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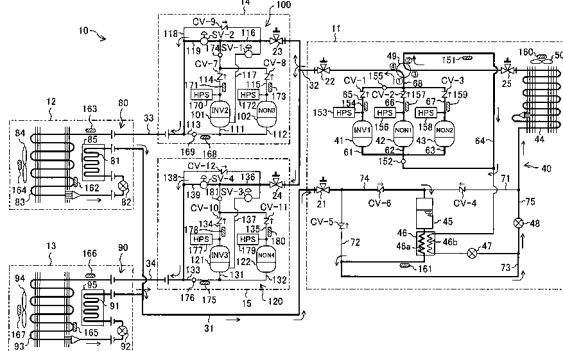
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(54) **REFRIGERATION APPARATUS**

(57) A refrigerant circuit (20) includes a low stage compressor (101, 102, 121, 122), a high stage compressor (41, 42, 43), an outdoor heat exchanger (44) and a utilization side heat exchanger (83, 93). During a defrosting operation of the refrigeration system (10), the high stage compressor (41, 42, 43) is driven. Refrigerant dis-

charged from the high stage compressor (41, 42, 43) is pumped into the utilization side heat exchanger (83, 93) to heat frost on it from its inside. Thereafter, the refrigerant evaporates in the outdoor heat exchanger (44), is then compressed by the high stage compressor (41, 42, 43) and is sent again to the utilization side heat exchanger (83, 93).

FIG. 3



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**Description****Technical Field**

5 **[0001]** This invention relates to refrigeration systems operating in a two-stage compression refrigeration cycle and particularly relates to techniques for defrosting a utilization side heat exchanger for cooling the internal air in a freezer or the like.

**Background Art**

10 **[0002]** Refrigeration systems are conventionally known that include a refrigerant circuit operating in a refrigeration cycle and they are widely used as cooling machines for chillers or freezers for storing food and other materials.

**[0003]** For example, Patent Document 1 discloses a refrigeration system for cooling the internal air of a freezer such as in a convenience store. Connected in the refrigerant circuit of this refrigeration system are a low stage compressor, a high stage compressor, an outdoor heat exchanger (heat-source side heat exchanger) and a cooling heat exchanger (utilization side heat exchanger). This refrigeration system operates in a so-called two-stage compression refrigeration cycle in which the cooling heat exchanger serves as an evaporator, the heat-source side heat exchanger serves as a condenser and the refrigerant is compressed in two stages by driving the low stage compressor and the high stage compressor.

20 **[0004]** In the refrigeration system, the evaporation temperature of refrigerant in the cooling heat exchanger is set at a relatively low temperature. This causes a problem that moisture in the air adheres to the cooling heat exchanger and freezes on it and the frost on it prevents the cooling of the internal air in the freezer. Therefore, such a refrigeration system must perform an operation of melting the frost on the cooling heat exchanger, i.e., a defrosting operation for the cooling heat exchanger.

25 **[0005]** The defrosting operation is commonly carried out using an electric heater as disclosed, for example, in Patent Document 2. In this defrosting operation, air heated by the electric heater is supplied to the cooling heat exchanger to heat the frost on the cooling heat exchanger with the air and thereby melt it.

Patent Document 1: Published Japanese Patent Application No. 2002-228297

30 Patent Document 2: Published Japanese Patent Application No. H09-324978

**Disclosure of the Invention***Problems to Be Solved by the Invention*

35 **[0006]** However, since, in the defrosting operation in the above Patent Document 2, the frost on the cooling heat exchanger is melted by supplying air heated by the electric heater to the cooling heat exchanger, the heated air may flow into the freezer and raise the internal temperature of the freezer. Furthermore, the frost on the cooling heat exchanger must be heated with air from the outside surface of the cooling heat exchanger. Therefore, it takes a long time (for example, 40 minutes or more) to defrost the cooling heat exchanger, which invites another problem that the power consumption is large and the running cost of the refrigeration system thereby increases.

40 **[0007]** The present invention has been made in view of the foregoing points and an object thereof is that the refrigeration system operating in a two-stage compression refrigeration cycle reduces the time taken to defrost the utilization side heat exchanger and reduces the power consumption during the defrosting operation.

*Means to Solve the Problems*

45 **[0008]** A first aspect of the invention is directed to a refrigeration system including a refrigerant circuit (20) in which a low stage compressor (101, 102, 121, 122), a high stage compressor (41, 42, 43), a heat-source side heat exchanger (44) and a utilization side heat exchanger (83, 93) are connected, the refrigeration system being operable in a two-stage compression refrigeration cycle by driving the low stage compressor (101, 102, 121, 122) and the high stage compressor (41, 42, 43) during a cooling operation in which the heat-source side heat exchanger (44) serves as a condenser and the utilization side heat exchanger (83, 93) serves as an evaporator. Furthermore, the refrigeration system is configured to be switchable between the cooling operation and a defrosting operation for defrosting the utilization side heat exchanger (83, 93) and operate, during the defrosting operation, in a refrigeration cycle in which the high stage compressor (41, 42, 43) is driven, the utilization side heat exchanger (83, 93) serves as a condenser and the heat-source side heat exchanger (44) serves as an evaporator.

**[0009]** During the cooling operation in the first aspect of the invention, the refrigerant circuit (20) operates in a two-

stage compression refrigeration cycle, whereby air in a freezer or the like is cooled by the utilization side heat exchanger (83, 93) serving as an evaporator. Specifically, refrigerant compressed by the high stage compressor (41, 42, 43) is condensed in the heat-source side heat exchanger (44) and then reduced in pressure, for example, by an expansion valve. The refrigerant evaporates in the utilization side heat exchanger (83, 93), while the air in the freezer or the like gives heat of evaporation to the refrigerant and is thereby cooled. The refrigerant having evaporated in the utilization side heat exchanger (83, 93) is compressed by the low stage compressor (101, 102, 121, 122). The refrigerant discharged from the low stage compressor (101, 102, 121, 122) is sucked into and further compressed by the high stage compressor (41, 42, 43) and then sent again to the heat-source side heat exchanger (44).

[0010] During the defrosting operation in this aspect of the invention, the high stage compressor (41, 42, 43) is put into operation so that the utilization side heat exchanger (83, 93) is defrosted. Specifically, refrigerant compressed by the high stage compressor (41, 42, 43) is pumped in a high-temperature and high-pressure state into the utilization side heat exchanger (83, 93). In the utilization side heat exchanger (83, 93), frost adhering to its surface is melted by heat from its inside. On the other hand, the refrigerant gives heat of melting to the frost and thereby condenses. The refrigerant having condensed in the utilization side heat exchanger (83, 93) is reduced in pressure, for example, by an expansion valve, and then flows through the heat-source side heat exchanger (44). In the heat-source side heat exchanger (44), the refrigerant takes heat from air and thereby evaporates. The refrigerant having evaporated in the heat-source side heat exchanger (44) is compressed again by the high stage compressor (41, 42, 43).

[0011] A second aspect of the invention is the refrigeration system according to the first aspect of the invention, wherein the refrigeration system is configured to keep the low stage compressor (101, 102, 121, 122) off during the defrosting operation.

[0012] In the second aspect of the invention, during the defrosting operation, the low stage compressor (101, 12, 121, 122) is shut off and the high stage compressor (41, 42, 43) is put into operation, whereby the defrosting operation is performed as in the first aspect of the invention.

[0013] A third aspect of the invention is the refrigeration system according to the second aspect of the invention, further including a bypass pipe (119, 139) that connects the suction side and the discharge side of the low stage compressor (41, 42, 43) and includes a shut-off valve (SV-2, SV-4), the shut-off valve (SV-2, SV-4) being open during the defrosting operation and being closed during the cooling operation.

[0014] During the cooling operation in the third aspect of the invention, the shut-off valve (SV-2, SV-4) of the bypass pipe (119, 139) is closed to interrupt communication between the suction side and the discharge side of the low stage compressor (83, 93). Therefore, the refrigerant having evaporated in the utilization side heat exchanger (83, 93) is sucked into the low stage compressor (101, 102, 121, 122) through the suction side thereof, compressed therein and then sent to the high stage compressor (41, 42, 43).

[0015] On the other hand, during the defrosting operation in this aspect of the invention, the shut-off valve (SV-2, SV-4) of the bypass pipe (119, 139) is open to provide communication between the suction side and the discharge side of the low stage compressor (83, 93). Therefore, the refrigerant sent from the high stage compressor (41, 42, 43) to the discharge side of the low stage compressor (101, 102, 121, 122) is sent via the bypass pipe (119, 139) to the suction side of the low stage compressor (101, 102, 121, 122). In other words, during the defrosting operation, the refrigerant discharged from the high stage compressor (41, 42, 43) bypasses the low stage compressor (101, 102, 121, 122) and is sent to the utilization side heat exchanger (83, 93).

[0016] A fourth aspect of the invention is the refrigeration system according to the second or third aspect of the invention, wherein a drain pan (85, 95) is disposed below the utilization side heat exchanger (83, 93), the refrigerant circuit (20) comprises a utilization side expansion valve (82, 92) connected upstream of the utilization side heat exchanger (83, 93) in the cooling operation and a drain pan heating pipe (81, 91) connected upstream of the utilization side expansion valve (82, 92) in the cooling operation and disposed along the drain pan (85, 95), and the refrigeration system is configured so that, during the cooling operation, refrigerant condensed in the heat-source side heat exchanger (44) flows through the drain pan heating pipe (81, 91), is then reduced in pressure by the utilization side expansion valve (82, 92) and is then fed into the utilization side heat exchanger (83, 93).

[0017] In the fourth aspect of the invention, a drain pan (85, 95) is disposed below the utilization side heat exchanger (83, 93). The drain pan (85, 95) recovers dew condensation water dropping from the surface of the utilization side heat exchanger (83, 93) and frost falling off from it. Furthermore, a drain pan heating pipe (81, 91) is disposed close to the drain pan (85, 95).

[0018] In this case, during the cooling operation in this aspect of the invention, refrigerant condensed in the heat-source side heat exchanger (44) flows through the drain pan heating pipe (81, 91). As a result, frost recovered in the drain pan (85, 95) and ice blocks produced by freezing of dew condensation water in the drain pan (85, 95) melt with heat from the refrigerant flowing through the drain pan heating pipe (81, 91). On the other hand, the refrigerant flowing through drain pan heating pipe (81, 91) gives heat of melting to the frost and ice blocks and is thereby cooled. In other words, the refrigerant gradually decreases its enthalpy as it flows through the drain pan heating pipe (81, 91). Thereafter, the refrigerant is reduced in pressure by the utilization side expansion valve (82, 92) and then evaporates in the utilization

side heat exchanger (83, 93). As a result, air in a freezer or the like is cooled by the utilization side heat exchanger (83, 93).

[0019] A fifth aspect of the invention is the refrigeration system according to the fourth aspect of the invention, wherein the refrigerant circuit (20) includes a heat-source side expansion valve (48) disposed upstream of the heat-source side heat exchanger (44) in the defrosting operation, and the refrigeration system is configured so that, during the defrosting operation, refrigerant condensed in the utilization side heat exchanger (83, 93) flows through the fully-open utilization side expansion valve (82, 92) and the drain pan heating pipe (81, 91), is then reduced in pressure by the heat-source side expansion valve (48) and is then fed into the heat-source side heat exchanger (44).

[0020] During the defrosting operation in the fifth aspect of the invention, the refrigerant condensed by heating frost adhering to the utilization side heat exchanger (83, 93) from its inside flows through the fully-open utilization side expansion valve (82, 92) and then flows through the drain pan heating pipe (81, 91). As a result, frost recovered in the drain pan (85, 95) and ice blocks produced in the drain pan (85, 95) melt with heat from the refrigerant flowing through the drain pan heating pipe (81, 91). Thereafter, the refrigerant is reduced in pressure by the heat-source side expansion valve (48) and then flows through the heat-source side heat exchanger (44). In the heat-source side heat exchanger (44), the refrigerant takes heat from air and thereby evaporates. The refrigerant having evaporated in the heat-source side heat exchanger (44) is compressed by the high stage compressor (41, 42, 43) and sent again to the utilization side heat exchanger (41, 42, 43).

[0021] A sixth aspect of the invention is the refrigeration system according to the first aspect of the invention, wherein the refrigeration system is configured, during the defrosting operation, to operate in a refrigeration cycle in which refrigerant discharged from the high stage compressor (41, 42, 43) is further compressed by the low stage compressor (101, 102, 121, 122), the utilization side heat exchanger (83, 93) serves as a condenser and the heat-source side heat exchanger (44) serves as an evaporator.

[0022] In the sixth aspect of the invention, unlike the second aspect of the invention, both the high stage compressor (41, 42, 43) and the low stage compressor (101, 102, 121, 122) are put into operation during the defrosting operation. Specifically, refrigerant compressed by the high stage compressor (41, 42, 43) is further compressed by the low stage compressor (101, 102, 121, 122) and then sent to the utilization side heat exchanger (83, 93) for use in defrosting it. Since, during the defrosting operation in this aspect of the invention, refrigerant is thus compressed by both the high stage compressor (41, 42, 43) and the low stage compressor (101, 102, 121, 122), this increases the amount of heat given to the refrigerant during the defrosting operation.

[0023] A seventh aspect of the invention is the refrigeration system according to the sixth aspect of the invention, wherein the refrigeration system is configured so that, during the defrosting operation, part of refrigerant discharged from the high stage compressor (41, 42, 43) is further compressed by the low stage compressor (101, 102, 121, 122) and then returned to the discharge side of the high stage compressor (41, 42, 43).

[0024] During the defrosting operation in the seventh aspect of the invention, part of the high stage compressor (41, 42, 43) is sucked into the low stage compressor (101, 102, 121, 22) and further compressed therein. The refrigerant compressed by the low stage compressor (101, 102, 121, 122) is mixed with the refrigerant discharged from the high stage compressor (41, 42, 43), and the mixed refrigerant is sent to the utilization side heat exchanger (83, 93) for use in defrosting it. Since, during the defrosting operation in this aspect of the invention, part of refrigerant discharged from the high stage compressor (41, 42, 43) is compressed by the low stage compressor (101, 102, 121, 122), this increases the amount of heat given to the refrigerant during the defrosting operation.

[0025] An eighth aspect of the invention is the refrigeration system according to the seventh aspect of the invention, wherein the refrigeration system is configured to return, during the defrosting operation, part of refrigerant condensed in the utilization side heat exchanger (83, 93) to the suction side of the low stage compressor (101, 102, 121, 122).

[0026] In the eighth aspect of the invention, during the defrosting operation in the seventh aspect of the invention, part of refrigerant liquefied by condensation in the utilization side heat exchanger (83, 93) is sent to the suction side of the low stage compressor (101, 102, 121, 122). In other words, during the defrosting operation in this aspect of the invention, so-called liquid injection is carried out for the low stage compressor (101, 102, 121, 122). As a result, the refrigerant sucked in the low stage compressor (101, 102, 121, 122) is cooled.

[0027] A ninth aspect of the invention is the refrigeration system according to the first aspect of the invention, further including a liquid return pipe (141, 142) connecting the suction side and the discharge side of the low stage compressor (101, 102, 121, 122), the refrigeration system being configured, after the completion of the defrosting operation, to perform a refrigerant recovery action by driving only the high stage compressor (41, 42, 43) to allow the high stage compressor (41, 42, 43) to suck refrigerant built up in the utilization side heat exchanger (83, 93) through the liquid return pipe (141, 142).

[0028] The refrigerant circuit (20) in the ninth aspect of the invention is provided with a liquid return pipe (141, 142) connecting the suction side and the discharge side of the low stage compressor (101, 102, 121, 122). Furthermore, in performing the cooling operation again after the completion of the defrosting operation, the refrigeration system according to this aspect of the invention performs a refrigerant recovery action in order to prevent liquid refrigerant from being sucked into the low stage compressor (101, 102, 121, 122).

**[0029]** Specifically, when the above defrosting operation is carried out, refrigerant in the utilization side heat exchanger (83, 93) releases heat of melting for defrosting and thereby gradually condenses. Therefore, after the completion of the defrosting operation, liquid refrigerant may be built up in the utilization side heat exchanger (83, 93). If in this state the above cooling operation is carried out by driving both the low stage compressor (101, 102, 121, 122) and the high stage compressor (41, 42, 43), liquid refrigerant built up in the utilization side heat exchanger (83, 93) will be sucked into the low stage compressor (101, 102, 121, 122) to cause a so-called liquid compression phenomenon (liquid back phenomenon), which may break down the low stage compressor (101, 102, 121, 122).

**[0030]** To cope with this, in this aspect of the invention, the following refrigerant recovery action is carried out after the completion of the defrosting operation. In the refrigerant recovery action, only the high stage compressor (41, 42, 43) is driven and the low stage compressor (101, 102, 121, 122) is shut off. Thus, refrigerant sent to the utilization side heat exchanger (83, 93) by driving the high stage compressor (41, 42, 43) flows out of the utilization side heat exchanger (83, 93) together with liquid refrigerant built up in the utilization side heat exchanger (83, 93). The refrigerant flows through the liquid return pipe (141, 142) so as to bypass the low stage compressor (101, 102, 121, 122) in off state and is then sucked into the high stage compressor (41, 42, 43).

**[0031]** As described above, in this aspect of the invention, liquid refrigerant built up in the utilization side heat exchanger (83, 93) is sucked via the liquid return pipe (141, 142) into the high stage compressor (41, 42, 43) after the completion of the defrosting operation. Therefore, it can be surely avoided that after the restart of the cooling operation after the defrosting operation, a liquid compression phenomenon occurs in the low stage compressor (101, 102, 121, 122).

**[0032]** Furthermore, when such a refrigerant recovery action is carried out, liquid refrigerant having flowed out of the utilization side heat exchanger (83, 93) is sucked via the liquid return pipe (141, 142) and the other connection pipes into the high stage compressor (41, 42, 43). Therefore, the liquid refrigerant can easily take heat from the air surrounding the pipes to evaporate when flowing through the pipes. Hence, it can be also avoided that during the refrigerant recovery action, liquid refrigerant is sucked into the high stage compressor (41, 42, 43).

**[0033]** A tenth aspect of the invention is the refrigeration system according to the ninth aspect of the invention, further including an oil separator (143, 144) disposed to the discharge side of the low stage compressor (101, 102, 121, 122) and an oil return pipe (141, 142) for sending refrigerating machine oil recovered by the oil separator (143, 144) to the suction side of the low stage compressor (101, 102, 121, 122), the oil return pipe (141, 142) serving also as the liquid return pipe during the refrigerant recovery action.

**[0034]** In the tenth aspect of the invention, an oil separator (143, 144) is disposed to the discharge side of the low stage compressor (101, 102, 121, 122). When refrigerant discharged from the low stage compressor (101, 102, 121, 122) flows into the oil separator (143, 144) during the above cooling operation, oil is separated from the refrigerant in the oil separator (143, 144) and recovered therein. The refrigerant after oil separation is sent to the high stage compressor (41, 42, 43) and further compressed therein, while the recovered oil is sent via the oil return pipe (141, 142) to the suction side of the low stage compressor (101, 102, 121, 122) and used again to lubricate sliding parts of the low stage compressor (101, 102, 121, 122).

**[0035]** In this aspect of the invention, the oil return pipe (141, 142) serves also as the oil return pipe in the ninth aspect of the invention. In other words, in the above refrigerant recovery action, the liquid refrigerant having flowed out of the utilization side heat exchanger (83, 93) is sent via the oil return pipe (141, 142) and the oil separator (143, 144) to the high stage compressor (41, 42, 43).

**[0036]** An eleventh aspect of the invention is the refrigeration system according to the tenth aspect of the invention, wherein the oil separator (143, 144) is configured, during the refrigerant recovery action, to separate gas refrigerant from refrigerant flowing thereinto from the liquid return pipe (141, 142) and send the gas refrigerant to the suction side of the high stage compressor (41, 42, 43).

**[0037]** In the eleventh aspect of the invention, during the refrigerant recovery action, the oil separator (143, 144) functions as a gas-liquid separator. Specifically, in the refrigerant recovery action in this aspect of the invention, when refrigerant including liquid refrigerant built up in the utilization side heat exchanger (83, 93) flows via the oil return pipe (141, 142) into the oil separator (143, 144), the refrigerant separates, in the oil separator (143, 144), into gas refrigerant and liquid refrigerant. Furthermore, in the refrigerant recovery action, only the gas refrigerant separated in the oil separator (143, 144) is sent to the high stage compressor (41, 42, 43). This effectively avoids a liquid compression phenomenon in the high stage compressor (41, 42, 43) during the refrigerant recovery action.

#### *Effects of the Invention*

**[0038]** According to the present invention, during the defrosting operation, frost adhering to the surface of the utilization side heat exchanger (83, 93) is heated from the inside of the utilization side heat exchanger (83, 93) by feeding the refrigerant discharged by the high stage compressor (41, 42, 43) into the utilization side heat exchanger (83, 93). Therefore, the utilization side heat exchanger (83, 93) can be effectively defrosted, which reduces the time taken to defrost it.

**[0039]** Furthermore, according to the present invention, since during the defrosting operation the heat-source side heat exchanger (44) serves as an evaporator, heat given from air to refrigerant can be used to defrost the utilization side heat exchanger (83, 93). In other words, according to the present invention, heat given to refrigerant by the high stage compressor (41, 42, 43) and heat given to refrigerant by the heat-source side heat exchanger (44) are both used to defrost the utilization side heat exchanger (83, 93). This reduces the defrosting time and in turn reduces the power consumption of the refrigeration system during the defrosting operation.

**[0040]** Particularly, since in the second aspect of the invention the defrosting operation is carried out with the low stage compressor (101, 102, 121, 122) off, this reduces the operating power during the defrosting operation.

**[0041]** Furthermore, according to the third aspect of the invention, by opening and closing the shut-off valve (SV-2, SV-4) of the bypass pipe (119, 139), the refrigeration system can easily switch between the cooling operation of compressing refrigerant evaporated by the utilization side heat exchanger (83, 93) in two stages, i.e., in the low stage compressor (101, 102, 121, 122) and the high stage compressor (41, 42, 43), and the defrosting operation of allowing refrigerant discharged from the high stage compressor (41, 42, 43) to bypass the low stage compressor (101, 102, 121, 22) and sending the refrigerant to the utilization side heat exchanger (83, 93).

**[0042]** Furthermore, in the fourth aspect of the invention, during the cooling operation, refrigerant condensed in the heat-source side heat exchanger (44) is allowed to flow through the drain pan heating pipes (81, 91) before being reduced in pressure by the utilization side expansion valve (82, 92). Therefore, according to this aspect of the invention, heat of condensation of refrigerant can be used to melt frost and ice blocks in the drain pan (85, 95) and the water thus obtained can be promptly drained as drainage away from the drain pan (85, 95). Furthermore, the refrigerant flowing through the drain pan heating pipe (81, 91) gives heat to frost and ice blocks in the drain pan (85, 95) and thereby gradually increases its degree of supercooling. Therefore, the enthalpy of refrigerant flowing into the utilization side heat exchanger (83, 93) can be reduced, which increases the air cooling effect of the utilization side heat exchanger (83, 93).

**[0043]** Furthermore, in the fifth aspect of the invention, during the defrosting operation, the refrigerant used to defrost the utilization side heat exchanger (83, 93) is sent, without reducing its pressure with the utilization side expansion valve (82, 92), to the drain pan heating pipe (81, 91). Therefore, according to this aspect of the invention, also during the defrosting operation, heat of refrigerant flowing through the drain pan heating pipe (81, 91) can be used to melt frost and ice blocks in the drain pan (85, 95).

**[0044]** On the other hand, the refrigerant having flowed through the drain pan heating pipe (81, 82) is reduced in pressure by the heat-source side expansion valve (48) and then flows through the heat-source side heat exchanger (44). Therefore, in the heat-source side heat exchanger (44), heat of evaporation of refrigerant is taken from air and therefore can be used to not only defrost the utilization side heat exchanger (83, 93) but also heat the drain pan (85, 95). This reduces the power consumption during the defrosting operation of the refrigeration system.

**[0045]** Furthermore, in the sixth and seventh aspects of the invention, during the defrosting operation, refrigerant is compressed by both the high stage compressor (41, 42, 43) and the low stage compressor (101, 102, 121, 122). Therefore, according to these aspects of the invention, the amount of heat given to refrigerant during the defrosting operation increases, which enhances the capacity to defrost the utilization side heat exchanger (83, 93). Hence, the utilization side heat exchanger (83, 93) can be effectively defrosted by the defrosting operation in these aspects of the invention even in such a case that the refrigeration system might cause a shortage of defrosting capacity, for example, during the defrosting operation in the second aspect of the invention.

**[0046]** Furthermore, in the eighth aspect of the invention, the refrigerant to be sucked in the low stage compressor (101, 102, 121, 122) is cooled during the defrosting operation by returning liquid refrigerant to the suction side of the low stage compressor (101, 102, 121, 122). Therefore, according to the eighth aspect of the invention, the temperature of refrigerant to be discharged from the low stage compressor (101, 102, 121, 122) can be prevented from abnormally increasing, which ensures the protection of the low stage compressor (101, 102, 121, 122).

**[0047]** In ninth aspect of the invention, after the completion of the defrosting operation, the refrigeration system performs a refrigerant recovery action for allowing the high stage compressor (141, 142) to suck liquid refrigerant built up in the utilization side heat exchanger (83, 93). Therefore, according to this aspect of the invention, it can be surely avoided that in performing the cooling operation again after the defrosting operation, liquid compression occurs in the low stage compressor (101, 102, 121, 122). On the other hand, since the liquid refrigerant is thus sent to the high stage compressor (41, 42, 43), the total length of pipes through which the liquid refrigerant flows can be increased as compared with the case where the liquid refrigerant is sent to the low stage compressor (101, 102, 121, 122). Therefore, according to this aspect of the invention, the liquid refrigerant can be evaporated using heat of the air surrounding the pipes between exit of the liquid refrigerant from the utilization side heat exchanger (83, 93) and sucking thereof into the high stage compressor (141, 142). Hence, according to this aspect of the invention, it can be avoided that during the refrigerant recovery action, liquid compression occurs in the high stage compressor (141, 142).

**[0048]** In the tenth aspect of the invention, an oil separator (143, 144) is disposed to the discharge side of the low stage compressor (101, 102, 121, 122). Therefore, according to this aspect of the invention, during the cooling operation, oil having flowed out of the low stage compressor (101, 102, 121, 122) can be surely returned to the low stage compressor

(101, 102, 121, 122), which eliminates the shortage of refrigerating machine oil in the low stage compressor (101, 102, 121, 122).

[0049] In addition, in this aspect of the invention, the oil return pipe (141, 142) for returning oil recovered by the oil separator (143, 144) to the low stage compressor (101, 102, 121, 122) is used also as a liquid return pipe. Therefore, according to this aspect of the invention, the refrigerant circuit (20) can be simplified.

[0050] In the eleventh aspect of the invention, during the refrigerant recovery action, liquid refrigerant built up in the utilization side heat exchanger (83, 93) is sent to the oil separator (143, 144) and gas refrigerant separated in the oil separator (143, 144) is sent to the high stage compressor (41, 42, 43). Therefore, according to this aspect of the invention, it can be surely avoided that during the refrigerant recovery action, liquid compression occurs in the high stage compressor (41, 42, 43). In addition, in this aspect of the invention, the oil separator (143, 144) used to separate oil during the cooling operation is used as a gas-liquid separator during the refrigerant recovery action. Therefore, according to this aspect of the invention, it can be avoided that liquid compression occurs in the high stage compressor (41, 42, 43) during the refrigerant recovery action, without the need to additionally provide a gas-liquid separator.

## Brief Description of Drawings

### [0051]

[Fig. 1] Figure 1 is a piping diagram showing a schematic configuration of a refrigeration system according to Embodiment 1.

[Fig. 2] Figure 2 is a piping diagram showing the behavior of a cooling operation of the refrigeration system according to Embodiment 1.

[Fig. 3] Figure 3 is a piping diagram showing the behavior of a defrosting operation of the refrigeration system according to Embodiment 1.

[Fig. 4] Figure 4 is a piping diagram showing a schematic configuration of a refrigeration system according to Embodiment 2.

[Fig. 5] Figure 5 is a piping diagram showing the behavior of a second defrosting operation of the refrigeration system according to Embodiment 2.

[Fig. 6] Figure 6 is a piping diagram showing a schematic configuration of a refrigeration system according to Embodiment 3.

[Fig. 7] Figure 7 is an enlarged schematic structural diagram of an oil separator and its surroundings in the refrigeration system according to Embodiment 3.

[Fig. 8] Figure 8 is a piping diagram showing the behavior of a cooling operation of the refrigeration system according to Embodiment 3.

[Fig. 9] Figure 9 is a piping diagram showing the behavior of a defrosting operation of the refrigeration system according to Embodiment 3.

[Fig. 10] Figure 10 is a piping diagram showing a refrigerant recovery action of the refrigeration system according to Embodiment 3.

[Fig. 11] Figure 11 is a piping diagram showing a schematic configuration of a refrigeration system according to a modification of Embodiment 3.

### List of Reference Numerals

### [0052]

|                    |                                                          |
|--------------------|----------------------------------------------------------|
| 10                 | refrigeration system                                     |
| 20                 | refrigerant circuit                                      |
| 41, 42, 43         | high stage compressor                                    |
| 44                 | heat-source side heat exchanger (outdoor heat exchanger) |
| 48                 | heat-source side expansion valve                         |
| 81, 91             | drain pan heating pipe                                   |
| 82, 92             | utilization side expansion valve                         |
| 83, 93             | utilization side heat exchanger (cooling heat exchanger) |
| 85, 95             | drain pan                                                |
| 101, 102, 121, 122 | low stage compressor                                     |
| 119, 139           | bypass pipe                                              |
| 141, 142           | oil return pipe (liquid return pipe)                     |
| 143, 144           | oil separator                                            |

**Best Mode for Carrying Out the Invention**

**[0053]** Embodiments of the present invention will be described below in detail with reference to the drawings.

5 <<Embodiment 1>>

**[0054]** A refrigeration system (10) of Embodiment 1 is placed, for example, in a convenience store and used to cool the interiors of a plurality of freezers.

10 **[0055]** As shown in Figure 1, the refrigeration system (10) of Embodiment 1 includes an outdoor unit (11), a first freezer display case (12), a second freezer display case (13), a first booster unit (14) and a second booster unit (15). The outdoor unit (11) is placed outdoors. On the other hand, the other units (12, 13, 14, 15) are all placed in a store, such as a convenience store.

15 **[0056]** The outdoor unit (11), the first freezer display case (12), the second freezer display case (13), the first booster unit (14) and the second booster unit (15) include an outdoor circuit (40), a first freezing circuit (80), a second freezing circuit (90), a first booster circuit (100) and a second booster circuit (120), respectively. In this refrigeration system (10), a refrigerant circuit (20) operable in a vapor compression refrigeration cycle is constituted by connecting these circuits (40, 80, 90, 100, 120) via pipes.

20 **[0057]** The first freezing circuit (80) and the first booster circuit (100) are connected in series to each other to form a first cooling circuit. The second freezing circuit (90) and the second booster circuit (120) are connected in series to each other to form a second cooling circuit. The first and second cooling circuits are connected in parallel to the outdoor circuit (40).

25 **[0058]** Specifically, a first shut-off valve (21) and a second shut-off valve (22) are disposed at ends of the outdoor circuit (40), a third shut-off valve (23) is disposed at an end of the first booster circuit (100) and a fourth shut-off valve (24) is disposed at an end of the second booster circuit (120). The first shut-off valve (21) is connected to one end of a liquid connection pipe (31). The other end of the liquid connection pipe (31) is divided into two branch lines, one branch line connected to an end of the first freezing circuit (80) and the other connected to an end of the second freezing circuit (90). The second shut-off valve (22) is connected to one end of a gas connection pipe (32). The other end of the gas connection pipe (32) is divided into two branch lines, one branch line connected to the third shut-off valve (23) and the other connected to the fourth shut-off valve (24).

30 <<Outdoor Unit>>

35 **[0059]** The outdoor circuit (40) of the outdoor unit (11) includes a first variable displacement compressor (41), a first fixed displacement compressor (42), a second fixed displacement compressor (43), an outdoor heat exchanger (44), a receiver (45), a supercooling heat exchanger (46), a first outdoor expansion valve (47), a second outdoor expansion valve (48) and a four-way selector valve (49).

40 **[0060]** The first variable displacement compressor (41), the first fixed displacement compressor (42) and the second fixed displacement compressor (43) are all fully-enclosed, high-pressure domed scroll compressors and constitute high stage compressors of the refrigerant circuit (20). The first variable displacement compressor (41) is supplied with electric power through an inverter. The first variable displacement 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 first fixed displacement compressor (42) and the second fixed displacement compressor (43) have their respective motors always operated at constant rotational speeds and are not changeable in displacement.

45 **[0061]** The suction side of the first variable displacement compressor (41) is connected to a first suction pipe (61), the suction side of the first fixed displacement compressor (42) is connected to one end of a second suction pipe (62), and the suction side of the second fixed displacement compressor (43) is connected to one end of a third suction pipe (63). The other ends of these suction pipes (61, 62, 63) are connected via a high stage suction pipe (64) to the four-way selector valve (49).

50 **[0062]** The discharge side of the first variable displacement compressor (41) is connected to a first discharge pipe (65), the discharge side of the first fixed displacement compressor (42) is connected to a second discharge pipe (66), and the discharge side of the second fixed displacement compressor (43) is connected to a third discharge pipe (67). The other ends of these discharge pipes (65, 66, 67) are connected via a high stage discharge pipe (68) to the four-way selector valve (49).

55 **[0063]** The outdoor heat exchanger (44) is a cross-fin type fin-and-tube heat exchanger and constitutes a heat-source side heat exchanger. Disposed close to the outdoor heat exchanger (44) is an outdoor fan (50). The outdoor heat exchanger (44) provides heat exchange between refrigerant therein and outdoor air blown by the outdoor fan (50). One end of the outdoor heat exchanger (44) is connected via a fifth shut-off valve (25) to the four-way selector valve (49). On the other hand, the other end of the outdoor heat exchanger (44) is connected via a first liquid pipe (71) to the top

of the receiver (45).

[0064] The supercooling heat exchanger (46) includes a high-pressure channel (46a) and a low-pressure channel (46b) and provides heat exchange between refrigerants flowing through the channels (46a, 46b). The supercooling heat exchanger (46) is composed of, for example, a plate heat exchanger.

[0065] The inflow end of the high-pressure channel (46a) is connected to the bottom of the receiver (45). Furthermore, the outflow end of the high-pressure channel (46a) is connected via a second liquid pipe (72) to the first shut-off valve (21). On the other hand, the inflow end of the low-pressure channel (46b) is connected via a first branch pipe (73) to a midpoint of the second liquid pipe (72). Furthermore, the outflow end of the low-pressure channel (46b) is connected to the high stage suction pipe (64).

[0066] The second liquid pipe (72) is connected at a point between the junction with the first branch pipe (73) and the first shut-off valve (21) to one end of a second branch pipe (74). The other end of the second branch pipe (74) is connected to the first liquid pipe (71) midway between the outdoor heat exchanger (44) and the receiver (45).

[0067] The first branch pipe (73) is provided with the first outdoor expansion valve (47). The first outdoor expansion valve (47) is composed of an electronic expansion valve controllable in opening. Furthermore, the first branch pipe (73) is connected at a point upstream of the first outdoor expansion valve (47) to one end of a third branch pipe (75). The other end of the third branch pipe (75) is connected to the first liquid pipe (71) midway between the junction with the second branch pipe (74) and the outdoor heat exchanger (44). The third branch pipe (75) is provided with the second outdoor expansion valve (48). The second outdoor expansion valve (48) is an electronic expansion valve controllable in opening and constitutes a heat-source side expansion valve.

[0068] The four-way selector valve (49) is connected at a first port thereof to the high stage discharge pipe (68), connected at a second port thereof to the high stage suction pipe (64), connected at a third port thereof to the outdoor heat exchanger (44) and connected at a fourth port thereof to the second shut-off valve (22). The four-way selector valve (49) is switchable between a first position (the position shown in the solid lines in Figure 1) in which the first and third ports are communicated with each other and the second and fourth ports are communicated with each other and a second position (the position shown in the broken lines in Figure 1) in which the first and fourth ports are communicated with each other and the second and third ports are communicated with each other.

[0069] The outdoor circuit (40) is provided also with various kinds of sensors and pressure switches. Specifically, the high stage suction pipe (64) is provided with a first suction temperature sensor (151) and a first suction pressure sensor (152). The first discharge pipe (65) is provided with a first high-side pressure switch (153), a first discharge temperature sensor (154) and a first discharge pressure sensor (155). The second discharge pipe (66) is provided with a second high-side pressure switch (156) and a second discharge temperature sensor (157). The third discharge pipe (67) is provided with a third high-side pressure switch (158) and a third discharge temperature sensor (159). Disposed close to the outdoor fan (50) for the outdoor heat exchanger (44) is an outdoor air temperature sensor (160). The second liquid pipe (72) is provided with a liquid temperature sensor (161).

[0070] Furthermore, the outdoor circuit (40) is provided also with a plurality of check valves for allowing refrigerant flow in one direction and prohibiting refrigerant flow in the opposite direction. Specifically, the first discharge pipe (65), the second discharge pipe (66) and the third discharge pipe (67) are provided with a check valve (CV-1), a check valve (CV-2) and a check valve (CV-3), respectively. Furthermore, the first liquid pipe (71) has a check valve (CV-4) provided between the junction thereof with the third branch pipe (75) and the junction thereof with the second branch pipe (74). The second liquid pipe (72) has a check valve (CV-5) provided between the junction thereof with the first branch pipe (73) and the junction thereof with the second branch pipe (74). The second branch pipe (74) is provided with a check valve (CV-6). These check valves (CV-1, CV-2,...) are configured to allow only refrigerant flow in the direction of the arrows accompanying the signs indicating the check valves in Figure 1.

<<Freezer Display Case>>

[0071] The first freezing circuit (80) in the first freezer display case (12) includes, in the order from its liquid side end towards its gas side end, a first drain pan heating pipe (81), a first indoor expansion valve (82) and a first cooling heat exchanger (83).

[0072] The first indoor expansion valve (82) is an electronic expansion valve controllable in opening and constitutes a utilization side expansion valve. Furthermore, the first cooling heat exchanger (83) is a cross-fin type fin-and-tube heat exchanger and constitutes a utilization side heat exchanger. Disposed close to the first cooling heat exchanger (83) is a first in-case fan (84). The first cooling heat exchanger (83) provides heat exchange between refrigerant therein and in-case air blown by the first in-case fan (84). Disposed below the first cooling heat exchanger (83) is a first drain pan (85). The first drain pan (85) is configured to recover frost and dew condensation water dropped from the surface of the first cooling heat exchanger (83).

[0073] The first drain pan heating pipe (81) is composed of a refrigerant pipe disposed along the bottom surface of the first drain pan (85). The first drain pan heating pipe (81) is configured to use heat from refrigerant to melt frost

recovered by the first drain pan (85) and ice blocks produced by freezing of liquid drops in the first drain pan (85).

[0074] The first freezing circuit (80) is provided with three temperature sensors. Specifically, the heat exchanger tube of the first cooling heat exchanger (83) is provided with a first refrigerant temperature sensor (162). Disposed close to the gas side end of the first freezing circuit (80) is a first gas temperature sensor (163). Disposed close to the first in-

case fan (84) is a first in-case temperature sensor (164).  
[0075] The second freezing circuit (90) in the second freezer display case (13) has the same structure as the first freezing circuit (80). Specifically, the second freezing circuit (90) includes, like the first freezing circuit (80), a second drain pan heating pipe (91), a second indoor expansion valve (92), a second cooling heat exchanger (93), a second in-

<<Booster Unit>>

[0076] The first booster circuit (100) in the first booster unit (14) is connected via a first booster connection pipe (33) to the gas side end of the first freezing circuit (80). The first booster circuit (100) includes a second variable displacement compressor (101) and a third fixed displacement compressor (102).

[0077] The second variable displacement compressor (101) and the third fixed displacement compressor (102) are both fully-enclosed, high-pressure domed scroll compressors and constitute low stage compressors of the refrigerant circuit (20). The second variable displacement compressor (101) is supplied with electric power through an inverter. The second variable displacement compressor (101) 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 third fixed displacement compressor (102) has its motor always operated at a constant rotational speed and is not changeable in displacement.

[0078] The suction side of the second variable displacement compressor (101) is connected to one end of a fourth suction pipe (111) and the suction side of the third fixed displacement compressor (102) is connected to one end of a fifth suction pipe (112). The other ends of these suction pipes (111, 112) are connected via a first low stage suction pipe (113) to the first booster connection pipe (33).

[0079] The discharge side of the second variable displacement compressor (101) is connected to one end of a fourth discharge pipe (114) and the discharge side of the third fixed displacement compressor (102) is connected to one end of a fifth discharge pipe (115). The other ends of these discharge pipes (114, 115) are connected via a first low stage discharge pipe (116) to the third shut-off valve (23).

[0080] The first booster circuit (100) further includes a first oil discharge pipe (117), a first escape pipe (118) and a first bypass pipe (119).

[0081] The first oil discharge pipe (117) is connected at its one end to an oil discharge port of the second variable displacement compressor (101) and connected at the other end to the first low stage discharge pipe (116). The first oil discharge pipe (117) is provided with a solenoid valve (SV-1). The solenoid valve (SV-1) is turned open when refrigerating machine oil in the second variable displacement compressor (101) becomes excessive. As a result, the refrigerating machine oil flows through the first oil discharge pipe (117) into the outdoor circuit (40) and is then sucked into the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43).

[0082] The first escape pipe (118) is connected at its one end to the first low stage suction pipe (113) and connected at the other end to the first low stage discharge pipe (116). For example, when the second variable displacement compressor (101) or the third fixed displacement compressor (102) goes out of order, the first escape pipe (118) sends refrigerant flowing through the first low stage suction pipe (113) to the outdoor circuit (40) via the first low stage discharge pipe (116), thereby allowing the first variable displacement compressor (41) and the first and second fixed displacement compressor (42, 43) to suck the refrigerant.

[0083] The first bypass pipe (119) is connected at its one end to the first escape pipe (118) and connected at the other end to the first low stage discharge pipe (116). The first bypass pipe (119) is provided with a solenoid valve (SV-2). The solenoid valve (SV-2) is held open during a cooling operation of the refrigeration system (10) and held closed during a defrosting operation thereof (detailed operational behavior of the defrosting operation will be described later).

[0084] The first booster circuit (100) is provided also with various kinds of sensors and pressure switches. Specifically, the first low stage suction pipe (113) is provided with a second suction temperature sensor (168) and a second suction pressure sensor (169). The fourth discharge pipe (114) is provided with a fourth high-side pressure switch (170) and a fourth discharge temperature sensor (171). The fifth discharge pipe (115) is provided with a fifth high-side pressure switch (172) and a fifth discharge temperature sensor (173). The first low stage discharge pipe (116) is provided with a second discharge pressure sensor (174).

[0085] The first booster circuit (100) is provided also with a plurality of check valves. Specifically, the fourth discharge pipe (114), the fifth discharge pipe (115) and the first escape pipe (118) are provided with a check valve (CV-7), a check

valve (CV-8) and a check valve (CV-9), respectively.

[0086] The second booster circuit (120) in the second booster unit (15) is connected via a second booster connection pipe (34) to the gas side end of the second freezing circuit (90). The second booster circuit (120) has the same configuration as the first booster circuit (100). Specifically, the second booster circuit (120) includes, like the first booster circuit (100), a third variable displacement compressor (121) and a fourth fixed displacement compressor (122).

[0087] The second booster circuit (120) further includes, like the first booster circuit (100), a sixth suction pipe (131), a seventh suction pipe (132), a second low stage suction pipe (133), a sixth discharge pipe (134), a seventh discharge pipe (135), a second low stage discharge pipe (136), a second oil discharge pipe (137), a second escape pipe (138) and a second bypass pipe (139). The second oil discharge pipe (137) and the second bypass pipe (139) are provided with a solenoid valve (SV-3) and a solenoid valve (SV-4), respectively.

[0088] Furthermore, the second booster circuit (120) is provided, like the first booster circuit (100), also with various kinds of sensors and pressure switches. Specifically, the second low stage suction pipe (133) is provided with a third suction temperature sensor (175) and a third suction pressure sensor (176). The sixth discharge pipe (134) is provided with a sixth high-side pressure switch (177) and a sixth discharge temperature sensor (178). The seventh discharge pipe (135) is provided with a seventh high-side pressure switch (179) and a seventh discharge temperature sensor (180). The second low stage discharge pipe (136) is provided with a third discharge pressure sensor (181).

[0089] The second booster circuit (120) is provided also with a plurality of check valves. Specifically, the sixth discharge pipe (134), the seventh discharge pipe (135) and the second escape pipe (138) are provided with a check valve (CV-10), a check valve (CV-11) and a check valve (CV-12), respectively.

- Operational Behavior -

[0090] A description is given below of the operational behavior of the refrigeration system (10) of Embodiment 1.

<Cooling Operation>

[0091] In the cooling operation of this refrigeration system (10), the interiors of the first freezer display case (12) and the second freezer display case (13) are cooled.

[0092] As shown in Figure 2, in the outdoor circuit (40) during the cooling operation, the four-way selector valve (49) is selected to the first position. In addition, the second outdoor expansion valve (48) is fully closed and the opening of the first outdoor expansion valve (47) is adjusted as appropriate. In the first freezing circuit (80), the opening of the first indoor expansion valve (82) is adjusted as appropriate. In the second freezing circuit (90), the opening of the second indoor expansion valve (92) is adjusted as appropriate. In the first booster circuit (100), the solenoid valve (SV-1) and the solenoid valve (SV-2) are selected to their closed positions. In the second booster circuit (120), the solenoid valve (SV-3) and the solenoid valve (SV-4) are selected to their closed positions.

[0093] During the cooling operation, the compressors (41, 42, 43) in the outdoor circuit (40), the compressors (101, 102) in the first booster circuit (100) and the compressors (121, 122) in the second booster circuit (120) are driven. As a result, the outdoor heat exchanger (44) provides a condenser and the cooling heat exchangers (83, 93) provide evaporators, so that the refrigerant circuit (20) operates in a two-stage compression refrigeration cycle.

[0094] The refrigerant discharged from the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43) flows through the high stage discharge pipe (68), then the four-way selector valve (49) and then the outdoor heat exchanger (44). In the outdoor heat exchanger (44), the refrigerant is given heat from the outdoor air and thereby condenses.

[0095] The refrigerant having condensed in the outdoor heat exchanger (44) flows through the first liquid pipe (71), the receiver (45) and the high-pressure channel (46a) of the supercooling heat exchanger (46) and then flows into the second liquid pipe (72). Part of the refrigerant having flowed into the second liquid pipe (72) is distributed to the first branch pipe (73) and the rest flows into the liquid connection pipe (31).

[0096] The refrigerant having flowed into the first branch pipe (73) flows through the first outdoor expansion valve (47) to reduce its pressure and then flows through the low-pressure channel (46b) of the supercooling heat exchanger (46). In the supercooling heat exchanger (46), heat is exchanged between high-pressure refrigerant flowing through the high-pressure channel (46a) and low-pressure refrigerant flowing through the low-pressure channel (46b). As a result, heat of the refrigerant flowing through the high-pressure channel (46a) is taken as heat of evaporation of refrigerant flowing through the low-pressure channel (46b). In other words, in the supercooling heat exchanger (46), the refrigerant flowing through the high-pressure channel (46a) is supercooled. The refrigerant evaporated in the low-pressure channel (46b) in the supercooling heat exchanger (46) flows into the high stage suction pipe (64).

[0097] On the other hand, the refrigerant having flowed into the liquid connection pipe (31) is distributed to the first freezing circuit (80) and the second freezing circuit (90).

[0098] The refrigerant having flowed into the first freezing circuit (80) flows through the first drain pan heating pipe

(81). At this time, the first drain pan (85) has accumulated frost dropped from the surface of the first cooling heat exchanger (83) and ice blocks produced by freezing of recovered dew condensation water. Therefore, as the refrigerant flowing through the first drain pan heating pipe (81) heats around the first drain pan (85), the frost and ice blocks in the first drain pan (85) melt. The water obtained in the above manner is drained as drainage away from the first drain pan (85).

[0099] On the contrary, the refrigerant flowing through the first drain pan heating pipe (81) gives heat of melting to frost and ice blocks in the first drain pan (85) and is thereby cooled. As a result, the refrigerant flowing through the first drain pan heating pipe (81) is further supercooled.

[0100] The refrigerant having flowed out of the first drain pan heating pipe (81) flows through the first indoor expansion valve (82) to reduce its pressure and then flows through the first cooling heat exchanger (83). In the first cooling heat exchanger (83), the refrigerant takes heat from the in-case air to evaporate. As a result, the in-case air in the first freezer display case (12) is cooled and the in-case temperature is held, for example, at -20°C.

[0101] The refrigerant having evaporated in the first cooling heat exchanger (83) flows via the first booster connection pipe (33) into the first booster circuit (100), then flows through the first low stage suction pipe (113) and is then sucked into the second variable displacement compressor (101) and the third fixed displacement compressor (102). The refrigerant compressed by the compressors (101, 102) flows through the first low stage discharge pipe (116) and then into the gas connection pipe (32).

[0102] The refrigerant having flowed into the second freezing circuit (90) flows through the second drain pan heating pipe (91). At this time, the second drain pan (95) has accumulated frost dropped from the surface of the second cooling heat exchanger (93) and ice blocks produced by freezing of recovered dew condensation water. Therefore, as the refrigerant flowing through the second drain pan heating pipe (91) heats around the second drain pan (95), the frost and ice blocks in the second drain pan (95) melt. The water obtained in the above manner is drained as drainage away from the second drain pan (95).

[0103] On the contrary, the refrigerant flowing through the second drain pan heating pipe (91) gives heat of melting to frost and ice blocks recovered in the second drain pan (95) and is thereby cooled. As a result, the refrigerant flowing through the second drain pan heating pipe (91) is further supercooled.

[0104] The refrigerant having flowed out of the second drain pan heating pipe (91) flows through the second indoor expansion valve (92) to reduce its pressure and then flows through the second cooling heat exchanger (93). In the second cooling heat exchanger (93), the refrigerant takes heat from the in-case air to evaporate. As a result, the in-case air in the second freezer display case (13) is cooled and the in-case temperature is held, for example, at -20°C.

[0105] The refrigerant having evaporated in the second cooling heat exchanger (93) flows via the second booster connection pipe (34) into the second booster circuit (120), then flows through the second low stage suction pipe (133) and is then sucked into the third variable displacement compressor (121) and the fourth fixed displacement compressor (122). The refrigerant compressed by the compressors (121, 122) flows through the second low stage discharge pipe (136) and then into the gas connection pipe (32).

[0106] The refrigerant combined in the gas connection pipe (32) flows through the four-way selector valve (49) and then into the high stage suction pipe (64). The combined refrigerant is further combined with the refrigerant having evaporated in the low-pressure channel (46b) of the supercooling heat exchanger (46) and then sucked into the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43).

<Defrosting Operation>

[0107] During the defrosting operation of the refrigeration system (10), the first cooling heat exchanger (83) and the second cooling heat exchanger (93) are simultaneously defrosted.

[0108] As shown in Figure 3, in the outdoor circuit (40) during the defrosting operation, the four-way selector valve (49) is selected to the second position. In addition, the first outdoor expansion valve (47) is fully closed and the opening of the second outdoor expansion valve (48) is adjusted as appropriate. In the first freezing circuit (80), the first indoor expansion valve (82) is fully opened. In the second freezing circuit (90), the second indoor expansion valve (92) is fully opened. In the first booster circuit (100), the solenoid valve (SV-1) is selected to its closed position and the solenoid valve (SV-2) is selected to its open position. In the second booster circuit (120), the solenoid valve (SV-3) is selected to its closed position and the solenoid valve (SV-4) is selected to its open position.

[0109] During the defrosting operation, the compressors (41, 42, 43) in the outdoor circuit (40) are driven while the compressors (101, 102) in the first booster circuit (100) and the compressors (121, 122) in the second booster circuit (120) are shut off. As a result, the outdoor heat exchanger (44) provides an evaporator and the cooling heat exchangers (83, 93) provide condensers, so that the refrigerant circuit (20) operates in a refrigeration cycle.

[0110] The refrigerant discharged from the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43) flows through the high stage discharge pipe (68) and then the four-way selector valve (49) and then into the gas connection pipe (32). The refrigerant having flowed into the gas connection pipe (32) is distributed to the first booster circuit (100) and the second booster circuit (120).

[0111] The refrigerant having flowed into the first booster circuit (100) flows midway through the first low stage discharge pipe (116), then flows through the first bypass pipe (119) and the first low stage suction pipe (113) and then flows into the first freezing circuit (80). In other words, the refrigerant having flowed into the first booster circuit (100) bypasses the shut-off second variable displacement compressor (101) and third fixed displacement compressor (102) and then flows out of the first booster circuit (100).

[0112] The refrigerant having flowed into the first freezing circuit (80) flows through the first cooling heat exchanger (83). In the first cooling heat exchanger (83), frost on its surface is melted by heat from its inside while the refrigerant gives heat of melting to the frost to condense. The refrigerant having condensed in the first cooling heat exchanger (83) flows through the fully-opened first indoor expansion valve (82) and then the first drain pan heating pipe (81). As a result, the refrigerant heats around the first drain pan (85) to melt the frost and ice blocks in the first drain pan (85). On the contrary, the refrigerant flowing through the first drain pan heating pipe (81) gives heat of melting to frost and ice blocks in the first drain pan (85). Thereafter, the refrigerant having flowed through the first freezing circuit (80) flows into the liquid connection pipe (31).

[0113] On the other hand, the refrigerant having flowed into the second booster circuit (120) flows midway through the second low stage discharge pipe (136), then flows through the second bypass pipe (139) and the second low stage suction pipe (133) and then flows into the second freezing circuit (90). In other words, the refrigerant having flowed into the second booster circuit (120) bypasses the shut-off third variable displacement compressor (121) and fourth fixed displacement compressor (122) and then flows out of the second booster circuit (120).

[0114] The refrigerant having flowed into the second freezing circuit (90) flows through the second cooling heat exchanger (93). In the second cooling heat exchanger (93), frost on its surface is melted by heat from its inside while the refrigerant gives heat of melting to the frost to condense. The refrigerant having condensed in the second cooling heat exchanger (93) flows through the fully-opened second indoor expansion valve (92) and then the second drain pan heating pipe (91). As a result, the refrigerant heats around the second drain pan (95) to melt the frost and ice blocks in the second drain pan (95). On the contrary, the refrigerant flowing through the second drain pan heating pipe (91) gives heat of melting to frost and ice blocks in the second drain pan (95). Thereafter, the refrigerant having flowed through the second freezing circuit (90) flows into the liquid connection pipe (31).

[0115] The refrigerant combined in the liquid connection pipe (31) flows midway through the second liquid pipe (72) and then flows through the second branch pipe (74), then the receiver (45) and then the high-pressure channel (46a) of the supercooling heat exchanger (46). The refrigerant flows through the first branch pipe (73), then flows through the second outdoor expansion valve (48) of the third branch pipe (75) to reduce its pressure and then flows through the outdoor heat exchanger (44). In the outdoor heat exchanger (44), the refrigerant takes heat from the outdoor air to evaporate. The refrigerant having evaporated in the outdoor heat exchanger (44) flows through the four-way selector valve (49) and then into the high stage suction pipe (64) and is then sucked into the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43).

- Effects of Embodiment 1 -

[0116] According to Embodiment 1, during the defrosting operation, frost adhering to the surfaces of the cooling heat exchangers (83, 93) are heated from the insides of the cooling heat exchangers (83, 93) by feeding the refrigerant discharged by the high stage compressors (41, 42, 43) into the utilization side heat exchangers (83, 93). Therefore, the cooling heat exchangers (83, 93) can be effectively defrosted, which reduces the time taken to defrost them.

[0117] Furthermore, according to Embodiment 1, since during the defrosting operation the outdoor heat exchanger (44) serves as an evaporator, heat given from air to refrigerant is used to defrost the utilization side heat exchangers (83, 93). In other words, according to Embodiment 1, heat given to refrigerant by the high stage compressors (41, 42, 43) and heat given to refrigerant by the outdoor heat exchanger (44) are both used to defrost the cooling heat exchangers (83, 93). This reduces the time required for defrosting and in turn reduces the power consumption of the refrigeration system (10) during the defrosting operation.

[0118] Furthermore, in Embodiment 1, during the cooling operation, refrigerant condensed in the outdoor heat exchanger (44) is allowed to flow through the drain pan heating pipes (81, 91). Therefore, according to Embodiment 1, heat of refrigerant can be used to melt frost and ice blocks in the drain pans (85, 95) and the melted moisture can be promptly drained as drainage. Furthermore, in this case, the refrigerant flowing through the drain pan heating pipes (81, 91) gives heat of melting to frost and ice blocks in the drain pans (85, 95) and is thereby supercooled. Therefore, during the cooling operation, the enthalpy difference between air and liquid refrigerant in the utilization side heat exchangers (83, 93) becomes large, which increases the air cooling effect of the utilization side heat exchangers (83, 93).

[0119] Furthermore, in Embodiment 1, during the defrosting operation, the refrigerant used to defrost the cooling heat exchangers (83, 93) is sent, without reducing its pressure with the indoor expansion valves (82, 92), to the drain pan heating pipes (81, 91). Therefore, heat of condensation of refrigerant flowing through the drain pan heating pipes (81, 91) can be used to melt frost and ice blocks in the drain pans (85, 95).

<<Embodiment 2>>

**[0120]** A refrigeration system (10) of Embodiment 2 is different from that of Embodiment 1 in the configuration of the refrigerant circuit (20) and the behavior during the defrosting operation. A description is given below of different points from Embodiment 1.

**[0121]** As shown in Figure 4, the refrigerant circuit (20) in Embodiment 2 includes two liquid injection pipes (190, 192). One end of the first liquid injection pipe (190) is connected to the first freezing circuit (80) midway between the first cooling heat exchanger (83) and the first indoor expansion valve (82). The other end of the first liquid injection pipe (190) is connected to the first low stage suction pipe (113) in the first booster circuit (100). The first liquid injection pipe (190) is provided with a first liquid injection valve (191). The first liquid injection valve (191) is composed of an electronic expansion valve controllable in opening. On the other hand, one end of the second liquid injection pipe (192) is connected to the second freezing circuit (90) midway between the second cooling heat exchanger (93) and the second indoor expansion valve (92). The other end of the second liquid injection pipe (192) is connected to the second low stage suction pipe (133) in the second booster circuit (120). The second liquid injection pipe (192) is provided with a second liquid injection valve (193). The second liquid injection valve (193) is composed of an electronic expansion valve controllable in opening.

- Operational Behavior -

**[0122]** The refrigeration system (10) of Embodiment 2 selectively performs the above-mentioned defrosting operation in Embodiment 1 (first defrosting operation) and the after-mentioned defrosting operation (second defrosting operation). The selection between these two defrosting operations is made according to the detected temperatures of the first refrigerant temperature sensor (162) and the second refrigerant temperature sensor (165) provided at the first cooling heat exchanger (83) and the second cooling heat exchanger (93), respectively.

**[0123]** Specifically, when the refrigeration system (10) of Embodiment 2 defrosts the cooling heat exchangers (83, 93), it performs the first defrosting operation like Embodiment 1. During the first defrosting operation, the compressors (41, 42, 43) in the outdoor circuit (40) is driven while the compressors (101, 102) in the first booster circuit (100) and the compressors (121, 122) in the second booster circuit (120) are shut off, whereby the cooling heat exchangers (83, 93) are defrosted in the above manner.

**[0124]** On the other hand, if the first defrosting operation may cause a shortage of capacity to defrost the cooling heat exchangers (83, 93) and, thus, it may take a long time to defrost the cooling heat exchangers (83, 93), the second defrosting operation is performed in the following manner.

**[0125]** Specifically, if during the first defrosting operation the detected temperature of the first refrigerant temperature sensor (162) or the second refrigerant temperature sensor (165) does not readily reach a specified temperature, the refrigeration system (10) is determined to be lacking in the capacity to defrost the cooling heat exchangers (83, 93). As a result, the refrigeration system (10) switches from the first defrosting operation to the second defrosting operation.

**[0126]** In the second defrosting operation, as in the first defrosting operation, the four-way selector valve (49) in the outdoor circuit (40) is selected to the second position. In addition, the first outdoor expansion valve (47) is fully closed and the opening of the second outdoor expansion valve (48) is adjusted as appropriate. In the first freezing circuit (80), the first indoor expansion valve (82) is fully opened. In the second freezing circuit (90), the second indoor expansion valve (92) is fully opened. In the first booster circuit (100), the solenoid valve (SV-1) is selected to its closed position and the solenoid valve (SV-2) is selected to its open position. In the second booster circuit (120), the solenoid valve (SV-3) is selected to its closed position and the solenoid valve (SV-4) is selected to its open position.

**[0127]** In contrast to the first defrosting operation, during the second defrosting operation, the compressors (41, 42, 43) in the outdoor circuit (40) are driven and the compressors (101, 102) in the first booster circuit (100) and the compressors (121, 122) in the second booster circuit (120) are also driven. As a result, the outdoor heat exchanger (44) provides an evaporator and the cooling heat exchangers (83, 93) provide condensers, so that the refrigerant circuit (20) operates in a refrigeration cycle.

**[0128]** The refrigerant discharged from the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43) flows through the high stage discharge pipe (68) and then the four-way selector valve (49) and then into the gas connection pipe (32). The refrigerant having flowed into the gas connection pipe (32) is distributed to the first booster circuit (100) and the second booster circuit (120).

**[0129]** The refrigerant having flowed into the first booster circuit (100) flows midway through the first low stage discharge pipe (116) and then flows through the first bypass pipe (119). Part of the refrigerant having flowed through the first bypass pipe (119) is sucked via the first low stage suction pipe (113) into the second variable displacement compressor (101) and the third fixed displacement compressor (102). The refrigerant compressed by the compressors (101, 102) is sent again to the first bypass pipe (119) to combine with the refrigerant discharged from the high stage compressors (41, 42, 43). The rest of the refrigerant having flowed through the first bypass pipe (119) flows into the first freezing

circuit (80). In other words, in the first booster circuit (100), part of the refrigerant circulates therethrough while being compressed by the second variable displacement compressor (101) and the third fixed displacement compressor (102) and heat input from these compressors (101, 102) is given to the refrigerant.

[0130] The refrigerant having flowed into the first freezing circuit (80) flows through the first cooling heat exchanger (83). In the first cooling heat exchanger (83), frost on its surface is melted by heat from its inside while the refrigerant gives heat of melting to the frost to condense. The refrigerant having condensed in the first cooling heat exchanger (83) flows through the fully-opened first indoor expansion valve (82) and then the first drain pan heating pipe (81). As a result, the refrigerant heats around the first drain pan (85) to melt the frost and ice blocks in the first drain pan (85). On the contrary, the refrigerant flowing through the first drain pan heating pipe (81) gives heat of melting to frost and ice blocks in the first drain pan (85). Thereafter, the refrigerant having flowed through the first freezing circuit (80) flows into the liquid connection pipe (31).

[0131] On the other hand, the refrigerant having flowed into the second booster circuit (120) flows midway through the second low stage discharge pipe (136) and then flows through the second bypass pipe (139). Part of the refrigerant having flowed through the second bypass pipe (139) is sucked via the second low stage suction pipe (133) into the third variable displacement compressor (121) and the fourth fixed displacement compressor (122). The refrigerant compressed by the compressors (121, 122) is sent again to the second bypass pipe (139) to combine with the refrigerant discharged from the high stage compressors (41, 42, 43). The rest of the refrigerant having flowed through the second bypass pipe (139) flows into the second freezing circuit (90). In other words, in the second booster circuit (120), part of the refrigerant circulates therethrough while being compressed by the third variable displacement compressor (121) and the fourth fixed displacement compressor (122) and heat input from these compressors (101, 102) is given to the refrigerant.

[0132] The refrigerant having flowed into the second freezing circuit (90) flows through the second cooling heat exchanger (93). In the second cooling heat exchanger (93), frost on its surface is melted by heat from its inside while the refrigerant gives heat of melting to the frost to condense. The refrigerant having condensed in the second cooling heat exchanger (93) flows through the fully-opened second indoor expansion valve (92) and then the second drain pan heating pipe (91). As a result, the refrigerant heats around the second drain pan (95) to melt the frost and ice blocks in the second drain pan (95). On the contrary, the refrigerant flowing through the second drain pan heating pipe (91) gives heat of melting to frost and ice blocks in the second drain pan (95). Thereafter, the refrigerant having flowed through the second freezing circuit (90) flows into the liquid connection pipe (31).

[0133] The refrigerant combined in the liquid connection pipe (31) flows midway through the second liquid pipe (72) and then flows through the second branch pipe (74), then the receiver (45) and then the high-pressure channel (46a) of the supercooling heat exchanger (46). The refrigerant flows through the first branch pipe (73), then flows through the second outdoor expansion valve (48) of the third branch pipe (75) to reduce its pressure and then flows through the outdoor heat exchanger (44). In the outdoor heat exchanger (44), the refrigerant takes heat from the outdoor air to evaporate. The refrigerant having evaporated in the outdoor heat exchanger (44) flows through the four-way selector valve (49) and then into the high stage suction pipe (64) and is then sucked into the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43).

[0134] In the second defrosting operation, part of the refrigerant compressed by the high stage compressors (41, 42, 43) in the outdoor circuit (40) is further compressed by the low stage compressors (101, 102, 121, 122) in the booster circuits (100, 120). Therefore, if such operation is continued, the temperature of refrigerant discharged from the low stage compressors (101, 102, 121, 122) may significantly rise up to break down these compressors (101, 102, 121, 122). Hence, in order to prevent the breakdown of the compressors (101, 102, 121, 122), the refrigeration system (10) of Embodiment 2 performs the following liquid injection action.

[0135] Specifically, during the second defrosting operation, the opening of the first liquid injection valve (191) is controlled according to the degree of superheat of refrigerant to be sucked into the second variable displacement compressor (101) and the third fixed displacement compressor (102). The degree of superheat of the refrigerant is properly calculated based on the detected values of the second suction temperature sensor (168) and the second suction pressure sensor (169). If, for example, the degree of superheat is higher than a specified degree of superheat, the opening of the first liquid injection valve (191) is increased. As a result, part of the refrigerant having condensed in the first cooling heat exchanger (83) is sent via the first liquid injection pipe (190) to the suction sides of the second variable displacement compressor (101) and the third fixed displacement compressor (102). Thus, the refrigerant to be sucked into the compressors (101, 102) is cooled, which prevents the temperature of refrigerant discharged by the compressors (101, 102) from abnormally increasing.

[0136] Likewise, the opening of the second liquid injection valve (193) is appropriately controlled according to the degree of superheat of refrigerant to be sucked into the third variable displacement compressor (121) and the fourth fixed displacement compressor (122). As a result, the temperature of refrigerant discharged by the compressors (121, 122) is prevented from abnormally increasing.

## - Effects of Embodiment 2 -

[0137] According to Embodiment 2, like Embodiment 1, during the defrosting operation, frost adhering to the surfaces of the cooling heat exchangers (83, 93) are heated from the insides of the cooling heat exchangers (83, 93) by feeding the refrigerant discharged by the high stage compressors (41, 42, 43) into the cooling heat exchangers (83, 93). Therefore, the cooling heat exchangers (83, 93) can be effectively defrosted, which reduces the time taken to defrost them.

[0138] Furthermore, in Embodiment 2, the refrigeration system (10) can selectively perform the first defrosting operation and the second defrosting operation. According to Embodiment 2, when during the first defrosting operation the refrigeration system (10) is lacking in the capacity to defrost the cooling heat exchangers (83, 93), the low stage compressors (101, 102, 121, 122) are also driven. Therefore, according to Embodiment 2, the amount of heat given to refrigerant can be increased by the second defrosting operation, which enhances the capacity to defrost the cooling heat exchangers (83, 93). Hence, the second defrosting operation provides effective defrosting of the cooling heat exchangers (83, 93).

[0139] Furthermore, in Embodiment 2, the refrigerant to be sucked in the low stage compressors (101, 102, 121, 122) is cooled during the second defrosting operation by returning liquid refrigerant to the suction sides of the low stage compressors (101, 102, 121, 122). This prevents the temperature of refrigerant to be discharged from the low stage compressors (101, 102, 121, 122) from abnormally increasing, which ensures the protection of the low stage compressors (101, 102, 121, 122).

<<Embodiment 3>>

[0140] A refrigeration system (10) of Embodiment 3 is different from those of Embodiments 1 and 2 in the configuration of the booster units (14, 15). A description is given below of different points from Embodiments 1 and 2.

[0141] As shown in Figure 6, the first booster circuit (100) in the first booster unit (14) includes a first oil separator (143) disposed to the discharge sides of the second variable displacement compressor (101) and the third fixed displacement compressor (102). Likewise, the second booster circuit (120) in the second booster unit (15) includes a second oil separator (144) disposed to the discharge sides of the third variable displacement compressor (121) and the fourth fixed displacement compressor (122).

[0142] As shown in Figure 7, each oil separator (143, 144) is formed of a so-called demister oil separator. Each oil separator (143, 144) includes a hermetic oil recovery vessel (145) and a demister (146). Each oil recovery vessel (145) is formed in the shape of a hollow cylinder, in which its upper interior space constitutes a gas reservoir (147) and its lower interior space constitutes a liquid reservoir (148). Each demister (146) is disposed in the gas reservoir (147). The demister (146) separates refrigerating machine oil from gas refrigerant by trapping oil in the gas refrigerant.

[0143] The first oil separator (143) is connected to a first oil return pipe (141), a first low stage discharge pipe (116a) and a first discharge connection pipe (116b). The second oil separator (144) is connected to a second oil return pipe (142), a second low stage discharge pipe (136a) and a second discharge connection pipe (136b).

[0144] Each oil return pipe (141, 142) is connected to the bottom of the oil recovery vessel (145) of the associated oil separator (143, 144). One end of each oil return pipe (141, 142) opens into the liquid reservoir (148) of the associated oil separator (143, 144). The other end of each oil return pipe (141, 142) is connected to the associated low stage suction pipe (113, 133). Furthermore, the oil return pipes (141, 142) are provided with solenoid valves (SV-5, SV-6), respectively, that can be appropriately opened and closed.

[0145] Each low stage discharge pipe (116a, 136a) is connected to the peripheral wall of the oil recovery vessel (145) of the associated oil separator (143, 144). Each low stage discharge pipe (116a, 136a) opens into the gas reservoir (147) of the associated oil separator (143, 144). Each discharge connection pipe (116b, 136b) is connected to the top of the oil recovery vessel (145) of the associated oil separator (143, 144). Each discharge connection pipe (116b, 136b) opens into the gas reservoir (147) of the associated oil separator (143, 144).

[0146] The booster circuits (100, 120) are connected to bypass pipes (119, 139), respectively, like Embodiments 1 and 2. The first bypass pipe (119) is connected at its one end to the first low stage suction pipe (113) and connected at the other end to a midpoint of the first oil return pipe (141). The second bypass pipe (139) is connected at its one end to the second low stage suction pipe (133) and connected at the other end to a midpoint of the second oil return pipe (142). The bypass pipes (119, 139) are provided, like Embodiments 1 and 2, with solenoid valves (SV-2, SV-4), respectively, that can be appropriately opened and closed.

[0147] Each oil return pipe (141, 142) serves also as a liquid return pipe for allowing, during a refrigerant recovery action, liquid refrigerant accumulated in the associated cooling heat exchanger (83, 93) to bypass the associated low stage compressors (101, 102, 121, 122) to the suction sides of the high stage compressors (41, 42, 43). Furthermore, each oil separator (143, 144) constitutes a gas-liquid separator for separating gas refrigerant from refrigerant flowing therein via the associated oil return pipe (141, 142) during the refrigerant recovery action to send only the gas refrigerant to the high stage compressors (41, 42, 43).

The details of the refrigerant recovery action will be described later.

## - Operational Behavior -

**[0148]** The refrigeration system (10) of Embodiment 3, like Embodiment 1, selectively performs the cooling operation and the defrosting operation. Furthermore, the refrigeration system (10) of Embodiment 3 performs, after the completion of the defrosting operation, a refrigerant recovery action for recovering liquid refrigerant built up in each cooling heat exchanger (83, 93).

## &lt;Cooling Operation&gt;

**[0149]** In the cooling operation of the refrigeration system (10) of Embodiment 3, like Embodiments 1 and 2, the interiors of the first freezer display case (12) and the second freezer display case (13) are cooled.

**[0150]** As shown in Figure 8, in the outdoor circuit (40) during the cooling operation, the four-way selector valve (49) is selected to the first position. In addition, the second outdoor expansion valve (48) is fully closed and the opening of the first outdoor expansion valve (47) is adjusted as appropriate. In the first freezing circuit (80), the opening of the first indoor expansion valve (82) is adjusted as appropriate. In the second freezing circuit (90), the opening of the second indoor expansion valve (92) is adjusted as appropriate. In the first booster circuit (100), the solenoid valve (SV-1) and the solenoid valve (SV-2) are selected to their closed positions while the solenoid valve (SV-5) is opened or closed as appropriate. In the second booster circuit (120), the solenoid valve (SV-3) and the solenoid valve (SV-4) are selected to their closed positions while the solenoid valve (SV-6) is opened or closed as appropriate.

**[0151]** During the cooling operation, the compressors (41, 42, 43) in the outdoor circuit (40), the compressors (101, 102) in the first booster circuit (100) and the compressors (121, 122) in the second booster circuit (120) are driven. As a result, the outdoor heat exchanger (44) provides a condenser and the cooling heat exchangers (83, 93) provide evaporators, so that the refrigerant circuit (20) operates in a two-stage compression refrigeration cycle.

**[0152]** The refrigerant discharged from the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43) flows through the high stage discharge pipe (68), then the four-way selector valve (49) and then the outdoor heat exchanger (44). In the outdoor heat exchanger (44), the refrigerant is given heat from the outdoor air and thereby condenses.

**[0153]** The refrigerant having condensed in the outdoor heat exchanger (44) flows through the first liquid pipe (71), the receiver (45) and the high-pressure channel (46a) of the supercooling heat exchanger (46) and then flows into the second liquid pipe (72). Part of the refrigerant having flowed into the second liquid pipe (72) is distributed to the first branch pipe (73) and the rest flows into the liquid connection pipe (31). In the supercooling heat exchanger (46), like Embodiment 1, the refrigerant flowing through the high-pressure channel (46a) is supercooled.

**[0154]** On the other hand, the refrigerant having flowed into the liquid connection pipe (31) is distributed to the first freezing circuit (80) and the second freezing circuit (90).

**[0155]** The refrigerant having flowed into the first freezing circuit (80) melts ice blocks in the first drain pan (85), is then reduced in pressure by the first indoor expansion valve (82) and then flows through the first cooling heat exchanger (83). In the first cooling heat exchanger (83), the refrigerant takes heat from the in-case air to evaporate. As a result, the in-case air in the first freezer display case (12) is cooled.

**[0156]** The refrigerant having evaporated in the first cooling heat exchanger (83) flows via the first booster connection pipe (33) into the first booster circuit (100), then flows through the first low stage suction pipe (113) and is then sucked into the second variable displacement compressor (101) and the third fixed displacement compressor (102). The refrigerant compressed by the compressors (101, 102) flows through the first low stage discharge pipe (116a) and then into the first oil separator (143).

**[0157]** In the first oil separator (143), refrigerant in the oil recovery vessel (145) flows upward while passing through the demister (146). As the refrigerant passes through the demister (146), oil in the refrigerant is trapped by the demister (146). The oil trapped by the demister (146) is recovered by the liquid reservoir (148) in the oil recovery vessel (145). On the other hand, gas refrigerant separated from oil flows via the first discharge connection pipe (116b) into the gas connection pipe (32).

**[0158]** The oil recovered in the first oil separator (143) is returned to the suction sides of the second variable displacement compressor (101) and the third fixed displacement compressor (112) as appropriate. In other words, the solenoid valve (SV-5) of the first oil return pipe (141) is appropriately opened according to the setting time of a timer, the liquid level of oil accumulated in the oil recovery vessel (145) or other specified conditions. As a result, oil accumulated in the liquid reservoir (148) flows through the first oil return pipe (141) and is then sent to the first low stage suction pipe (113). The oil is sucked into the second variable displacement compressor (101) and the third fixed displacement compressor (112) and used to lubricate sliding parts of the compressors (101, 112).

**[0159]** The refrigerant having flowed into the second freezing circuit (90) melts ice blocks in the second drain (95), is then reduced in pressure by the second indoor expansion valve (92) and then flows through the second cooling heat exchanger (93). In the second cooling heat exchanger (93), the refrigerant takes heat from the in-case air to evaporate.

As a result, the in-case air in the second freezer display case (13) is cooled.

[0160] The refrigerant having evaporated in the second cooling heat exchanger (93) flows via the second booster connection pipe (34) into the second booster circuit (120), then flows through the second low stage suction pipe (133) and is then sucked into the third variable displacement compressor (121) and the fourth fixed displacement compressor (122). The refrigerant compressed by the compressors (121, 122) flows through the second low stage discharge pipe (136a) and then flows into the second oil separator (144).

[0161] In the second oil separator (144), like in the first oil separator (143), oil in the gas refrigerant is trapped by the demister (146) and the trapped oil is then recovered in the liquid reservoir (148). The gas refrigerant separated from oil flows via the second discharge connection pipe (136b) into the gas connection pipe (32). The oil in the second oil separator (144) is returned to the suction sides of the third variable displacement compressor (121) and the fourth fixed displacement compressor (122) by appropriately opening the solenoid valve (SV-6) of the second oil return pipe (142).

[0162] The refrigerant combined in the gas connection pipe (32) flows through the four-way selector valve (49) and then into the high stage suction pipe (64). The combined refrigerant is further combined with the refrigerant having evaporated in the low-pressure channel (46b) of the supercooling heat exchanger (46) and then sucked into the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43).

#### <Defrosting Operation>

[0163] During the defrosting operation of the refrigeration system of Embodiment 3, like Embodiments 1 and 2, the first cooling heat exchanger (83) and the second cooling heat exchanger (93) are simultaneously defrosted.

[0164] As shown in Figure 9, in the outdoor circuit (40) during the defrosting operation, the four-way selector valve (49) is selected to the second position. In addition, the first outdoor expansion valve (47) is fully closed and the opening of the second outdoor expansion valve (48) is adjusted as appropriate. In the first freezing circuit (80), the first indoor expansion valve (82) is fully opened. In the second freezing circuit (90), the second indoor expansion valve (92) is fully opened. In the first booster circuit (100), the solenoid valve (SV-1) and the solenoid valve (SV-5) are selected to their closed positions and the solenoid valve (SV-2) is selected to its open position. In the second booster circuit (120), the solenoid valve (SV-3) and the solenoid valve (SV-6) are selected to their closed positions and the solenoid valve (SV-4) is selected to its open position.

[0165] During the defrosting operation, the compressors (41, 42, 43) in the outdoor circuit (40) are driven while the compressors (101, 102) in the first booster circuit (100) and the compressors (121, 122) in the second booster circuit (120) are shut off. As a result, the outdoor heat exchanger (44) provides an evaporator and the cooling heat exchangers (83, 93) provide condensers, so that the refrigerant circuit (20) operates in a refrigeration cycle.

[0166] The refrigerant discharged from the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43) flows through the high stage discharge pipe (68) and then the four-way selector valve (49) and then into the gas connection pipe (32). The refrigerant having flowed into the gas connection pipe (32) is distributed to the first booster circuit (100) and the second booster circuit (120).

[0167] The refrigerant having flowed into the first booster circuit (100) flows via the first discharge connection pipe (116b) into the first oil separator (143). The gas refrigerant having flowed into the oil recovery vessel (145) of the first oil separator (143) flows through the gas reservoir (146) and then the liquid reservoir (148) and then flows out to the first oil return pipe (141). During the time, oil and liquid refrigerant accumulated in the liquid reservoir (148) also flows out to the first oil return pipe (141), together with the gas refrigerant. The refrigerant having flowed out to the first oil return pipe (141) flows through the first bypass pipe (119) and then the first low stage suction pipe (113) and then flows into the first freezing circuit (80).

[0168] In the second booster circuit (120), as in the first booster circuit (100), gas refrigerant flows through the second oil separator (144), then flows through the second oil return pipe (142), the second bypass pipe (139) and the second low stage suction pipe (133) and then flows into the second freezing circuit (90).

[0169] The refrigerant having flowed into each freezing circuit (80, 90) is used, like Embodiment 1, to defrost the associated cooling heat exchanger (83, 93) and melt ice blocks in the associated drain pan (85, 95).

[0170] The refrigerant flows having flowed out of the freezing circuits (80, 90) are combined together in the liquid connection pipe (31), and the combined refrigerant flow flows through the second liquid pipe (72), the second branch pipe (74), the receiver (45) and the first branch pipe (73) in this order. Thereafter, the refrigerant flows through the second outdoor expansion valve (48) of the third branch pipe (75) to reduce its pressure and then flows through the outdoor heat exchanger (44). In the outdoor heat exchanger (44), the refrigerant takes heat from the outdoor air to evaporate. The refrigerant having evaporated in the outdoor heat exchanger (44) flows through the four-way selector valve (49) and then into the high stage suction pipe (64) and is then sucked into the first variable displacement compressor (41) and the first and second fixed displacement compressors (42, 43).

## &lt;Refrigerant Recovery Action After Defrosting Operation&gt;

[0171] In each freezer display case (12, 13), when the above defrosting operation is performed, liquid refrigerant obtained by condensation in defrosting the associated cooling heat exchangers (83, 93) may build up in the cooling heat exchangers (83, 93). If under this condition the above cooling operation is restarted, liquid refrigerant built up in the cooling heat exchangers (83, 93) will be sucked into the low stage compressors (101, 102, 121, 122) in the booster circuits (100, 120). As a result, a so-called liquid compression phenomenon may occur to break down the low stage compressors (101, 102, 121, 122).

[0172] Therefore, in order to avoid such liquid compression in the low stage compressors (101, 102, 121, 122), the refrigeration system of Embodiment 3 performs the following refrigerant recovery action in restarting the cooling operation after the completion of the defrosting operation.

[0173] As shown in Figure 10, during the refrigerant recovery action, as during the cooling operation, the four-way selector valve (49) is selected to the first position. In addition, the second outdoor expansion valve (48) is fully closed and the opening of the first outdoor expansion valve (47) is adjusted as appropriate. In the first freezing circuit (80), the opening of the first indoor expansion valve (82) is adjusted as appropriate. In the second freezing circuit (90), the opening of the second indoor expansion valve (92) is adjusted as appropriate. In the first booster circuit (100), the solenoid valve (SV-1) and the solenoid valve (SV-2) are selected to their closed positions while the solenoid valve (SV-5) is opened. In the second booster circuit (120), the solenoid valve (SV-3) and the solenoid valve (SV-4) are selected to their closed positions while the solenoid valve (SV-6) is opened or closed as appropriate.

[0174] Furthermore, during the refrigerant recovery action, the high stage compressors (41, 42, 43) in the outdoor circuit (40) are driven while the low stage compressors (101, 102, 121, 122) in the booster circuits (100, 120) are shut off.

[0175] In the outdoor circuit (40) during the refrigerant recovery action, refrigerant compressed by the high stage compressors (41, 42, 43) flows through the same path as during the above cooling operation. Specifically, in the outdoor circuit (40), high-pressure refrigerant is condensed in the outdoor heat exchanger (44) and the condensed refrigerant flows into the liquid connection pipe (31) and is then distributed to the freezing circuits (80, 90).

[0176] The refrigerant having flowed into the first freezing circuit (80) is reduced in pressure by the first indoor expansion valve (82) and then flows through the first cooling heat exchanger (83). In the first cooling heat exchanger (83), the refrigerant takes heat from the in-case air to evaporate. Concurrently, the liquid refrigerant built in the first cooling heat exchanger (83) is forced out of the first cooling heat exchanger (83) by the gas refrigerant.

[0177] Thereafter, the refrigerant flows into the first booster circuit (100). The refrigerant flows through the first oil return pipe (141) serving as a liquid return pipe and then flows into the first oil separator (143). In the first oil separator (143), the refrigerant is separated, in the oil recovery vessel (145), into liquid refrigerant and gas refrigerant. The liquid refrigerant after the separation accumulates in the liquid reservoir (148) in the oil recovery vessel (145). On the other hand, the gas refrigerant after the separation accumulates in the gas reservoir (147) and flows out of the oil recovery vessel (145) through the first discharge connection pipe (116b).

[0178] Likewise, the refrigerant having flowed into the second freezing circuit (90) evaporates in the second cooling heat exchanger (93) and is sent to the second booster circuit (120) while carrying liquid refrigerant accumulated in the second cooling heat exchanger (93). The refrigerant flows via the second oil return pipe (142) serving as a liquid return pipe into the second oil separator (144). Also in the second oil separator (144), the refrigerant is separated into gas refrigerant and liquid refrigerant and only the gas refrigerant flows out of the oil recovery vessel (145) through the second discharge connection pipe (136b).

[0179] The refrigerant having flowed out of each booster circuit (100, 120) flows through the gas connection pipe (32). At this time, if liquid refrigerant still remains in the refrigerant flowing through the gas connection pipe (32), it takes heat from the air surrounding the gas connection pipe (32) to evaporate. The gas refrigerant having flowed out of the gas connection pipe (32) flows into the outdoor circuit (40) and is sucked into the high stage compressors (41, 42, 43).

## - Effects of Embodiment 3-

[0180] In Embodiment 3, after the completion of the defrosting operation, the refrigeration system (10) performs a refrigerant recovery action for allowing the high stage compressors (141, 142) to suck liquid refrigerant built up in each cooling heat exchanger (83, 93). Therefore, according to this embodiment, it can be surely avoided that in performing the cooling operation again after the defrosting operation, liquid compression occurs in the low stage compressors (101, 102, 121, 122). On the other hand, since the liquid refrigerant is thus sent to the high stage compressors (41, 42, 43), the total length of pipes through which the liquid refrigerant flows can be increased as compared with the case where the liquid refrigerant is sent to the low stage compressors (101, 102, 121, 122). Specifically, in Embodiment 3, the liquid refrigerant having flowed out of the cooling heat exchangers (83, 93) is sucked via the associated refrigerant pipes, such as the oil return pipes (141, 142) and the gas connection pipe (32), into the high stage compressors (141, 142). Therefore, according to Embodiment 3, liquid refrigerant remaining in the refrigerant in each refrigerant pipe can be evaporated

using heat of the air surrounding the refrigerant pipe. Hence, it can be avoided that during the refrigerant recovery action, liquid compression occurs in the high stage compressors (141, 142).

[0181] Furthermore, in Embodiment 3, the oil separators (143, 144) are disposed to the discharge sides of the associated low stage compressors (101, 102, 121, 122). Therefore, during the cooling operation of Embodiment 3, oil having flowed out of the low stage compressors (101, 102, 121, 122) can be surely returned to the low stage compressors (101, 102, 121, 122), which eliminates the shortage of refrigerating machine oil in the low stage compressors (101, 102, 121, 122).

[0182] In addition, in Embodiment 3, the oil return pipes (141, 142) for returning oil recovered by the oil separators (143, 144) to the low stage compressors (101, 102, 121, 122) are used also as liquid return pipes. Therefore, according to this embodiment, the refrigerant circuit (20) can be simplified.

[0183] Furthermore, during the refrigerant recovery action of Embodiment 3, liquid refrigerant built up in the cooling heat exchangers (83, 93) is sent to the associated oil separators (143, 144) and gas refrigerant separated in the oil separators (143, 144) is sent to the high stage compressors (41, 42, 43). Therefore, according to Embodiment 3, it can surely be avoided that during the refrigerant recovery action, liquid compression occurs in the high stage compressors (41, 42, 43). In addition, in Embodiment 3, the oil separators (143, 144) used to separate oil during the cooling operation are used as gas-liquid separators during the refrigerant recovery action. Therefore, according to Embodiment 3, it can be avoided that liquid compression occurs in the high stage compressors (41, 42, 43) during the refrigerant recovery action, without the need to additionally provide gas-liquid separators.

<Modifications of Embodiment 3>

[0184] The oil separators (143, 144) and the oil return pipes (141, 142) described in Embodiment 3 may be applied to the refrigeration systems (10) of Embodiments 1 and 2 so that the refrigeration systems (10) can perform a similar cooling operation, a similar defrosting operation and a similar refrigerant recovery action to those in Embodiment 3.

[0185] Furthermore, for example, in the booster circuits (100, 120) in Embodiment 3 shown in Figure 9, the bypass pipes (119, 139) may be connected at their one ends to the discharge connection pipes (116b, 136b), respectively, and connected at the other ends to the low stage suction pipes (113, 133), respectively. According to this configuration, during the defrosting operation, the cooling heat exchangers (83, 93) can be defrosted, without sending high-pressure refrigerant into the oil separators (143, 144), by directly introducing it into the bypass pipes (119, 139).

[0186] Furthermore, for example, as shown in Figure 11, the oil return pipes (141, 142) may be configured to serve also as bypass pipes (119, 139) for use in the defrosting operation. Specifically, in this modification, during the cooling operation, the solenoid valves (SV-5, SV-6) of the oil return pipes (141, 142) are opened or closed as appropriate, whereby oil recovered in the oil separators (143, 144) is returned via the associated oil return pipes (141, 142) to the associated low stage compressors (101, 102, 121, 122). Furthermore, during the defrosting operation in this modification, the solenoid valves (SV-5, SV-6) are opened, whereby high-pressure refrigerant sent from the outdoor circuit (40) is sent via the associated oil return pipes (141, 142) to the associated freezing circuits (80, 90). In other words, during the defrosting operation in this modification, the oil return pipes (141, 142) function as bypass pipes described above. Furthermore, during the refrigerant recovery action after the defrosting operation in this modification, the solenoid valves (SV-5, SV-6) are held open, whereby liquid refrigerant built up in the cooling heat exchangers (83, 93) flows via the associated oil return pipes (141, 142) into the associated oil separators (143, 144) and gas refrigerant separated in the oil separators (143, 144) is sent to the high stage compressors (41, 42, 43). Since, in this modification shown in Figure 11, the oil return pipes (141, 142) for oil return serve also as both of bypass pipes during the defrosting operation and liquid return pipes during the refrigerant recovery action in the above manner, the configuration of the refrigerant circuit (20) can be further simplified.

<<Other Embodiments>>

[0187] The above embodiments may have the following configurations.

[0188] Although in Embodiments 1 and 2 all the high stage compressors (41, 42, 43) are driven during the cooling operation and the defrosting operation, only one or two of these high stage compressors (41, 42, 43) may be driven during each operation.

[0189] Furthermore, although in Embodiment 2 both the low stage compressors (101, 102, 121, 122) in each booster circuit (100, 120) are driven during the second defrosting operation, only one of both the low stage compressors (101, 102, 121, 122) may be driven during it.

[0190] Furthermore, although during the second defrosting operation the openings of the liquid injection valves (191, 193) are appropriately controlled according to the degree of superheat of refrigerant to be sucked into the compressors (101, 102, 121, 122), they may be appropriately controlled according to the temperature of refrigerant discharged from the low stage compressors (101, 102, 121, 122), instead of the degree of superheat. Also in this case, the temperature

of refrigerant discharged from the low stage compressors (101, 102, 121, 122) can be prevented from abnormally increasing.

[0191] Furthermore, although in Embodiment 2 the refrigeration system decreases the discharge temperatures of the compressors (101, 102, 121, 122) in the booster circuits (100, 120) by performing liquid injection, it may be configured not to perform the liquid injection. In this case, for example, the operating frequency of the second variable displacement compressor (101) or the third variable displacement compressor (121) may be reduced to decrease the temperature of discharged refrigerant, or either one of both the low stage compressors (101, 102, 121, 122) in each booster circuit (100, 120) may be shut off.

[0192] Furthermore, although in the refrigeration systems (10) of the above embodiments the refrigerant circuit (20) includes a plurality of cooling heat exchangers (83, 93) to simultaneously cool the interiors of a plurality of freezer display cases (12, 13), the refrigerant circuit (20) may include a single cooling heat exchanger to cool the interior of a single freezer display case.

[0193] The above embodiments are merely preferred embodiments in nature and are not intended to limit the scope, applications and use of the invention.

## Industrial Applicability

[0194] As can be seen from the above description, the present invention relates to refrigeration systems operating in a two-stage compression refrigeration cycle and is particularly useful for techniques for defrosting a utilization side heat exchanger for cooling the internal air in a freezer or the like.

## Claims

1. A refrigeration system including a refrigerant circuit in which a low stage compressor, a high stage compressor, a heat-source side heat exchanger and a utilization side heat exchanger are connected, the refrigeration system being operable in a two-stage compression refrigeration cycle by driving the low stage compressor and the high stage compressor during a cooling operation in which the heat-source side heat exchanger serves as a condenser and the utilization side heat exchanger serves as an evaporator, wherein the refrigeration system is configured to be switchable between the cooling operation and a defrosting operation for defrosting the utilization side heat exchanger and operate, during the defrosting operation, in a refrigeration cycle in which the high stage compressor is driven, the utilization side heat exchanger serves as a condenser and the heat-source side heat exchanger serves as an evaporator.
2. The refrigeration system of claim 1, wherein the refrigeration system is configured to keep the low stage compressor off during the defrosting operation.
3. The refrigeration system of claim 2, further including a bypass pipe that connects the suction side and the discharge side of the low stage compressor and includes a shut-off valve, the shut-off valve being open during the defrosting operation and being closed during the cooling operation.
4. The refrigeration system of claim 2 or 3, wherein a drain pan is disposed below the utilization side heat exchanger, the refrigerant circuit comprises a utilization side expansion valve connected upstream of the utilization side heat exchanger in the cooling operation and a drain pan heating pipe connected upstream of the utilization side expansion valve in the cooling operation and disposed along the drain pan, and the refrigeration system is configured so that, during the cooling operation, refrigerant condensed in the heat-source side heat exchanger flows through the drain pan heating pipe, is then reduced in pressure by the utilization side expansion valve and is then fed into the utilization side heat exchanger.
5. The refrigeration system of claim 4, wherein the refrigerant circuit includes a heat-source side expansion valve disposed upstream of the heat-source side heat exchanger in the defrosting operation, and the refrigeration system is configured so that, during the defrosting operation, refrigerant condensed in the utilization side heat exchanger flows through the fully-open utilization side expansion valve and the drain pan heating pipe, is then reduced in pressure by the heat-source side expansion valve and is then fed into the heat-source side heat exchanger.

6. The refrigeration system of claim 1, wherein the refrigeration system is configured, during the defrosting operation, to operate in a refrigeration cycle in which refrigerant discharged from the high stage compressor is further compressed by the low stage compressor, the utilization side heat exchanger serves as a condenser and the heat-source side heat exchanger serves as an evaporator.

7. The refrigeration system of claim 6, wherein the refrigeration system is configured so that, during the defrosting operation, part of refrigerant discharged from the high stage compressor is further compressed by the low stage compressor and then returned to the discharge side of the high stage compressor.

8. The refrigeration system of claim 7, wherein the refrigeration system is configured to return, during the defrosting operation, part of refrigerant condensed in the utilization side heat exchanger to the suction side of the low stage compressor.

9. The refrigeration system of claim 1, further including a liquid return pipe connecting the suction side and the discharge side of the low stage compressor, the refrigeration system being configured, after the completion of the defrosting operation, to perform a refrigerant recovery action by driving only the high stage compressor to allow the high stage compressor to suck refrigerant built up in the utilization side heat exchanger through the liquid return pipe.

10. The refrigeration system of claim 9, further including:

an oil separator disposed to the discharge side of the low stage compressor; and  
an oil return pipe for sending refrigerating machine oil recovered by the oil separator to the suction side of the low stage compressor, the oil return pipe serving also as the liquid return pipe during the refrigerant recovery action.

11. The refrigeration system of claim 10, wherein the oil separator is configured, during the refrigerant recovery action, to separate gas refrigerant from refrigerant flowing therein from the liquid return pipe and send the gas refrigerant to the suction side of the high stage compressor.

FIG. 1

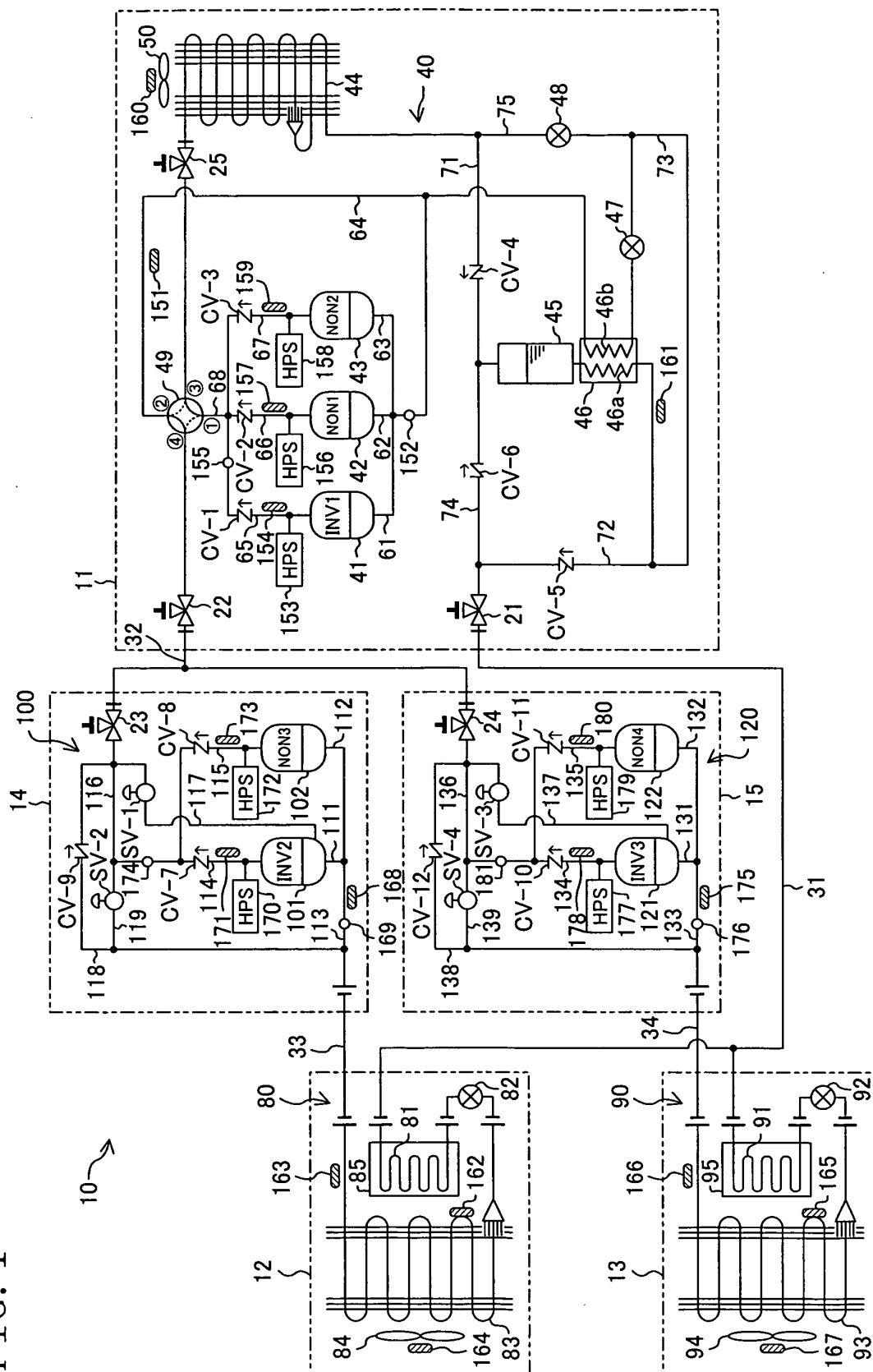


FIG. 2

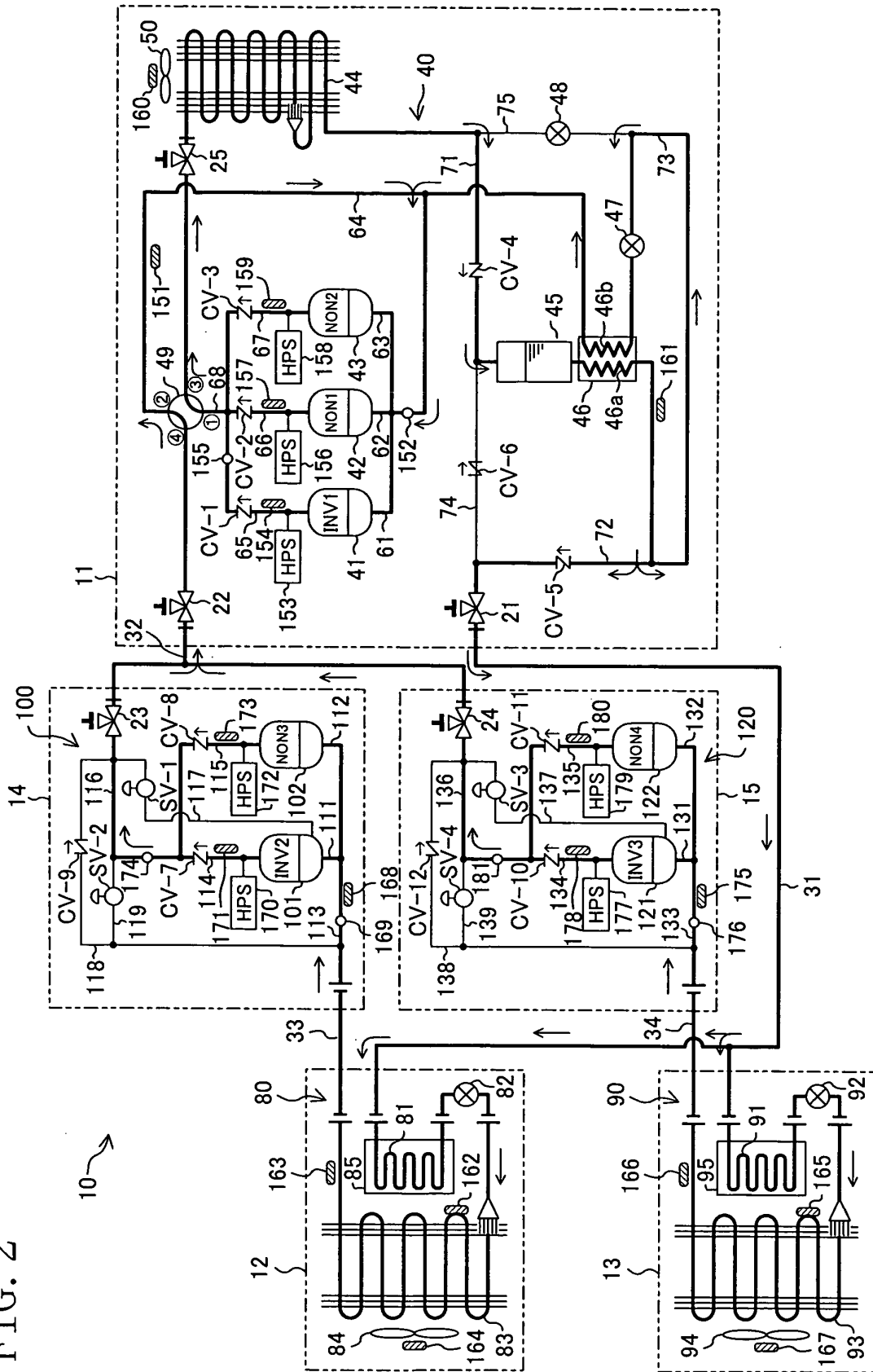


FIG. 3

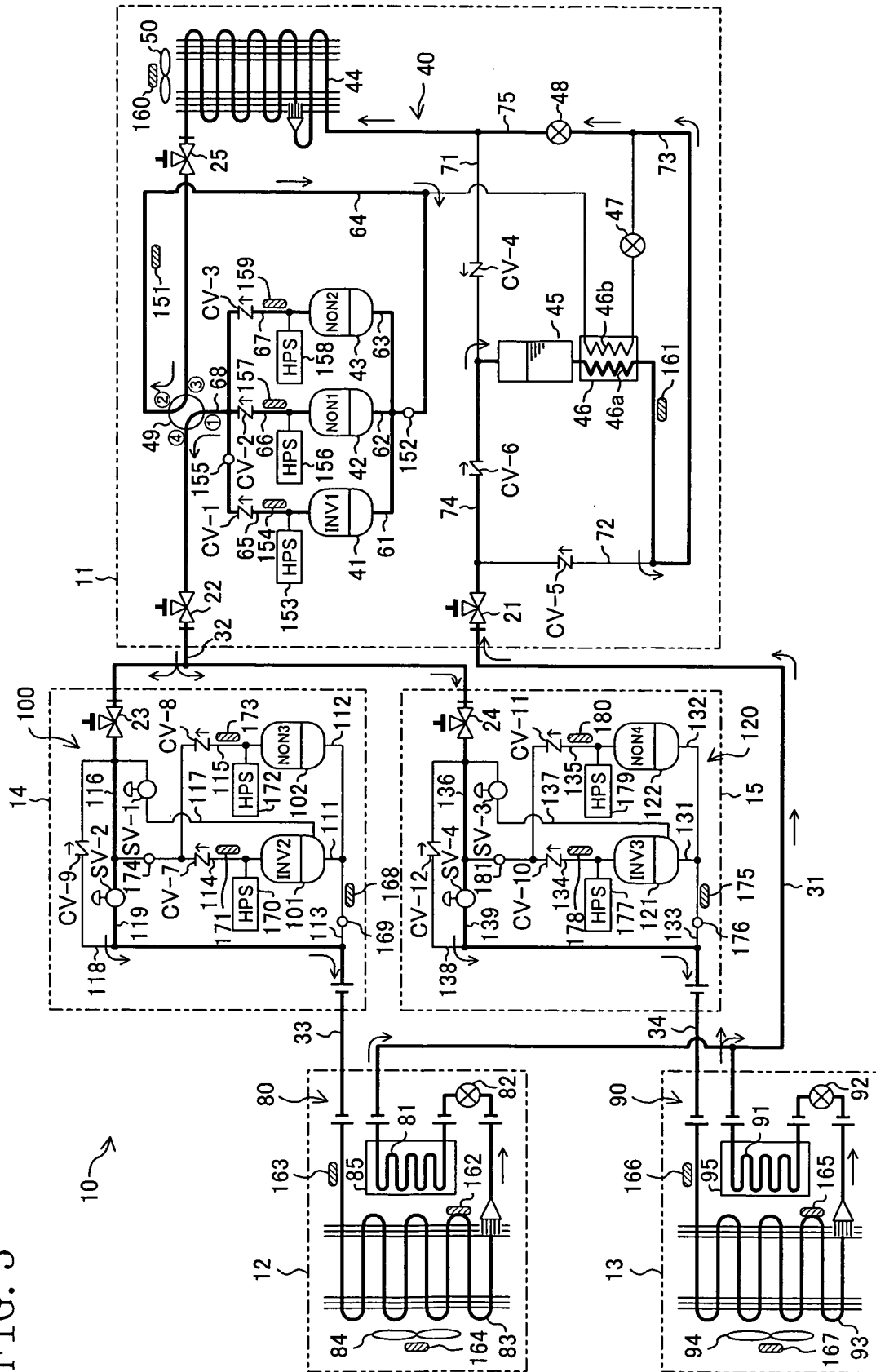


FIG. 4

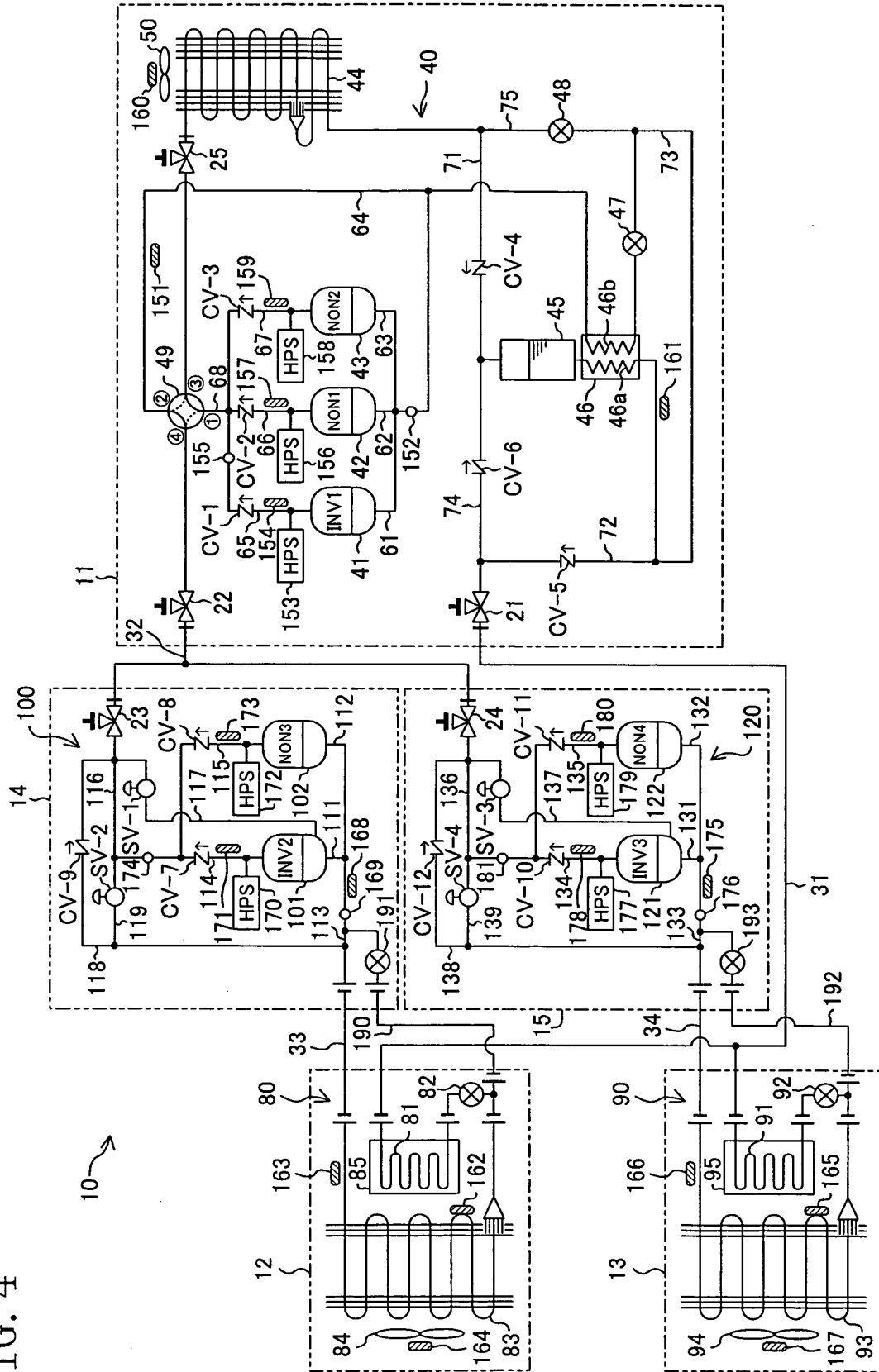


FIG. 5

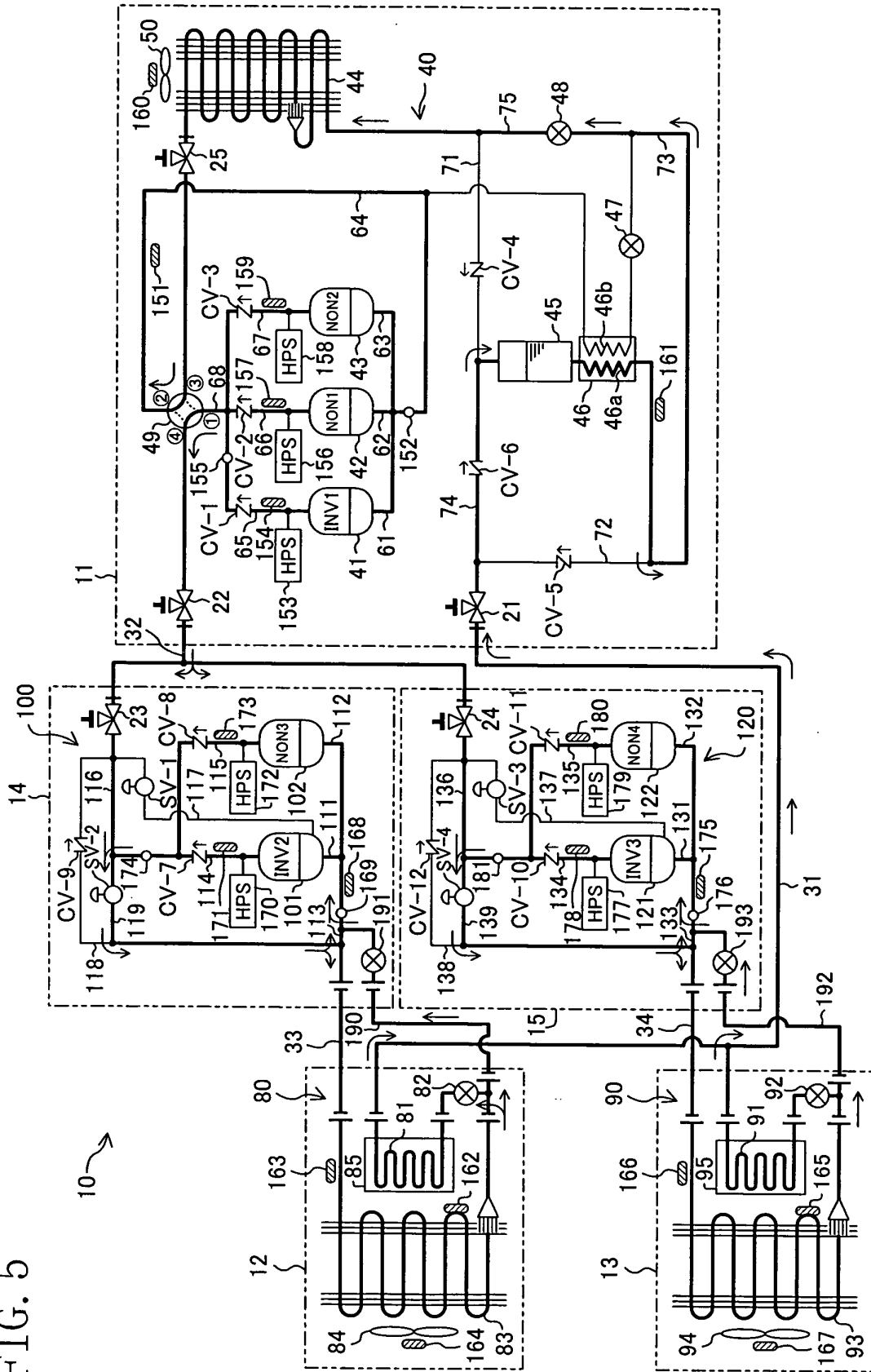


FIG. 6

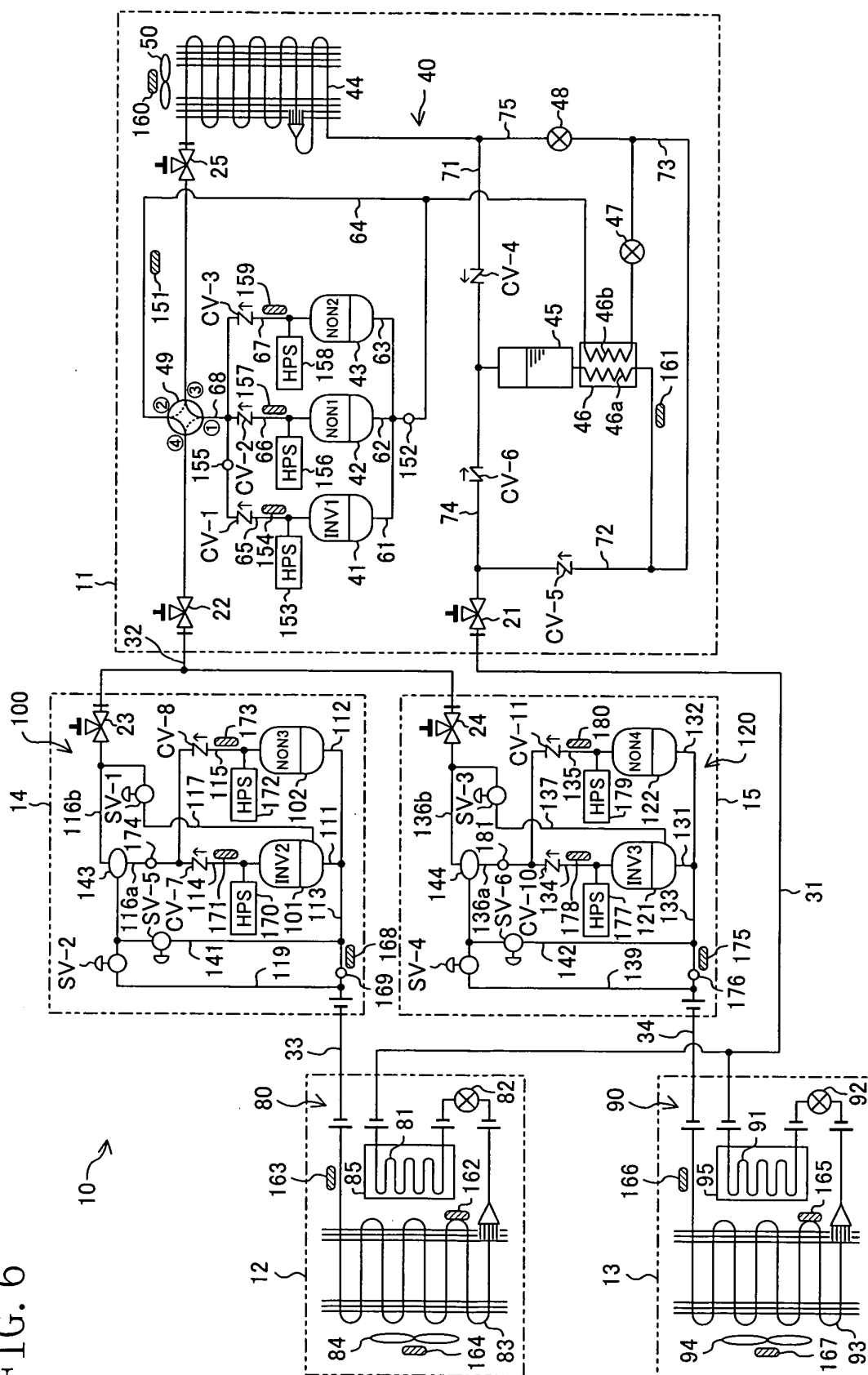


FIG. 7

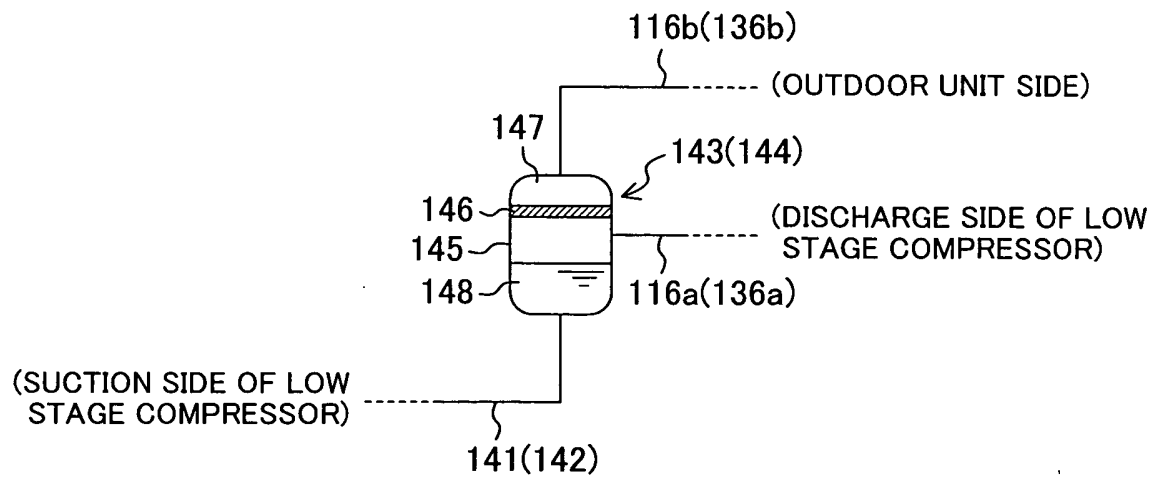


FIG. 8

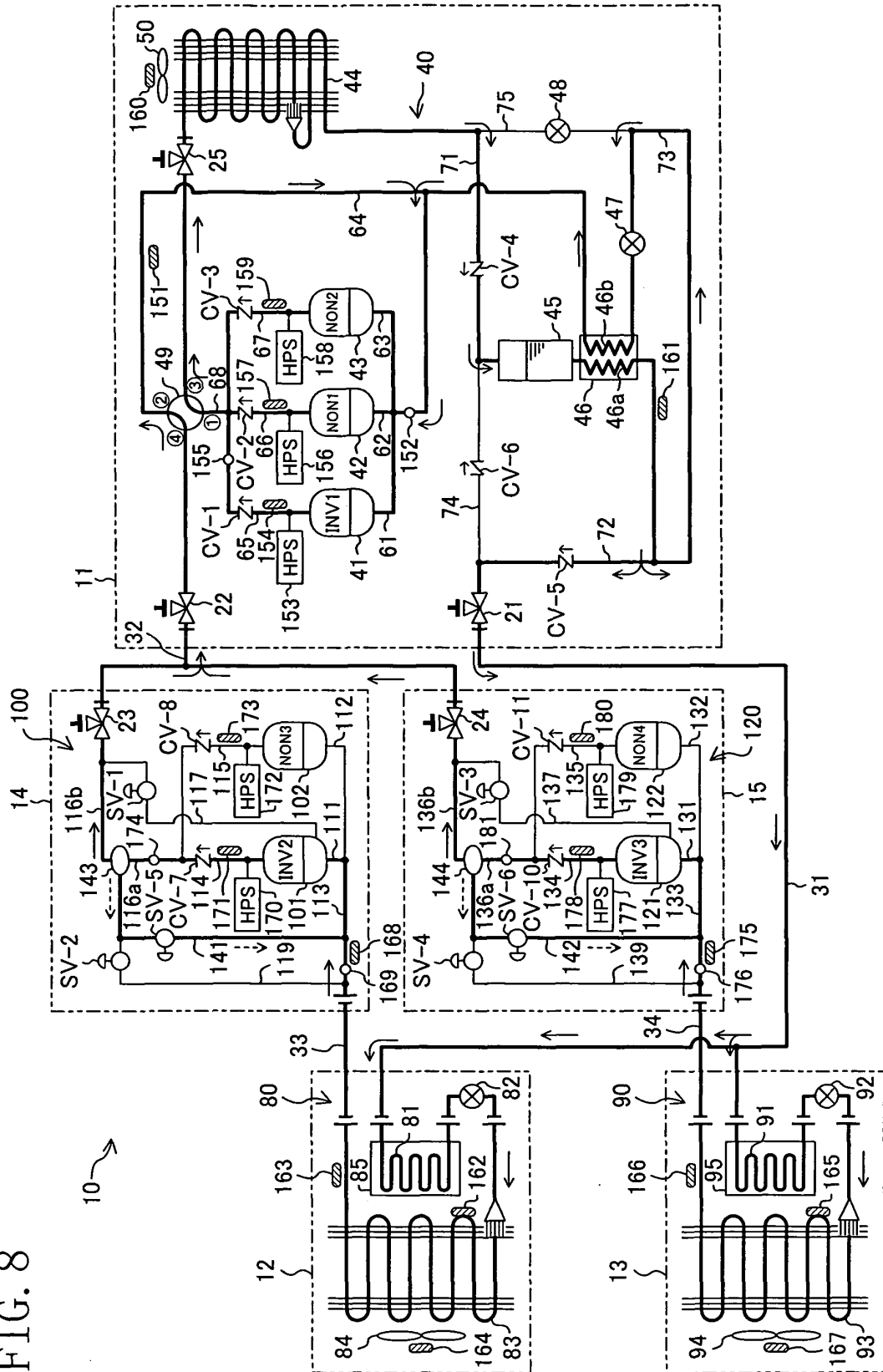


FIG. 9

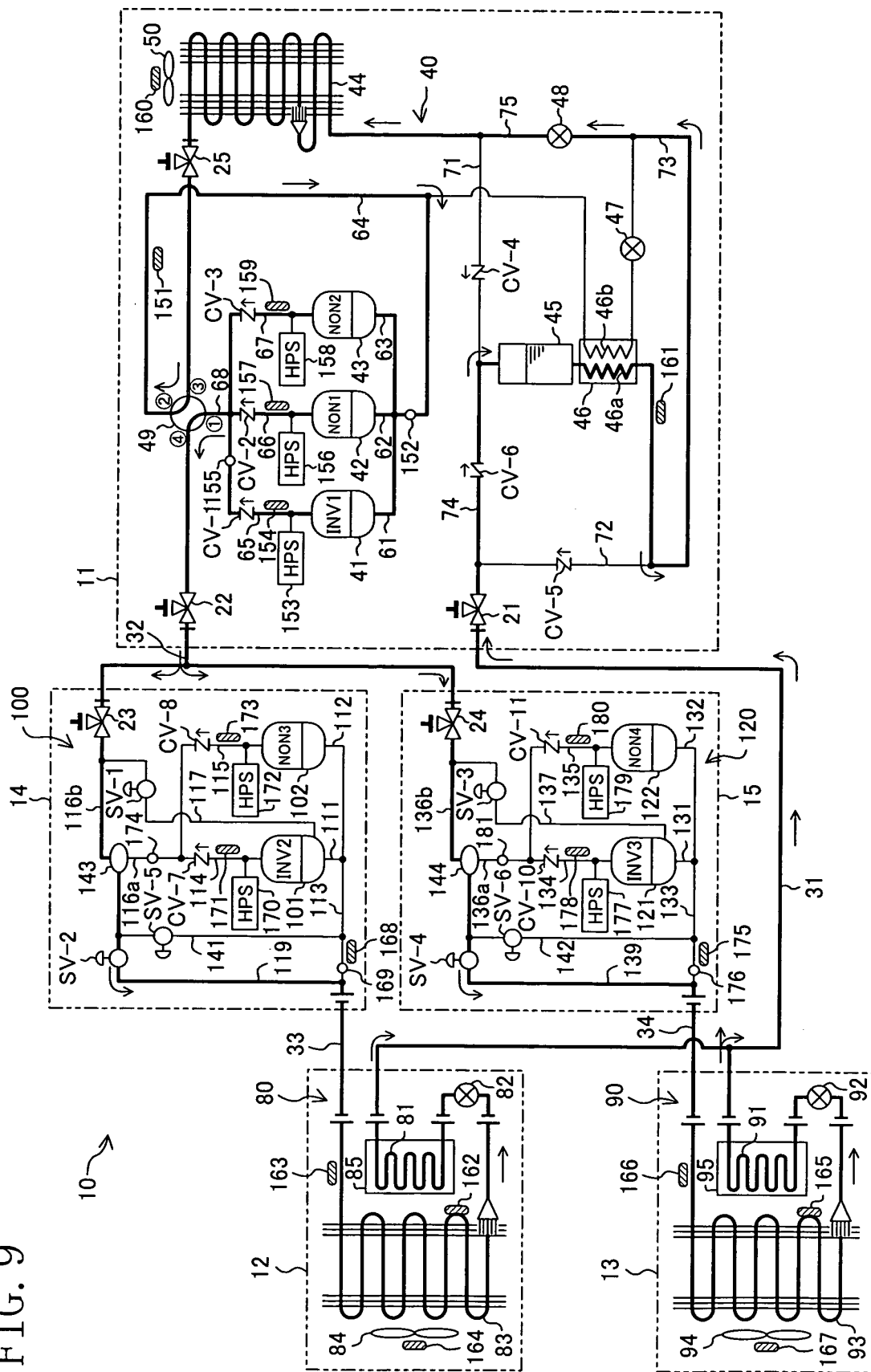


FIG. 10

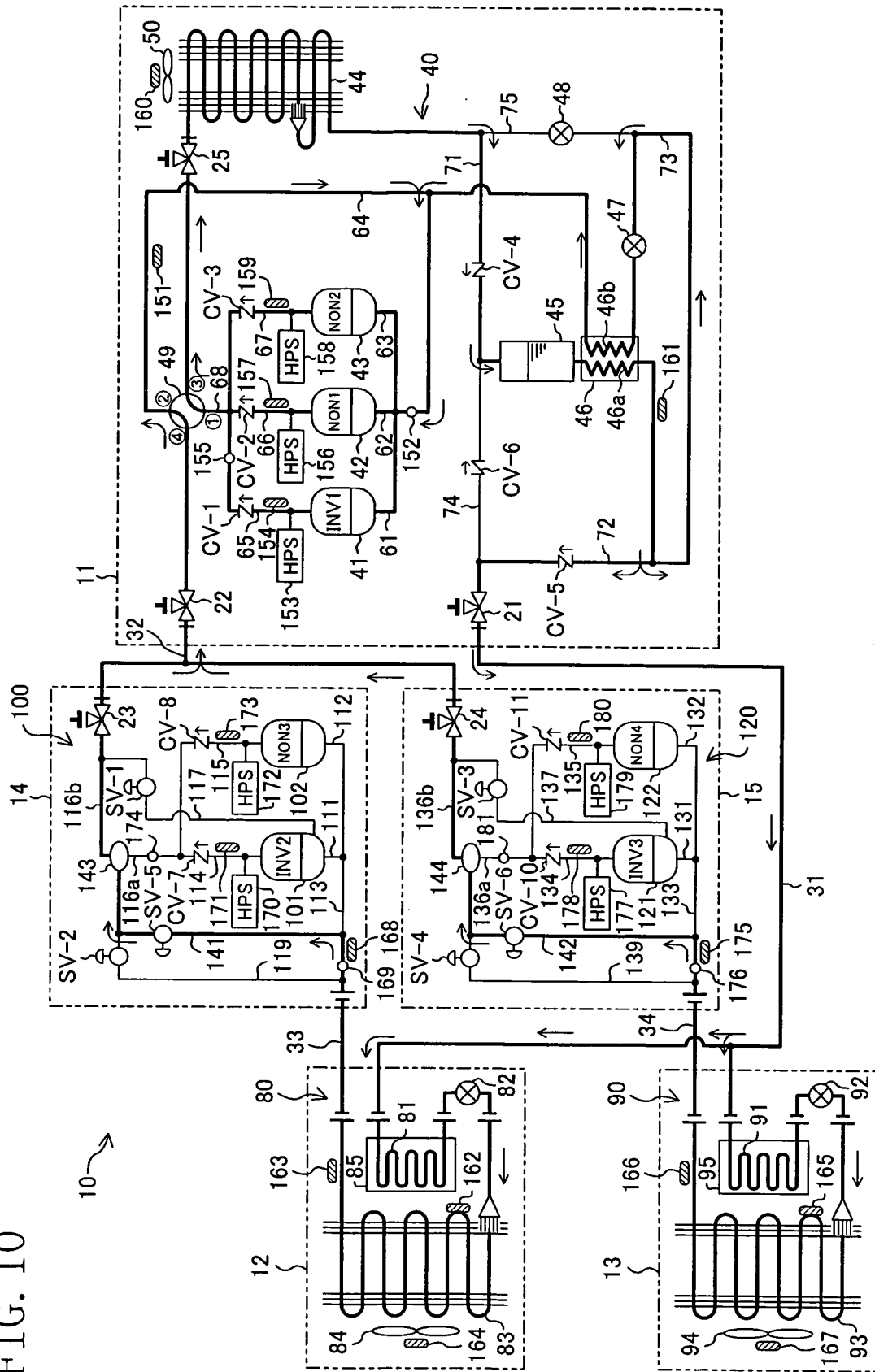
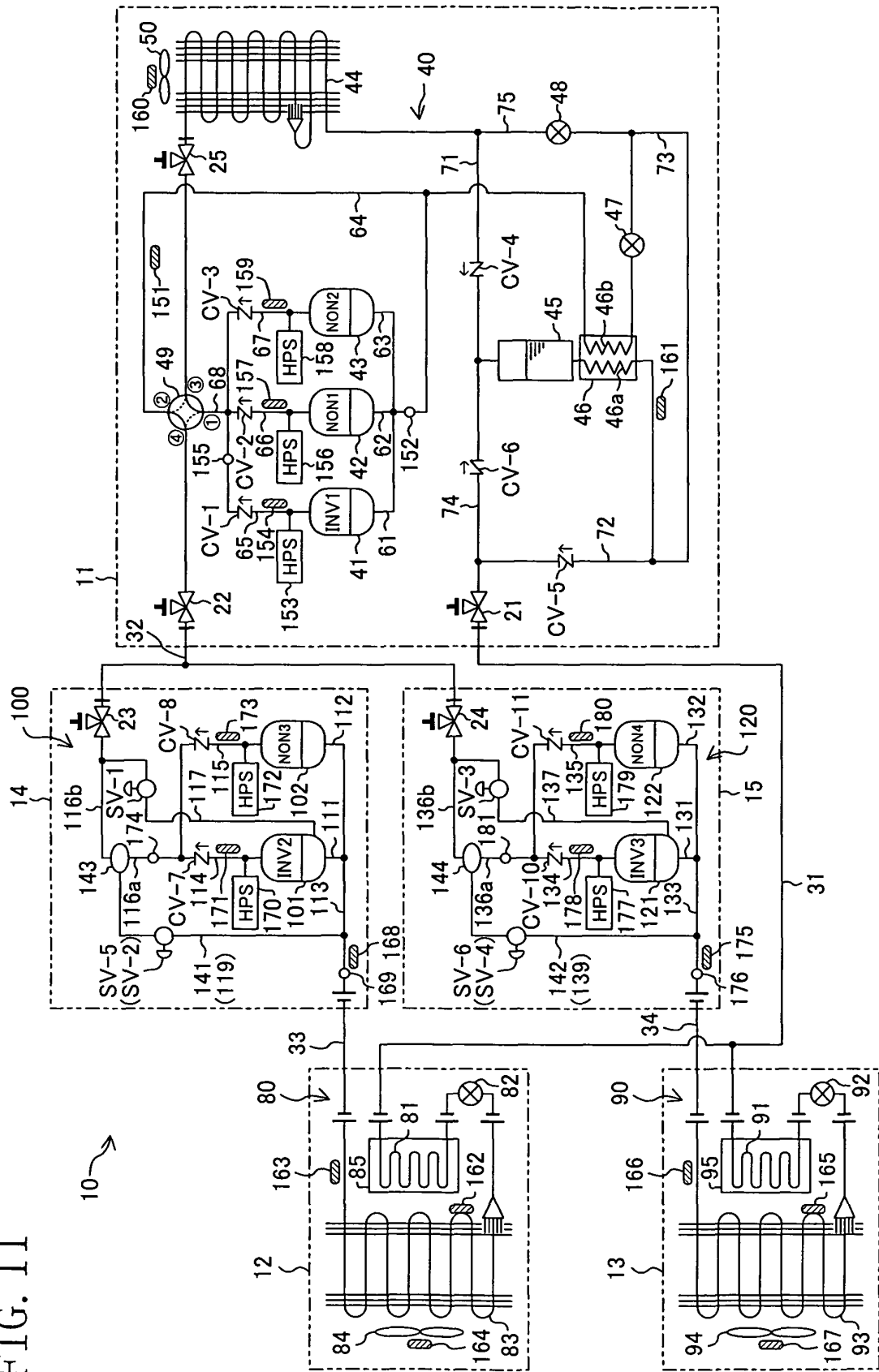


FIG. 11



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2006/313233

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br><i>F25B47/02</i> (2006.01) i, <i>F25B1/00</i> (2006.01) i, <i>F25B1/10</i> (2006.01) i, <i>F25D21/14</i> (2006.01) i<br><br>According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                      |                                                                                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br><i>F25B47/02</i> , <i>F25B1/00</i> , <i>F25B1/10</i> , <i>F25D21/14</i><br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br>Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2006<br>Kokai Jitsuyo Shinan Koho 1971-2006 Toroku Jitsuyo Shinan Koho 1994-2006<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                      |                                                                                   |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                      |                                                                                   |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document, with indication, where appropriate, of the relevant passages                                                   | Relevant to claim No.                                                             |
| X<br>Y<br>A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | JP 2004-85047 A (Daikin Industries, Ltd.),<br>18 March, 2004 (18.03.04),<br>Par. Nos. [0070] to [0073]; Fig. 4<br>(Family: none)     | 1, 2<br>3-5<br>6-11                                                               |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | JP 2000-346478 A (Daikin Industries, Ltd.),<br>15 December, 2000 (15.12.00),<br>Par. Nos. [0020] to [0045]; Fig. 1<br>(Family: none) | 3                                                                                 |
| Y                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | JP 5-126440 A (Sanyo Electric Co., Ltd.),<br>21 May, 1993 (21.05.93),<br>Par. Nos. [0003] to [0007]; Figs. 5, 6<br>(Family: none)    | 4, 5                                                                              |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                                      |                                                                                   |
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| Date of the actual completion of the international search<br>11 October, 2006 (11.10.06)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                      | Date of mailing of the international search report<br>17 October, 2006 (17.10.06) |
| Name and mailing address of the ISA/<br>Japanese Patent Office                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                      | Authorized officer                                                                |
| Facsimile No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                                      | Telephone No.                                                                     |

Form PCT/ISA/210 (second sheet) (April 2005)

**REFERENCES CITED IN THE DESCRIPTION**

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