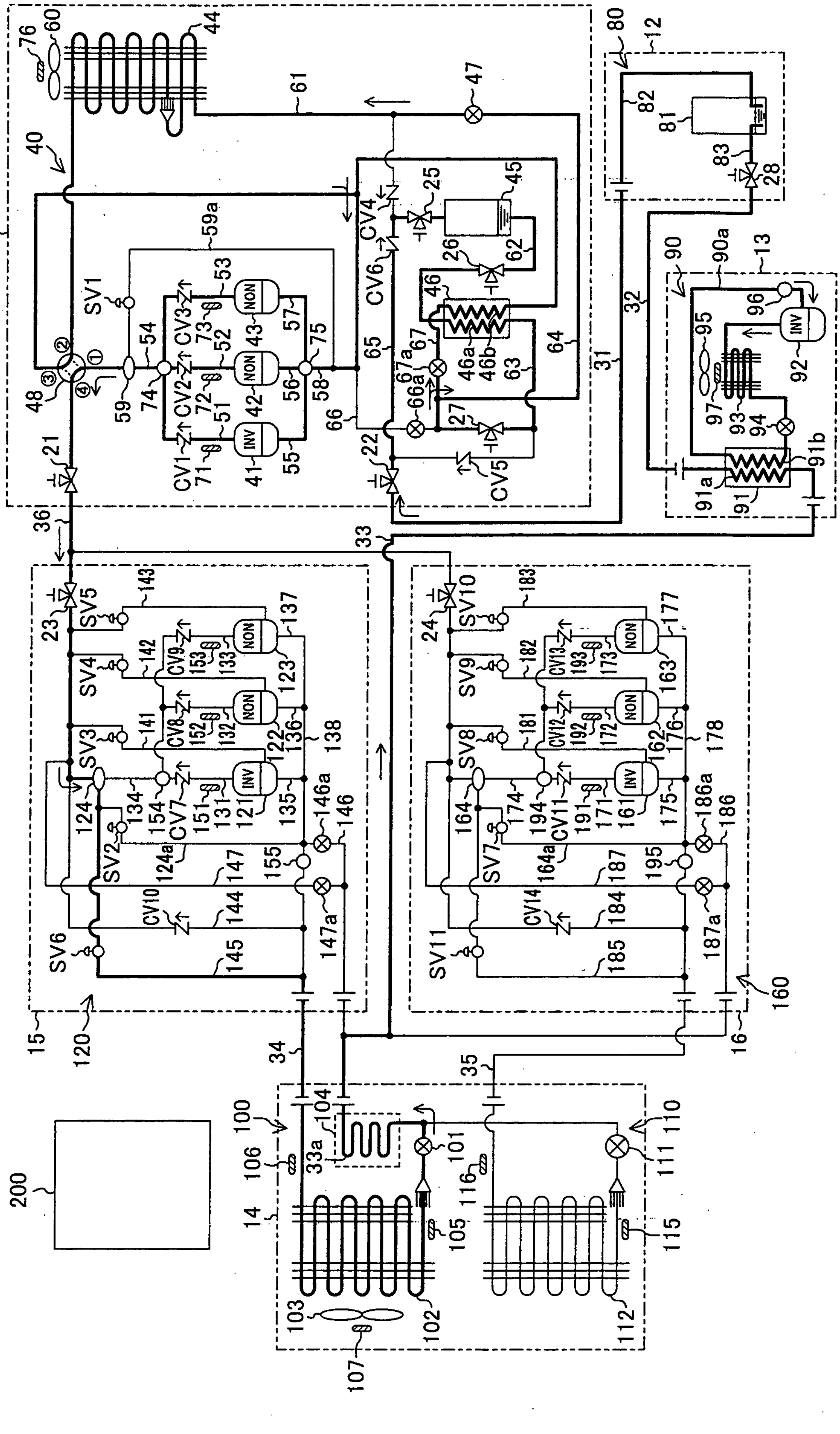

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FIG. 6

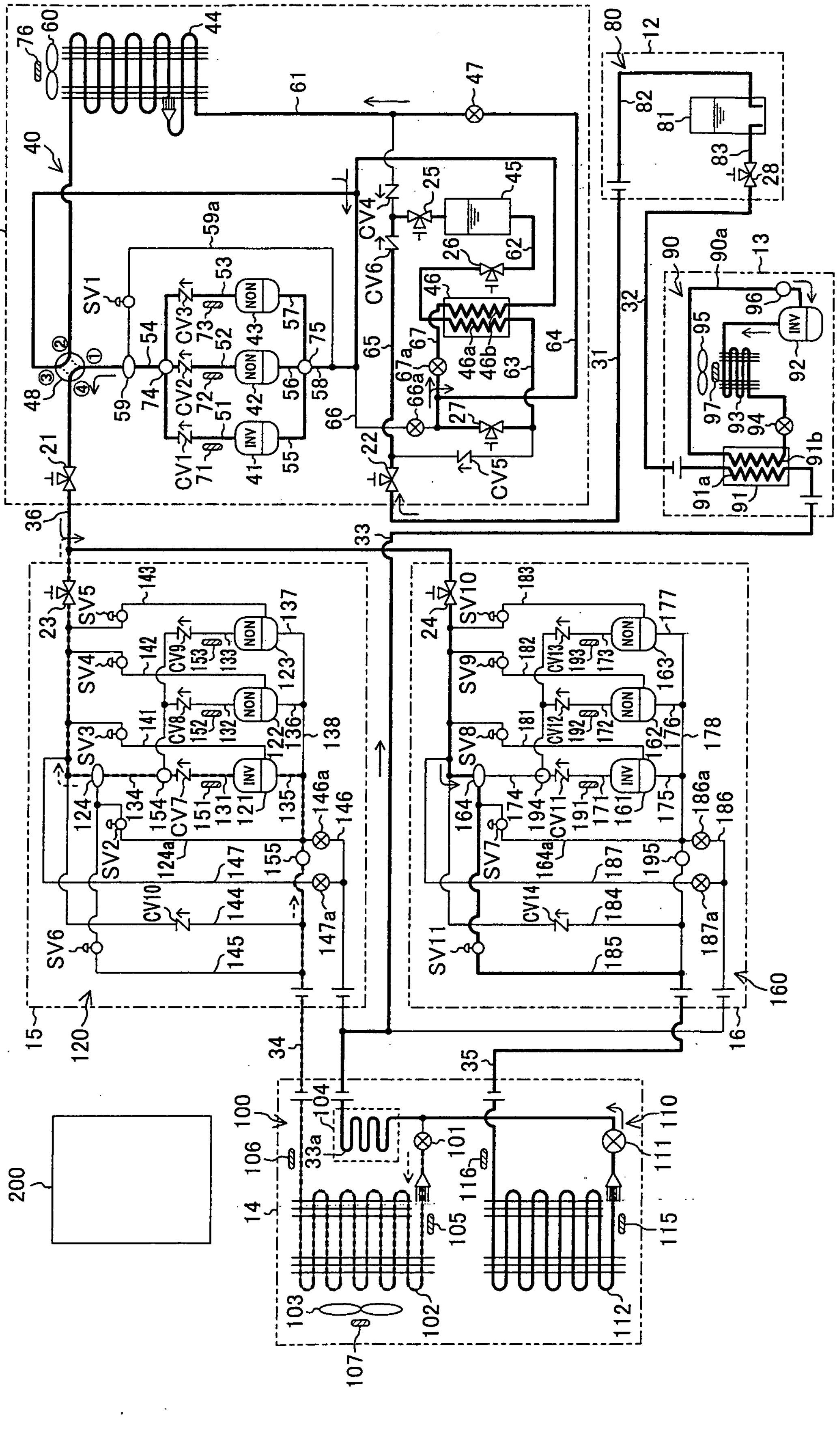
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FIG. 7

FIG. 8

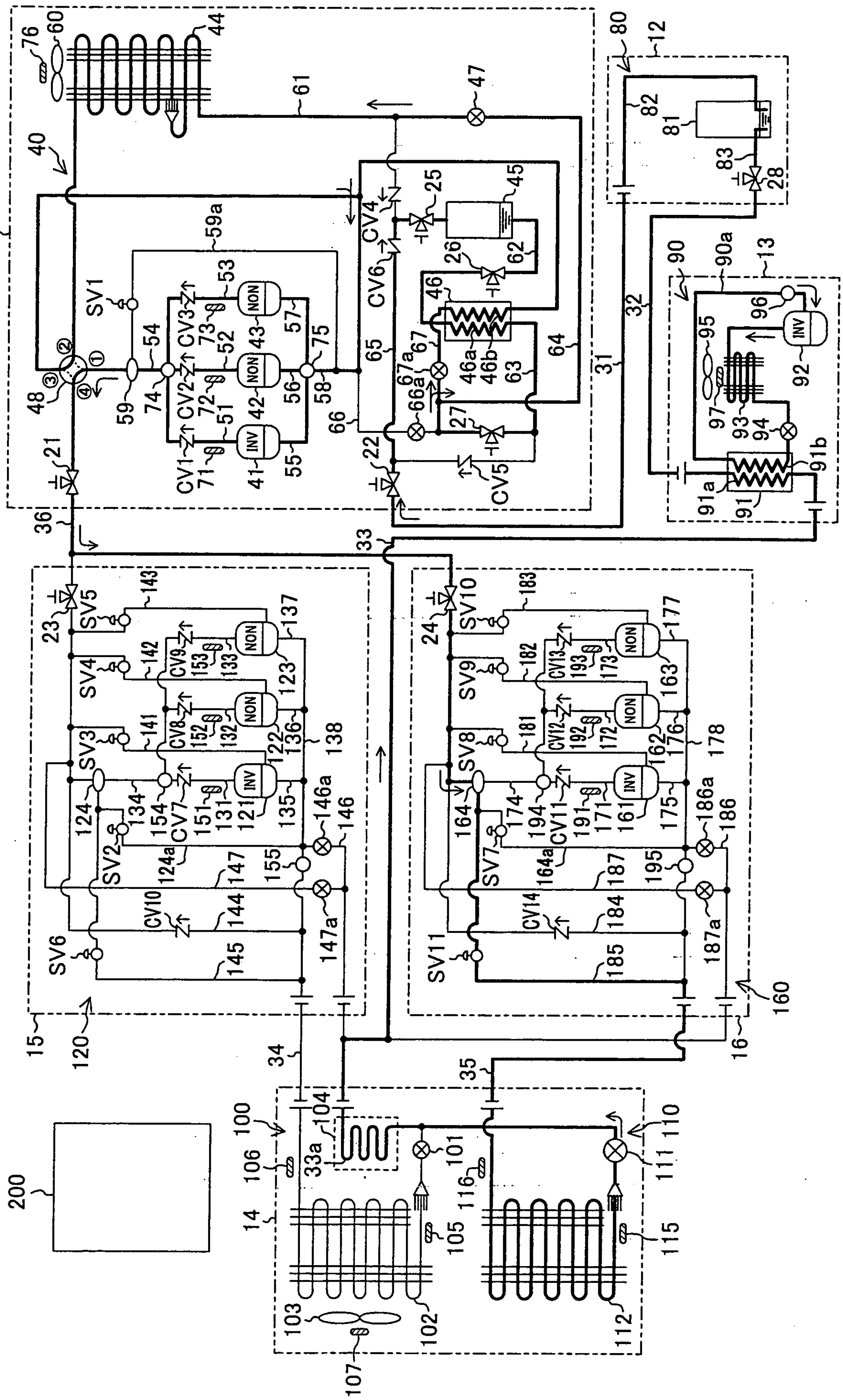
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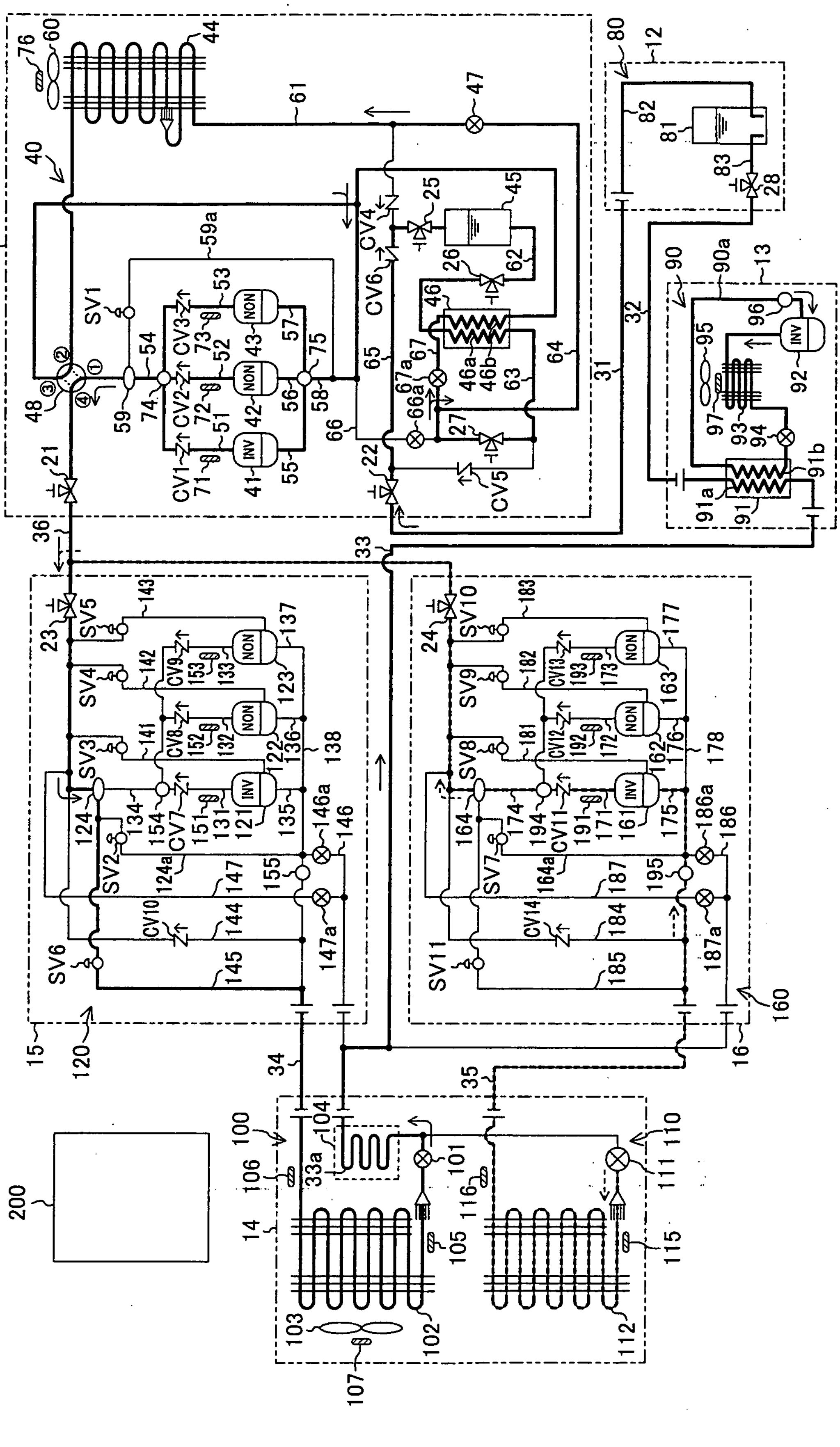
FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/050282

A. CLASSIFICATION OF SUBJECT MATTER
F25B47/02(2006.01)i, *F25B43/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B47/02, F25B43/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2000-121207 A (Daikin Industries, Ltd.), 28 April, 2000 (28.04.00), Claim 1; Par. Nos. [0009], [0012] to [0015], [0070]; Figs. 1 to 6 (Family: none)	1,9,11 2-8,10
Y A	JP 2000-205708 A (Daikin Industries, Ltd.), 28 July, 2000 (28.07.00), Claims 1, 2; Par. Nos. [0008], [0015], [0055], [0062]; Figs. 1 to 6 (Family: none)	1,9,11 2-8,10
Y A	JP 2002-243319 A (Daikin Industries, Ltd.), 28 August, 2002 (28.08.02), Par. Nos. [0034], [0038]; Fig. 1 (Family: none)	9 1-8,10,11

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

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Date of the actual completion of the international search	Date of mailing of the international search report
07 April, 2008 (07.04.08)	15 April, 2008 (15.04.08)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/050282

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Form PCT/ISA/210 (continuation of second sheet) (April 2007)

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- JP 2002228297 A **[0004]**