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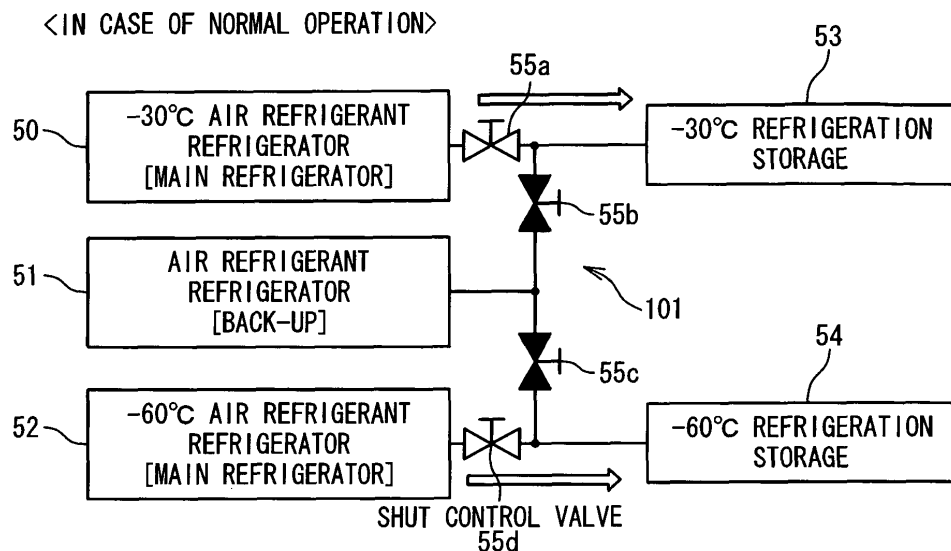
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(54) **Air cycle refrigerator system and backup method using the same**

(57) A refrigerator system includes a plurality of refrigeration storages (53, 54) respectively set to different cooling temperatures; a plurality of air refrigerant refrigerators (50-52, 80-83); and a pipe section (102, 104, 106, 108) provided between the plurality of main air refrigerant refrigerators and the plurality of refrigeration storages. The pipe section comprises a valve section configured to thermally connect each of the plurality of air refrigerant

refrigerators other than a specific air refrigerant refrigerator to at least one of the plurality of refrigeration storages in a normal operation mode; and to thermally connect the specific air refrigerant refrigerator to a specific one of the plurality refrigeration storages corresponding to a failed one of the plurality of air refrigerant refrigerators in place of the failed air refrigerant refrigerator in a failure operation mode.

Fig. 5A



Description

Background of the Invention

1. Field of the Invention

[0001] The present invention relates to an air refrigerant refrigerator system, and more particularly, to an air refrigerant refrigerator system having a backup function, and a backup method in the air refrigerant refrigerator system.

2. Description of the Related Art

[0002] In a conventional refrigerator system (for example, a refrigerator system formed from HFC refrigerators), main refrigerators 1A and 4A and backup refrigerators 2A and 5A are respectively connected in parallel for cooling temperatures of -30°C and -60°C, as shown in Figs. 1A and 1B. In this case, the backup refrigerator 2A and 5A need to have the same refrigeration powers as the main refrigerators 1A and 4A, respectively. Thus, the conventional refrigerator system has refrigeration power twice more than refrigeration power actually needed.

[0003] In another conventional refrigerator system shown in Figs. 1C and 1D, each of main refrigerators 1B and 2B has a half of the refrigeration power of the main refrigerator shown in Fig. 1A, and they are connected to each other in parallel, and each of main refrigerators 4B and 5B has a half of the refrigeration power of the main refrigerator shown in Fig. 1B, and they are connected to each other in parallel. In this system, even when either of the main refrigerators is failed, the cooling operation of the refrigeration storage 3 or 6 is possible. However, heat load in case of the failure is limited to 50% of an ordinary maximum heat load.

[0004] The reason why the backup HFC refrigerator must have the same refrigeration power as the main HFC refrigerator in Figs. 1A and 1B is in a cooling temperature range of the HFC refrigerator. As shown in Fig. 2, in the cooling operation by the conventional HFC refrigerator, refrigerant to be used is varied depending on the cooling temperature range. Especially, it is impossible for the HFC refrigerator to use a same type of refrigerant in the cooling temperature range of -50°C to -55°C. Thus, to cool the refrigeration storage in the cooling temperature range, a conventional refrigerator system needs to be provided with a main refrigerator using two kinds of refrigerants. For this reason, in such a conventional refrigerator system, at least one backup refrigerator is provided for each refrigerant.

[0005] As described above, in the refrigerator system formed from the conventional HFC refrigerators, the refrigerator having the refrigeration power of at least twice more than refrigeration power required actually is provided. Thus, reduction in manufacturing and maintenance costs of the system has been strongly demanded.

[0006] In conjunction with the above description,

"Standby Apparatus of Compressor for Refrigerator" is disclosed in Japanese Laid Open Patent Application (JP-P2000-292024A). In this conventional example, a standby apparatus of a compressor for a refrigerator is provided with an active compressor unit for supplying a refrigerant gas to a refrigerator unit and a standby compressor unit, which operates when the active compressor unit stops and supplies a refrigerant gas to the refrigerator unit.

Summary of the Invention

[0007] An object of the present invention is to provide a refrigerator system having a backup function.

[0008] In an aspect of the present invention, a refrigerator system includes a plurality of refrigeration storages respectively set to different cooling temperatures; a plurality of air refrigerant refrigerators; and a pipe section provided between the plurality of main air refrigerant refrigerators and the plurality of refrigeration storages. The pipe section comprises a valve section configured to thermally connect each of the plurality of air refrigerant refrigerators other than a specific air refrigerant refrigerator to at least one of the plurality of refrigeration storages in a normal operation mode; and to thermally connect the specific air refrigerant refrigerator to a specific one of the plurality of refrigeration storages corresponding to a failed one of the plurality of air refrigerant refrigerators other than the specific air refrigerant refrigerator, in place of the failed air refrigerant refrigerator in a failure operation mode.

[0009] Here, the pipe section may thermally disconnect the failed air refrigerant refrigerator from the specific refrigeration storage in the failure operation mode, and thermally connect the specific air refrigerant refrigerator to the specific refrigeration storage in the failure operation mode.

[0010] Also, the specific air refrigerant refrigerator may be thermally connected to at least one of the plurality of air refrigerant refrigerators in the normal operation mode.

[0011] Also, the pipe section may further include a plurality of common pipe sections provided for the cooling temperatures and connected to the plurality of refrigeration storages, respectively. The valve section thermally connects each of the plurality of air refrigerant refrigerators other than the specific air refrigerant refrigerator to one of the plurality of common pipe sections.

[0012] Also, the specific air refrigerant refrigerator may be thermally connected to one of the plurality of common pipe sections corresponding to the failed air refrigerant refrigerator.

[0013] In this case, each of the plurality of air refrigerant refrigerators may include a brine heat exchanger, which is connected to a specific one of the plurality of common pipe sections as a brine pipe section through the valve section.

[0014] In this case, each of the plurality of common pipe sections may be thermally connected to a brine tank

which is thermally connected to one of the plurality of refrigeration storages.

[0015] Also, the brine heat exchanger in each of the plurality of air refrigerant refrigerators may be thermally connectable to the plurality of common pipe sections other than the specific common pipe section through the valve section.

[0016] Also, each of the plurality of air refrigerant refrigerators may include a plurality of brine heat exchangers, which are connected to the plurality of common pipe sections through the valve section, respectively.

[0017] In this case, each of the plurality of common pipe sections may be thermally connected to a brine tank which is thermally connected to one of the plurality of refrigeration storages.

[0018] Also, a flow route of cooled refrigerant in each of the plurality of air refrigerant refrigerators may be connected to the plurality of common pipe sections through the valve section. Each of the plurality of common pipe sections extends in one of the plurality of refrigeration storages.

[0019] Also, the plurality of air refrigerant refrigerators are preferable to be closed type air refrigerant refrigerators.

[0020] Also, at least one of the plurality of air refrigerant refrigerators may be an opened type air refrigerant refrigerator.

[0021] In another aspect of the present invention, a method of cooling a plurality of refrigeration storages respectively set to different cooling temperatures, is achieved by generating cooled refrigerant in each of a plurality of air refrigerant refrigerators other than a specific air refrigerant refrigerator in a normal operation mode; by thermally connecting each of the plurality of air refrigerant refrigerators other than a specific air refrigerant refrigerator to at least one of the plurality of refrigeration storages to be cooled, through a valve section in the normal operation mode; and by thermally connecting the specific air refrigerant refrigerator to a specific one of the plurality refrigeration storages corresponding to a failed one of the plurality of air refrigerant refrigerators other than the specific air refrigerant refrigerator, in place of the failed air refrigerant refrigerator in a failure operation mode.

[0022] Here, the thermally connecting the specific air refrigerant refrigerator may be achieved by thermally disconnecting the failed air refrigerant refrigerator from the specific refrigeration storage in the failure operation mode; and by thermally connecting the specific air refrigerant refrigerator to the specific refrigeration storage in the failure operation mode.

[0023] Also, the method may be achieved by further thermally connecting the specific air refrigerant refrigerator to at least one of the plurality of air refrigerant refrigerators in the normal operation mode.

[0024] In this case, each of the thermally connecting steps may be achieved by thermally connecting each of the plurality of air refrigerant refrigerators other than the

specific air refrigerant refrigerator to one of a plurality of common pipe sections, which are thermally connected to the plurality of refrigeration storages.

5 Brief Description of the Drawings

[0025]

Figs. 1A and 1B are schematic diagrams showing the configuration of a conventional refrigerator system having a backup function by use of HFC refrigerators;

Figs. 1C and 1D are schematic diagrams showing the configuration of another conventional refrigerator system having a backup function by use of HFC refrigerators;

Fig. 2 is a table showing a relationship of refrigerant and cooling temperature range;

Fig. 3 is a schematic diagram showing the configuration of an air refrigerant refrigerator;

Fig. 4 is a graph showing a relationship of the cooling temperature of a refrigeration storage and refrigeration power in the air refrigerant refrigerator;

Fig. 5A is a schematic diagram showing the configuration of a refrigerator system according to a first embodiment of the present invention;

Fig. 5B is a schematic diagram showing the refrigerator system in the first embodiment in case of failure of a -60°C refrigerator;

Fig. 5C is a schematic diagram showing the refrigerator system in the first embodiment in case of failure of a -30°C refrigerator;

Fig. 6A is a schematic diagram showing the configuration of the refrigerator system according to a second embodiment of the present invention;

Fig. 6B is a schematic diagram showing the refrigerator system in the second embodiment in case of failure of a -60°C refrigerator;

Fig. 6C is a schematic diagram showing the refrigerator system in the second embodiment in case of failure of a -30°C refrigerator;

Fig. 7A is a schematic diagram showing the configuration of the refrigerator system according to a third embodiment of the present invention;

Fig. 7B is a schematic diagram showing the refrigerator system in the third embodiment in case of failure of a -60°C refrigerator;

Fig. 7C is a schematic diagram showing the refrigerator system in the second embodiment in case of failure of a -30°C refrigerator;

Fig. 8 is a schematic diagram showing the configuration of the refrigerator system according to a fourth embodiment of the present invention;

Fig. 9A is a schematic diagram showing the refrigerator system in the fourth embodiment in case of a normal operation;

Fig. 9B is a schematic diagram showing the refrigerator system in the fourth embodiment in case of

failure of a -30°C refrigerator;

Fig. 9C is a schematic diagram showing the refrigerator system in the fourth embodiment in case of failure of a -60°C refrigerator;

Fig. 10 is a schematic diagram showing the configuration of the refrigerator system according to a fifth embodiment of the present invention; and

Fig. 11 is a schematic diagram showing the configuration of the refrigerator system according to a sixth embodiment of the present invention.

Description of the Preferred embodiments

[0026] Hereinafter, a refrigerator system and a backup method in the refrigerator system according to the present invention will be described in detail with reference to the attached drawings.

[0027] In order to cool objects to a plurality of different temperature ranges, the refrigerator system of the present invention has refrigeration storages equal to the number of the cooling temperature ranges. Each refrigeration storage is provided with a main air refrigerant refrigerator of a closed type to cool the refrigeration storage. In addition, at least one backup air refrigerant refrigerator is installed over the refrigeration storages.

[0028] Here, referring to Fig. 3, configuration and operating principle of the air refrigerant refrigerator used in the refrigerator system of the present invention will be described. The air refrigerant refrigerator 60 is of a closed type in this example and is provided with a turbine unit 40 having a motor 31, a compressor 38 and an expansion turbine 32; a first heat exchanger 34; a second heat exchanger 35; and a defroster 36. The cooled air refrigerant is supplied to a refrigeration storage 37.

[0029] The compressor 38 is directly coupled to one end of a shaft of the motor 31 and the expansion turbine 32 is coupled to the other end of the shaft of the motor 31. Thus, the compressor 38 and expansion turbine 32 are driven to rotate by the motor 31. Air is circulated in the motor 31 by a fan F to cool the motor 31. In the air refrigerant refrigerator 60, air refrigerant is compressed by the compressor 38, and is cooled by the first heat exchanger 34 through heat exchange with atmosphere. The cooled air refrigerant is supplied to the second heat exchanger 35 and subjected to heat exchange by the second heat exchanger 35 with cooled air refrigerant supplied through the refrigeration storage 37, and the further cooled air refrigerant is supplied to the expansion turbine 32. The expansion turbine 32 adiabatically expands the further cooled air refrigerant so as to be cooled to a lower temperature (up to about -80°C), and supplies to the refrigeration storage 37 through defroster 36. This lower-temperature air refrigerant keeps products stored in the refrigeration storage 37 at a lower temperature. In the air refrigerant refrigerator 60 shown in Fig. 3, the defroster 36 is provided in a flow pipe section connecting the expansion turbine 32 to the refrigeration storage 37 to remove frost generated through moisture condensation in

the air refrigerant.

[0030] It should be noted that although the first heat exchanger 34 in Fig. 3 is described as an air-cooling type heat exchanger, it may be a water-cooling type heat exchanger. Also, the defroster 36 may be omitted when dry air or dry nitrogen is used as the air refrigerant, since the frost is not generated.

[0031] In the air refrigerant refrigerator system 30, as shown in Fig. 4, the products stored in the refrigeration storage 37 can be kept in the cooling temperature range of -20°C to -100°C by varying refrigeration power (kW) for a heat load from the refrigerator storage per one air refrigerant refrigerator.

[0032] In the air refrigerant refrigerator system of the present invention, it could be understood from such principle of the air refrigerant refrigerator that the main air refrigerant refrigerators may be respectively provided for the cooling temperature ranges and at least one backup air refrigerant refrigerator may be provided for the main air refrigerant refrigerators. The backup main air refrigerant refrigerator can back up any failed one of the main air refrigerant refrigerators by setting the cooling temperature range of the backup refrigerator to a cooling temperature range of the failed refrigerator in the temperature range of -20°C to -100°C. Thus, in the present invention, since the number of the backup refrigerators is limited to be minimum, manufacturing and maintenance costs of the system can be reduced.

[First Embodiment]

[0033] Fig. 5A shows schematic configuration of an air refrigerant refrigerator system according to the first embodiment of the present invention. The refrigerator system in the first embodiment has a -30°C refrigeration storage 53 for cooling products to -30°C and a -60°C refrigeration storage 54 for cooling products to -60°C. The air refrigerators 50 to 52 are connected to the refrigeration storages 53 and 54 through a pipe section 101 which contains shut valves 55a to 55d. A -30°C air refrigerant refrigerator 50 is connected to the -30°C refrigeration storage 53 through the shut valve 55a of the pipe section 101. A -60°C air refrigerant refrigerator 52 is connected to the -60°C refrigeration storage 54 through the shut valve 55d of the pipe section 101. In addition, in the first embodiment, a backup air refrigerant refrigerator 51 is connected to the -30°C refrigeration storage 53 and -60°C refrigeration storage 54 through the shut valves 55b and 55c of the pipe section 101, respectively.

[0034] As shown in Fig. 5A, in case of a normal operation mode of the air refrigerant refrigerator system in the first embodiment, the shut valves 55b and 55c are closed and the shut valves 55a and 55d are opened. Thus, the -30°C air refrigerant refrigerator 50 is connected to the -30°C refrigeration storage 53 through the pipe section 101. Also, the -60°C air refrigerant refrigerator 52 is connected to the -60°C refrigeration storage 54 through the pipe section 101.

[0035] As shown in Fig. 5B, it is assumed that the -60°C air refrigerant refrigerator 52 is failed after start of the air refrigerant refrigerator system in the first embodiment. In this case, the main air refrigerant refrigerator 52 immediately stops its operation. Then, the shut valve 55d is closed and the backup air refrigerant refrigerator 51 is started. Subsequently, the shut valve 55c is opened. Thus, in place of the failed -60°C main refrigerator 52, the backup refrigerator 51 is driven as a -60°C refrigerator to maintain the cooling function for the -60°C refrigeration storage 54.

[0036] On the other hand, as shown in Fig. 5C, it is assumed that the -30°C air refrigerant refrigerator 50 is failed after start of the air refrigerant refrigerator system in the first embodiment. In this case, the main refrigerator 50 immediately stops its operation. Then, the shut valve 55a is closed and the backup air refrigerant refrigerator 51 is started. Subsequently, the shut valve 55b is opened. Thus, in place of the failed -30°C main refrigerator 50, the backup refrigerator 51 is driven as a -30°C refrigerator to maintain the cooling function for -30°C refrigeration storage 53.

[0037] In the first embodiment, the main air refrigerant refrigerators 50 and 52 are provided to cool the -30°C refrigeration storage 53 and -60°C refrigeration storage 54. The backup air refrigerant refrigerator 51 is provided in parallel to each of the -30°C main air refrigerant refrigerator 50 and -60°C main air refrigerant refrigerator 52. The backup air refrigerant refrigerator 51 can cope with both the failure of the -30°C main air refrigerant refrigerator 50 and the failure of the -60°C main air refrigerant refrigerator 52. For this reason, in the first embodiment, even when any of the refrigerators is failed, the refrigeration storage corresponding to the failed refrigerator can be kept cool to a predetermined temperature range while maintaining a constant refrigeration power at all times, by further providing one backup refrigerator in spite of the two refrigeration storages 53 and 54. Thus, the refrigeration storage can store medical samples and living bodies, or rare products absolutely requiring continuous refrigeration such as precious frozen samples. Moreover, in the first embodiment, manufacturing and maintenance costs of the refrigerator system having the backup function can be reduced.

[Second Embodiment]

[0038] Fig. 6A is a schematic diagram showing the configuration of the air refrigerant refrigerator system according to the second embodiment of the present invention. The second embodiment has the similar configuration to that of the first embodiment. In the second embodiment, the backup refrigerator in the first embodiment is not used. The -30°C air refrigerant refrigerators 50 and 51 are used in the normal operation mode and one of them functions as the backup refrigerator in a failure mode. That is, in the air refrigerant refrigerator system in the second embodiment, the -30°C air refrigerant refrig-

erators 50 and 51 are connected to the -30°C refrigeration storage 53 through the shut valves 55a and 55b in the pipe section 101, respectively. The -60°C air refrigerant refrigerator 52 is connected to the -60°C refrigeration storage 54 by the shut valve 55d of the pipe section 101. Furthermore, in the second embodiment, the -30°C air refrigerant refrigerator 51 is connectable to the -60°C air refrigeration storage 54 through the shut valve 55c of the pipe section 101.

[0039] As shown in Fig. 6A, in case of the normal operation mode of the air refrigerant refrigerator system in the second embodiment, the shut valve 55c is closed and the shut valves 55a, 55b and 55d are opened. Thus, the -30°C air refrigerant refrigerators 50 and 51 are connected to the -30°C refrigeration storage 53 through the shut valves 55a and 55b, respectively. Also, the -60°C air refrigerant refrigerator 52 is connected to the -60°C refrigeration storage 54 through the shut valve 55d. In the second embodiment, it is possible to cope with heat load of twice more than heat load when one refrigerator is connected.

[0040] Next, as shown in Fig. 6B, it is assumed that the -60°C air refrigerant refrigerator 52 is failed after start of the air refrigerant refrigerator system in the second embodiment. In this case, the main refrigerator 52 immediately stops its operation, and then, the shut valve 55d is closed. Subsequently, the shut valve 55b is closed and the shut valve 55c is opened. Thus, in place of the failed -60°C main refrigerator 52, the -30°C air refrigerant refrigerator 51 functions as a -60°C refrigerator to maintain the cooling function for the -60°C refrigeration storage 54.

[0041] On the other hand, as shown in Fig. 6C, it is assumed that the -30°C air refrigerant refrigerator 51 is failed after start of the air refrigerant refrigerator system in the second embodiment. In this case, the main refrigerator 51 immediately stops its operation. Then, the shut valve 55b is closed. Thereby, the failed -30°C main refrigerator 51 is separated from the -30°C refrigeration storage 53. Thus, in the second embodiment, by reducing the cooling function of the -30°C refrigeration storage 53 to a half, the heat load of the -30°C refrigeration storage 53 is reduced to a half, compared with the heat load before the failure of the -30°C main refrigerator 51. Nevertheless, even if no backup refrigerator is provided, the cooling function of the -30°C refrigeration storage 53 is maintained.

[0042] In the second embodiment, the main air refrigerant refrigerators 50, 51 and 52 are provided to cool the -30°C refrigeration storage 53 and the -60°C refrigeration storage 54 for different heat loads. The main air refrigerant refrigerators 50, 51 and 52 are connected to each other in parallel by the pipe section 101, and the pipe section 101 is connected to the -30°C refrigeration storage 53 and the -60°C refrigeration storage 54. In the air refrigerant refrigerator system in the second embodiment, even when any of the main air refrigerant refrigerators is failed, by changing open/close states of the shut valves as appropriate, non-failed main air refrigerant re-

frigerators are connected to the refrigeration storages. Thus, the cooling temperatures of the objects stored in the refrigeration storages can be maintained.

[0043] In the second embodiment, the air refrigerant refrigerators more than the number of refrigeration storages for different temperature ranges are provided, and the cooling temperatures in all refrigeration storages can be maintained without any specific backup air refrigerant refrigerator by changing the open/close states of the shut valves. For this reason, as in the first embodiment, the refrigeration storage can store medical samples and living bodies, or rare products absolutely requiring continuous refrigeration such as precious frozen samples. Moreover, in the second embodiment, since it is unnecessary to provide the backup air refrigerant refrigerator, manufacturing and maintenance costs of the system can be further reduced.

[Third Embodiment]

[0044] Fig. 7A is a schematic diagram showing the configuration of the air refrigerant refrigerator system according to the third embodiment of the present invention. The substantial configuration of the air refrigerant refrigerator system in the third embodiment is the same as that in the second embodiment. However, the third embodiment is different from the second embodiment in that the heat load to the -60°C refrigeration storage 54 is set to be twice more than the heat load to the -30°C refrigeration storage 53.

[0045] In the third embodiment, the -60°C air refrigerant refrigerators 51 and 52 are connected to the -60°C refrigeration storage 54 through the shut valves 55c and 55d of the pipe section 101, respectively. The -30°C air refrigerant refrigerator 50 is connected to the -30°C refrigeration storage 53 through the shut valve 55a of the pipe section 101. Furthermore, in the third embodiment, the -60°C air refrigerant refrigerator 51 is connected in parallel to the -60°C air refrigerant refrigerator 52 by the shut valve 55b of the pipe section 101.

[0046] Since the operating principle of the third embodiment is the same as that described in the second embodiment as shown in Figs. 7B and 7C, the description thereof is omitted.

[0047] In the third embodiment, like the second embodiment, the air refrigerant refrigerators more than the number of refrigeration storages 53 and 54 for different temperature ranges are provided, and the cooling temperature ranges of all the refrigeration storages 53 and 54 can be maintained without the backup air refrigerant refrigerator by changing the open/close states of the shut valves. For this reason, as in the first embodiment, the refrigeration storage can be used for storing medical samples and living bodies, or rare products absolutely requiring continuous refrigeration such as precious frozen samples. Moreover, in the third embodiment, since it is unnecessary to provide the backup air refrigerant refrigerator, manufacturing and maintenance costs of the

system can be reduced.

[Fourth Embodiment]

[0048] Fig. 8 is a schematic diagram showing the configuration of the air refrigerant refrigerator system according to the fourth embodiment of the present invention. The basic configuration in the fourth embodiment is the same as that in the second embodiment. Here, since the configurations of air refrigerant refrigerators 80 to 83 have been already described schematically with reference to Fig. 3, the description thereof is omitted. The air refrigerant refrigerators 80, 81 and 83 and the backup air refrigerant refrigerator 82 are thermally connectable to the refrigeration storages 53 and 54 through a pipe section 102. However, in the fourth embodiment, the air refrigerant refrigerators are provided with brine coolers (brine heat exchangers) 80f, 81f, 82f and 83f, respectively. Also, the pipe section includes a -30°C common brine pipe section 102-1 and a -60°C common brine pipe section 102-2. The pipe section 102 includes shut valves 80g and 80i and direction control valves 80h and 80j for the refrigerator 80, shut valves 81g and 81i and direction control valves 81h and 81j for the refrigerator 81, shut valves 82g and 82i and direction control valves 82h and 82j for the backup refrigerator 82, and shut valves 83g and 83i and direction control valves 83h and 83j for the refrigerator 83. Thus, the brine cooler 80f can be connected to a -30°C brine tank 84 through the shut valves 80g and 80i, the direction control valves 80h and 80j and the -30°C common brine pipe section 102-1. The brine cooler 81f can be connected to the -30°C brine tank 84 through the shut valves 81g and 81i, the direction control valves 81h and 81j and the -30°C common brine pipe section 102-1. The brine cooler 82f can be connected to the -30°C brine tank 84 through the shut valves 82g and 82i, the direction control valves 82h and 82j and the -30°C common brine pipe section 102-1. The brine cooler 83f can be connected to the -30°C brine tank 84 through the shut valves 83g and 83i, the direction control valves 83h and 83j and the -30°C common brine pipe section 102-1. Also, the brine cooler 80f can be connected to a -60°C brine tank 85 through the shut valves 80g and 80i, the direction control valves 80h and 80j and the -60°C common brine pipe section 102-2. The brine cooler 82f can be connected to the -60°C brine tank 85 through the shut valves 81g and 81i, the direction control valves 81h and 81j and the -60°C common brine pipe section 102-2. The brine cooler 82f can be connected to the -60°C brine tank 85 through the shut valves 82g and 82i, the direction control valves 82h and 82j and the -60°C common brine pipe section 102-2. The brine cooler 83f can be connected to the -60°C brine tank 85 through the shut valves 83g and 83i, the direction control valves 83h and 83j and the -60°C common brine pipe section 102-2. The brine in the -30°C brine tank 84 is circulated through the -30°C refrigeration storage 53 by a pump 84b. Also, the brine in the -60°C brine tank 85 is circulated through the -60°C

refrigeration storage 54 by a pump 85b.

[0049] In the fourth embodiment, the air refrigerants of the refrigerators 80 to 83 are cooled through first and second heat exchanges and adiabatic expansion and are subjected to heat exchange with a common brine by brine coolers (brine heat exchanger) 30f to 83f, respectively. In case of the -30°C common brine, the common brine cooled by the air refrigerants of the air refrigerant refrigerators 80 to 83 is filled in the -30°C brine tank 84a by a pump 84a. The brine filled in the -30°C brine tank 84a is circulated in the -30°C refrigeration storage 53 by the pump 84b to keep the inside temperature of the -30°C refrigeration storage 53. On the other hand, a -60°C common brine is cooled by the brine coolers (brine heat exchanger) 80f to 83f and filled in the -60°C brine tank 85 by a pump 85a. Then, the brine filled in the -60°C brine tank 85 is circulated in the -60°C refrigeration storage by the pump 85b to keep the inside temperature of the refrigeration storage 54.

[0050] The operation principle of the air refrigerant refrigerator system in the fourth embodiment is basically the same as that of the second embodiment. Here, the substantial operation principle when the backup air refrigerant refrigerator 82 is provided in the fourth embodiment, will be described. In Figs. 9A to 9C, a black valve indicates a closed state and a white valve indicates an opened state.

[0051] As shown in Fig. 9A, in case of a normal operation mode in the fourth embodiment, the shut valves 82g and 82i are closed and the other shut valves are opened. Thus, the backup air refrigerant refrigerator 82 is separated from each of the -30°C refrigeration storage 53 and the -60°C refrigeration storage 54. The directional control valves 80h and 80j, 81h and 81j, and 82h and 82j are controlled for the brine coolers 80f and 81f to be connected to the -30°C common brine pipe section 102-1. Also, the directional control valves 83h and 83j are controlled for the brine cooler 83f to be connected to the -60°C common brine pipe section 102-2. In the fourth embodiment, in the normal operation mode, by connecting the two -30°C air refrigerant refrigerators 80 and 81 to the -30°C refrigeration storage 53, it is possible to cope with heat load twice more than heat load when one refrigerator is connected.

[0052] Next, as shown in Fig. 9B, it is assumed that the -30°C air refrigerant refrigerator 81 is failed after start of the air refrigerant refrigerator system in the present embodiment. In this case, the main refrigerator 80 immediately stops its operation, and the directional control valves 81g and 81i are closed. Thus, the -30°C air refrigerant refrigerator 81 is separated from the refrigeration storages 53 and 54. Subsequently, the backup air refrigerant refrigerator 82 is started, and then, the shut valves 82g and 82i are opened. Thus, in place of the failed -30°C main refrigerator 81, the backup air refrigerant refrigerator 82 functions as a -30°C refrigerator. At this time, the cooling function for the -30°C refrigeration storage 53 is maintained as twice, compared with a case where one

air refrigerant refrigerator having normal heat load is connected.

[0053] On the other hand, as shown in Fig. 9C, it is assumed that the -60°C main refrigerator 83 is failed after the start of the air refrigerant refrigerator system in the fourth embodiment. In this case, the main refrigerator 83 immediately stops its operation, and then, the shut valves 83g and 83i are closed. Thus, the failed -60°C air refrigerant main refrigerator 83 is substantially separated from the -60°C refrigeration storage 54. Subsequently, the backup air refrigerant refrigerator 82 is started. Then, the shut valves 82g and 82i are opened and the directional control valves 82h and 82j are controlled for the refrigerator 82 to be connected to the storage 54. Thus, in place of the failed -60°C main refrigerator 83, the backup air refrigerant refrigerator 82 functions as a -60°C refrigerator to maintain the cooling function for the -60°C refrigeration storage 54.

[0054] In the fourth embodiment, by use of the common brine pipe sections 102-1 and 102-2, and changing connections to the refrigeration storages 53 and 54 through control of the shut valves and directional control valves, the backup air refrigerant refrigerator 82 can be used under the same heat load condition, even when any of the refrigerators is failed.

[0055] In the above description, although the case where the backup refrigerator is provided is described, in the fourth embodiment, like the second embodiment, even when the backup air refrigerant refrigerator 82 is not provided, the cooling temperatures of the refrigeration storages can be maintained by changing the cooling function of the refrigerator 83 to the refrigeration storages as appropriate.

[0056] In the fourth embodiment, when the air refrigerant refrigerators more than the number of refrigeration storages of different cooling temperatures are provided, including the backup air refrigerant refrigerator, since the common brine pipe sections are used, the cooling temperatures of all of the refrigeration storages can be maintained by controlling the directional control valves installed in the pipe sections as appropriate, even if a device for separating the brines depending on the temperature range is not provided. For this reason, the refrigeration storage can store medical samples and living bodies, or rare products absolutely requiring continuous refrigeration such as precious frozen samples. Furthermore, in the present embodiment, since the number of the air refrigerant refrigerators as components of the system is limited to minimum, manufacturing and maintenance costs of the system can be reduced.

[Fifth Embodiment]

[0057] Fig. 10 shows schematic configuration of the air refrigerant refrigerator system according to the fifth embodiment of the present invention. The basic configuration in the fifth embodiment is the same as that in the fourth embodiment. However, in the fifth embodiment,

different brines (cold fluid) are used for cooling the -30°C refrigeration storage 53 and the -60°C refrigeration storage 54. For this purpose, each of the air refrigerant refrigerators 80 to 83 in the present embodiment have a -30°C brine cooler (brine heat exchanger) 80m, 81m, 82m or 83m for carrying out heat exchange with the -30°C brine and a -60°C brine cooler (brine heat exchanger) 80n, 81n, 82n or 83n for carrying out heat exchange with the -60°C brine, in place of the brine coolers (brine heat exchangers) 80f to 83f in the fourth embodiment. Also, the -30°C brine cooler 80m, 81m, 82m or 83m and the -60°C brine cooler 80n, 81n, 82n or 83n are connected in parallel between two directional control valves 80k and 80l, 81k and 81l, 82k and 82l, or 83k and 83l. The pipe section 102 includes a -30°C common brine pipe section 102-1 and a -60°C common brine pipe section 102-2. The pipe section 102 includes shut valves 80o, 80p, 80q and 80r for the refrigerator 80, shut valves 81o, 81p, 81q and 81r for the refrigerator 81, shut valves 82o, 82p, 82q and 82r for the backup refrigerator 82, and shut valves 83o, 83q and 83r for the refrigerator 83. Thus, the brine cooler 80m is connected to a -30°C brine tank 84 through the shut valves 80o and 80p, and the -30°C common brine pipe section 102-1. The brine cooler 81m is connected to the -30°C brine tank 84 through the shut valves 81o and 81p, and the -30°C common brine pipe section 102-1. The brine cooler 82m is connected to the -30°C brine tank 84 through the shut valves 82o and 82p, and the -30°C common brine pipe section 102-1. The brine cooler 83m is connected to the -30°C brine tank 84 through the shut valves 83o and 83p, and the -30°C common brine pipe section 102-1. Also, the brine cooler 80n is connected to a -60°C brine tank 85 through the shut valves 80q and 80r and the -60°C common brine pipe section 102-2. The brine cooler 82n is connected to the -60°C brine tank 85 through the shut valves 81q and 81r, and the -60°C common brine pipe section 102-2. The brine cooler 82n is connected to the -60°C brine tank 85 through the shut valves 82q and 82r, and the -60°C common brine pipe section 102-2. The brine cooler 83n can be connected to the -60°C brine tank 85 through the shut valves 83q and 83r, and the -60°C common brine pipe section 102-2. The brine in the -30°C brine tank 84 is circulated through the -30°C refrigeration storage 53 by a pump 84b. Also, the brine in the -60°C brine tank 85 is circulated through the -60°C refrigeration storage 54 by a pump 85b.

[0058] In the fourth embodiment, the air refrigerants of the refrigerators 80 to 83 are cooled through first and second heat exchanges and adiabatic expansion and are subjected to heat exchange with a common brine by brine coolers (brine heat exchanger) 80m to 83m or 80n to 83n, respectively. In case of the -30°C common brine, the common brine cooled by the air refrigerants of the air refrigerant refrigerators 80 to 83 is filled in the -30°C brine tank 84a by a pump 84a. The brine filled in the -30°C brine tank 84a is circulated in the -30°C refrigeration storage 53 by the pump 84b to keep the inside temperature

of the -30°C refrigeration storage 53. On the other hand, a -60°C common brine is cooled by the brine coolers (brine heat exchanger) 80f to 83f and filled in the -60°C brine tank 85 by a pump 85a. Then, the brine filled in the -60°C brine tank 85 is circulated in the -60°C refrigeration storage by the pump 85b to keep the inside temperature of the refrigeration storage 54.

[0059] Since the operation principle in the fifth embodiment is the same as that in the fourth embodiment, the description thereof is omitted.

[0060] In the fifth embodiment, more inexpensive brine can be used for the -30°C common pipe section 102-1 by separately using the different brine for each common pipe section, compared with the fourth embodiment. Thus, purchase and maintenance costs of the brine can be reduced. Also, as in the fourth embodiment, even when one refrigerator in any cooling temperature range is failed, backup using the backup air refrigerant refrigerator 82 can be carried out under the same heat load condition by changing connection between the refrigeration storage 53 or 54 and any of air refrigerant refrigerators 80 to 83 in each temperature as appropriate through controls of the open/close states of the shut valves and the directions of the directional control valves 80k and 80l, 81k and 81l, 82k and 82l, or 83k and 83l connected to each brine cooler. Furthermore, even when the backup air refrigerant refrigerator 82 is not provided, the cooling temperature in the refrigeration storages can be maintained by changing the cooling function of the backup refrigerator 82 as appropriate.

[0061] In the fifth embodiment, the air refrigerant refrigerators 80 to 83 more than the number of the refrigeration storages of different cooling temperature ranges are provided, including the backup air refrigerant refrigerator. Also, the common brines are used for the refrigerators for every cooling temperature range, even if a device for separating the brines especially depending on the temperature range is not provided. Thus, the temperatures of the refrigeration storages can be maintained by controlling the open/close states of the shut valves and the directions of the directional control valves installed in the pipes as appropriate. For this reason, the refrigeration storage can store medical samples and living bodies, or rare products absolutely requiring continuous refrigeration such as precious frozen samples. Furthermore, in the present embodiment, since the number of the air refrigerant refrigerators as components of the system is limited to minimum, manufacturing and maintenance costs of the system can be reduced.

[Sixth Embodiment]

[0062] Fig. 11 shows the schematic configuration of the air refrigerant refrigerator system according to the sixth embodiment of the present invention. Although the basic configuration in the sixth embodiment is the same as those in the fourth and fifth embodiments. However, the sixth embodiment is different from the fifth embodi-

ment in that the brines coolers are no used. In the sixth embodiment, the cooled air refrigerants are used to directly cool the refrigeration storages 53 and 54 without using any brine as a cooling medium.

[0063] The air refrigerant refrigerator system in the sixth embodiment has the -30°C refrigeration storage 53 and the -60°C refrigeration storage 54. The -30°C air refrigerant refrigerator 80 and the -30°C air refrigerant refrigerator 81 are connected to the -30°C refrigeration storage 53 through the directional control valves 80s and 80t, and 81s and 81t, the -30°C common pipe section 102-1, and the shut valves 80u and 80v and 81u and 81v, respectively. The -60°C air refrigerant refrigerator 83 is connected to the -60°C refrigeration storage 54 through the directional control valves 83s and 83t, the -60°C common pipe section 102-2, and the shut valves 83u and 83v. Furthermore, in the sixth embodiment, the backup air refrigerant refrigerator 82 is connected to the -30°C refrigeration storage 53 or the -60°C refrigeration storage 54 through the directional control valves 82s and 82t, the -30°C common pipe section 102-1 or the -60°C common pipe section 102-2, and the shut valves 83u and 83v or 82w and 82x.

[0064] In the sixth embodiment, the air refrigerants cooled by the air refrigerant refrigerators 80 to 83 are circulated through the refrigeration storage 53 and 54 through the pipe section 102. Therefore, the refrigeration storages 53 and 54 can be cooled by transferring the cooled air refrigerant to the refrigeration storages 53 and 54. In this case, the cooled -30°C or -60°C air refrigerant may be burst directly into the refrigeration storage, or may be used for an air-to-air heat exchanger. In case of the bursting, the refrigerator is of an opened type.

[0065] It should be noted that when the refrigeration storage 53 is cooled, if the cooled object is directly cooled by the air refrigerant directly burst into the refrigeration storage, the present embodiment is effective in excellent heat efficiency. On the other hand, when the refrigeration storage 53 is cooled via the air-to-air heat exchanger, the cooled object is not directly cooled by the air refrigerant. Thus, the humidity in the refrigeration storage 53 is hard to change and it is especially effective for the cooled object which needs to hold moisture keeping humidity constant.

[0066] Similarly, the refrigeration storage 54 may be cooled by sending the cooled -60°C air refrigerant to the -60°C refrigeration storage 54 and directly bursting the air refrigerant into the refrigeration storage. Alternatively, the -60°C refrigeration storage 54 may be cooled via the air-to-air heat exchanger. Similarly, when the -60°C refrigeration storage 54 is cooled by bursting the air refrigerant thereinto, the cooled object is directly cooled, which is effective because of excellent heat efficiency. On the other hand, when the -60°C refrigeration storage 54 is cooled via the air-to-air heat exchanger, the cooled object is not directly cooled by the air refrigerant. Thus, the humidity in the -60°C refrigeration storage 54 is hard to change and it is especially effective for the cooled object

which needs to hold moisture keeping humidity constant.

[0067] Since the operation principle in the present embodiment is the same as that in the fourth and fifth embodiments, the description thereof is omitted.

[0068] In the sixth embodiment, since the brine is not used, purchase and maintenance costs of the brine can be reduced in comparison with the fourth and fifth embodiments. Furthermore, as in the fourth and fifth embodiments, even when any of the refrigerators in any temperature range is failed, backup using the backup air refrigerant refrigerator 82 can be carried out under the same heat load condition, by changing connection between the refrigeration storages 53 and -60°C refrigeration storage 54 and the air refrigerant refrigerators 80 to 83 in each cooling temperature range as appropriate through controls of the open/close states of the shut valves and the directions of the directional control valves. Also, when the backup air refrigerant refrigerator 82 is not provided, the cooling temperature of the refrigeration storage can be maintained by changing the cooling function of the cooling refrigeration storages 53 and -60°C refrigeration storage 54 as appropriate. In the sixth embodiment, although the shut valves 80u and 80v, 81u and 81v, 82u and 82v, and 83u and 83v are installed between the directional control valves 80s and 80t, 81s and 81t, 82s and 82t, and 83s and 83t, and the refrigeration storage, respectively. The shut valves may be installed between the corresponding air refrigerant refrigerator and the corresponding directional control valves. Furthermore, in the sixth embodiment, the air refrigerant refrigerators more than the number of refrigeration storages are provided, including the backup air refrigerant refrigerator. Thus, the temperatures of the refrigeration storages can be maintained by controlling the directional control valves. For this reason, the refrigeration storage can store medical samples and living bodies, or rare products absolutely requiring continuous refrigeration such as precious frozen samples. Furthermore, in the present embodiment, since the number of the air refrigerant refrigerators as components of the system is limited to minimum, manufacturing and maintenance costs of the system can be reduced.

[0069] According to the present invention, the air refrigerant refrigerator system having the backup function can be provided. Especially, according to the present invention, an air refrigerant refrigerator system having the backup function by using the requisite minimum number of refrigerators over an extremely large temperature range can be realized. Thus, it becomes possible to lower manufacturing costs of the refrigerator system and maintenance cost due to reduction in system components in number.

Claims

1. A refrigerator system comprising:

- a plurality of refrigeration storages (53, 54) respectively set to different cooling temperatures; a plurality of air refrigerant refrigerators (50-52, 80-83); and
 a pipe section (101, 102) provided between said plurality of main air refrigerant refrigerators and said plurality of refrigeration storages, wherein said pipe section comprises a valve section configured to thermally connect each of said plurality of air refrigerant refrigerators other than a specific air refrigerant refrigerator to at least one of said plurality of refrigeration storages in a normal operation mode; and to thermally connect said specific air refrigerant refrigerator to a specific one of said plurality refrigeration storages corresponding to a failed one of said plurality of air refrigerant refrigerators other than said specific air refrigerant refrigerator, in place of said failed air refrigerant refrigerator in a failure operation mode.
2. The refrigerator system according to claim 1, wherein said pipe section thermally disconnects said failed air refrigerant refrigerator from said specific refrigeration storage in the failure operation mode, and thermally connects said specific air refrigerant refrigerator to said specific refrigeration storage in the failure operation mode.
 3. The refrigerator system according to claim 1 or 2, wherein said specific air refrigerant refrigerator is thermally connected to at least one of said plurality of air refrigerant refrigerators in the normal operation mode.
 4. The refrigerator system according to any of claim 1 to 3, wherein said pipe section further comprises:

a plurality of common pipe sections provided for said cooling temperatures and connected to said plurality of refrigeration storages, respectively, and
 said valve section thermally connects each of said plurality of air refrigerant refrigerators other than said specific air refrigerant refrigerator to one of said plurality of common pipe sections.
 5. The refrigerator system according to claim 4, wherein said specific air refrigerant refrigerator is thermally connected to one of said plurality of common pipe sections corresponding to said failed air refrigerant refrigerator.
 6. The refrigerator system according to claim 4 or 5, wherein each of said plurality of air refrigerant refrigerators comprises a brine heat exchanger, which is connected to a specific one of said plurality of common pipe sections as a brine pipe section through
- said valve section.
7. The refrigerator system according to claim 6, wherein each of said plurality of common pipe sections is thermally connected to a brine tank which is thermally connected to one of said plurality of refrigeration storages.
 8. The refrigerator system according to claim 6 or 7, wherein said brine heat exchanger in each of said plurality of air refrigerant refrigerators is thermally connectable to said plurality of common pipe sections other than said specific common pipe section through said valve section.
 9. The refrigerator system according to claim 4 or 5, wherein each of said plurality of air refrigerant refrigerators comprises a plurality of brine heat exchangers, which are connected to said plurality of common pipe sections through said valve section, respectively.
 10. The refrigerator system according to claim 9, wherein each of said plurality of common pipe sections is thermally connected to a brine tank which is thermally connected to one of said plurality of refrigeration storages.
 11. The refrigerator system according to claim 4, wherein a flow route of cooled refrigerant in each of said plurality of air refrigerant refrigerators is connected to said plurality of common pipe sections through said valve section, and
 each of said plurality of common pipe sections extends in one of said plurality of refrigeration storages.
 12. The refrigerator system according to any of claims 1 to 11, wherein said plurality of air refrigerant refrigerators are closed type air refrigerant refrigerators.
 13. The refrigerator system according to any of claims 1 to 11, wherein at least one of said plurality of air refrigerant refrigerators is an opened type air refrigerant refrigerator.
 14. A method of cooling a plurality of refrigeration storages respectively set to different cooling temperatures, comprising:

generating cooled refrigerant in each of a plurality of air refrigerant refrigerators other than a specific air refrigerant refrigerator in a normal operation mode;
 thermally connecting each of said plurality of air refrigerant refrigerators other than a specific air refrigerant refrigerator to at least one of said plurality of refrigeration storages to be cooled, through a valve section in the normal operation

mode; and
thermally connecting said specific air refrigerant
refrigerator to a specific one of said plurality re-
frigeration storages corresponding to a failed
one of said plurality of air refrigerant refrigerators 5
other than said specific air refrigerant refrigera-
tor, in place of said failed air refrigerant refrig-
erator in a failure operation mode.

- 15.** The method according to claim 14, wherein said ther- 10
mally connecting said specific air refrigerant refrig-
erator comprises:

thermally disconnecting said failed air refriger- 15
ant refrigerator from said specific refrigeration
storage in the failure operation mode; and
thermally connecting said specific air refrigerant
refrigerator to said specific refrigeration storage
in the failure operation mode.

- 16.** The method according to claim 14 or 15, further com- 20
prising:

thermally connecting said specific air refrigerant
refrigerator to at least one of said plurality of air 25
refrigerant refrigerators in the normal operation
mode.

- 17.** The method according to any of claim 14 to 16, 30
wherein each of said thermally connecting steps
comprises:

thermally connecting each of said plurality of air
refrigerant refrigerators other than said specific
air refrigerant refrigerator to one of a plurality of 35
common pipe sections, which are thermally con-
nected to said plurality of refrigeration storages.

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Fig. 1A PRIOR ART

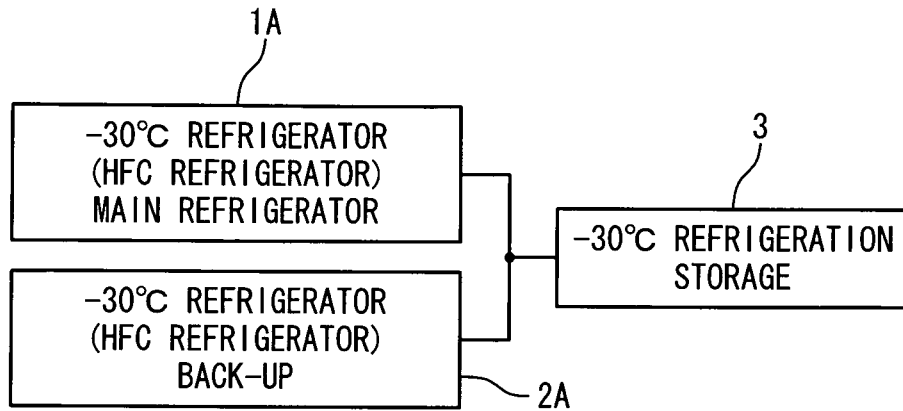


Fig. 1B PRIOR ART

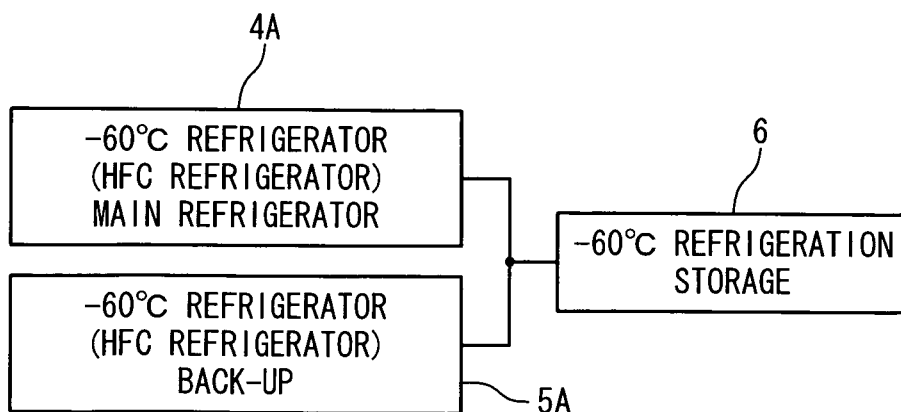


Fig. 1C PRIOR ART

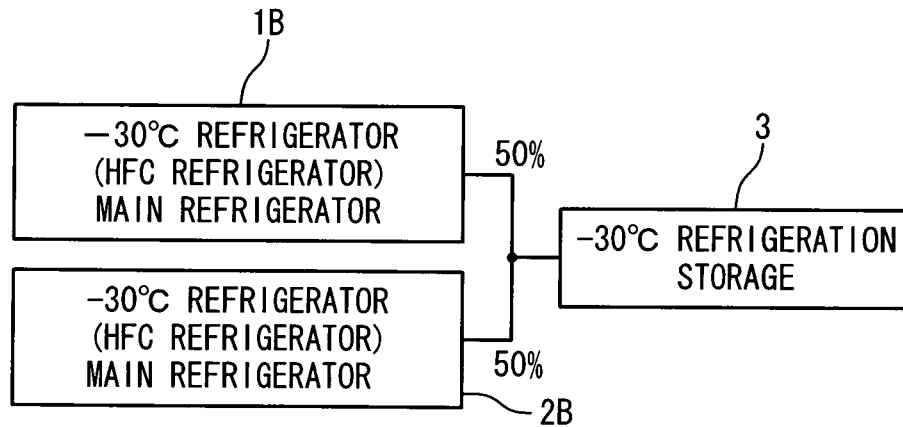
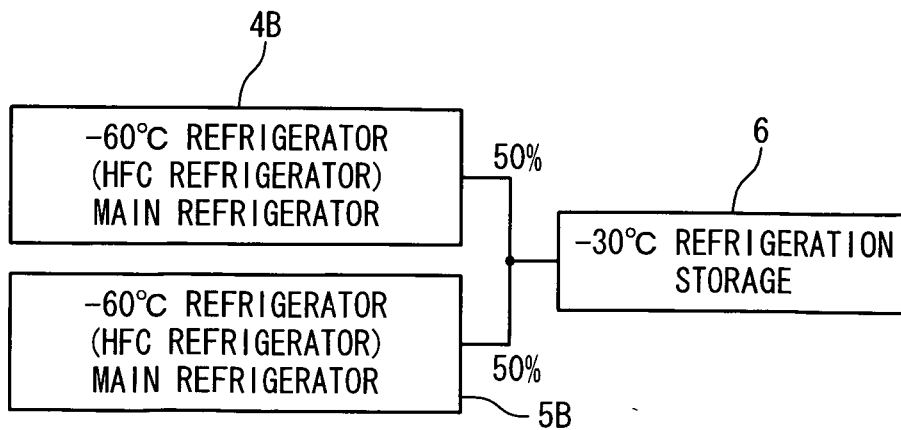


Fig. 1D PRIOR ART



F i g . 2

-60°C	R22 + R23, NH ₃ + R23, NH ₃ + ETHANE DUAL REFRIGERATOR
-55°C	
-50°C	2-STAGE COMPRESSION REFRIGERATOR OF R22 OR R404
-45°C	
-40°C	
-35°C	2-STAGE COMPRESSION REFRIGERATOR OF R22 OR NH ₃
-30°C	
-25°C	
-20°C	SINGLE STAGE COMPRESSION REFRIGERATOR OF R22 OR NH ₃

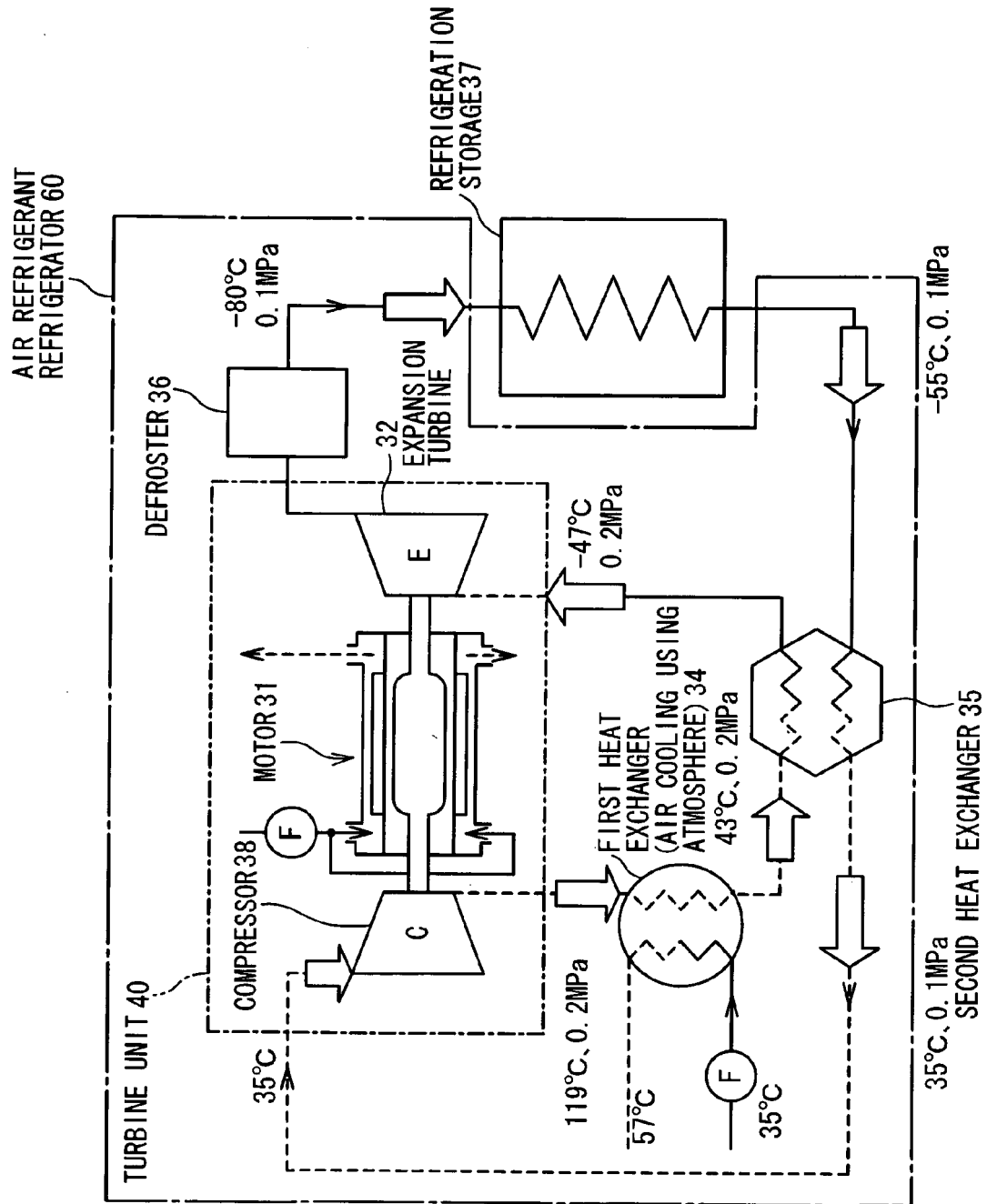


Fig. 3

Fig. 4

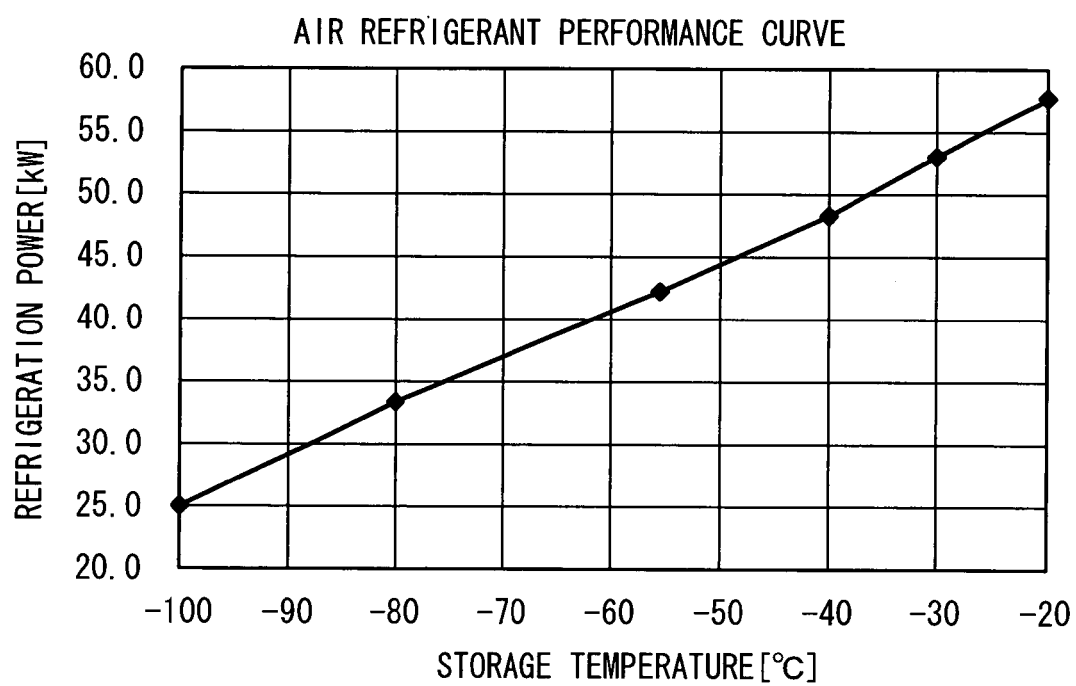


Fig. 5A

<IN CASE OF NORMAL OPERATION>

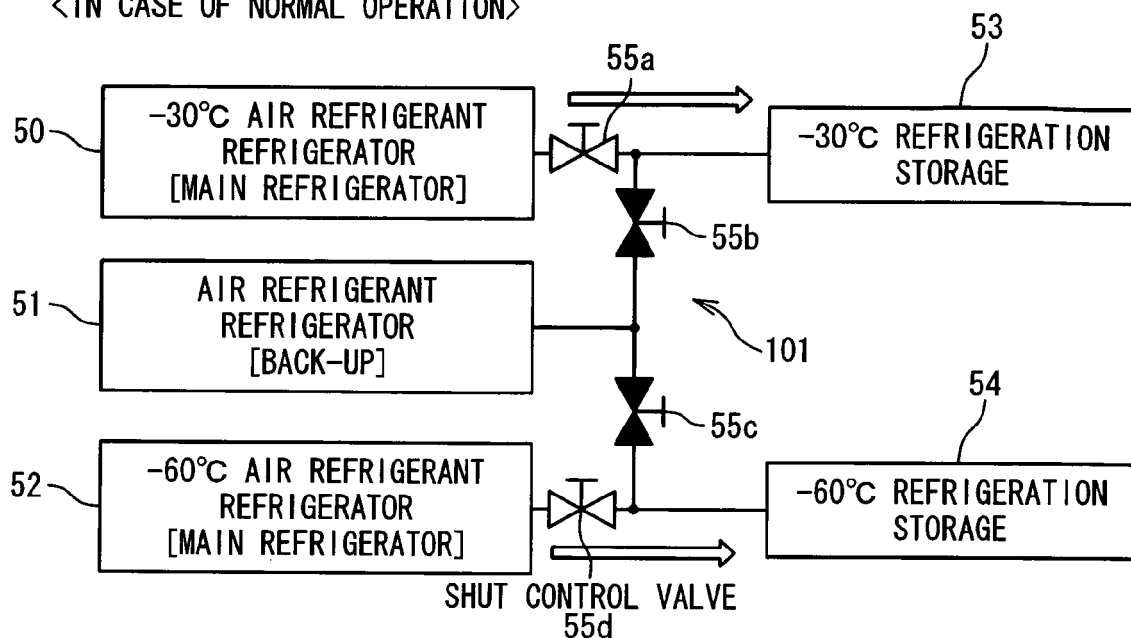


Fig. 5B

<IN CASE OF FAILURE OF -60°C REFRIGERATOR>

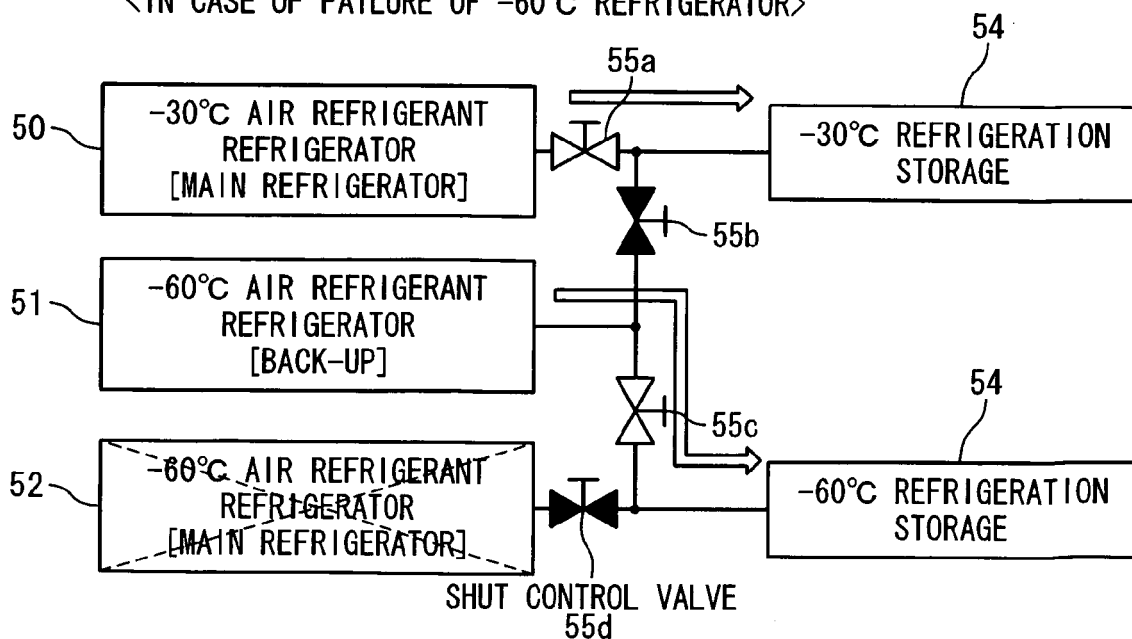


Fig. 5C

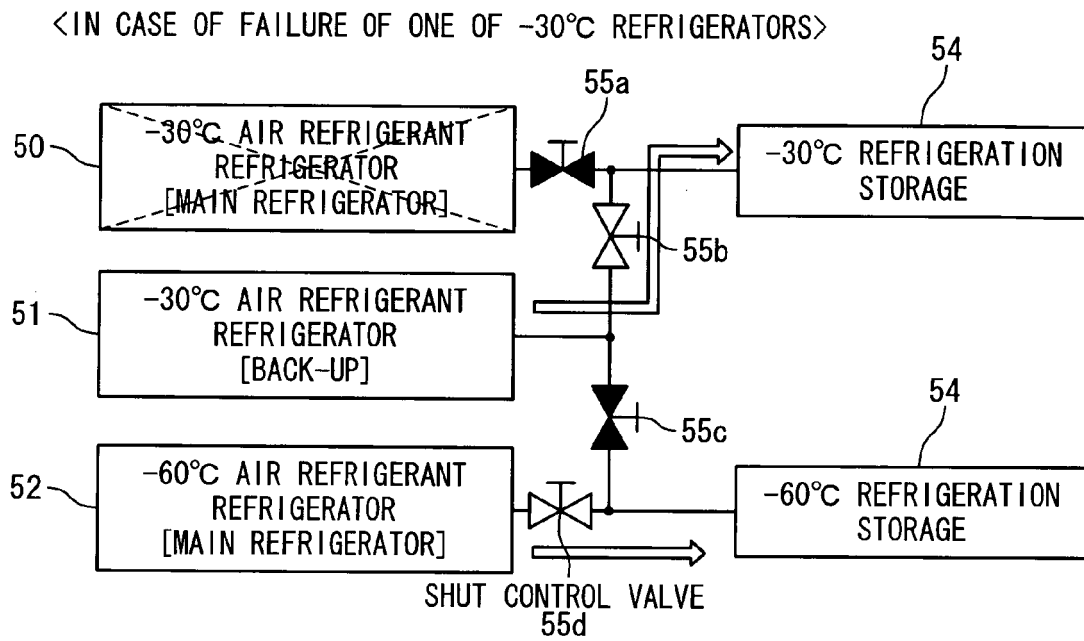


Fig. 6A

<IN CASE OF NORMAL OPERATION>

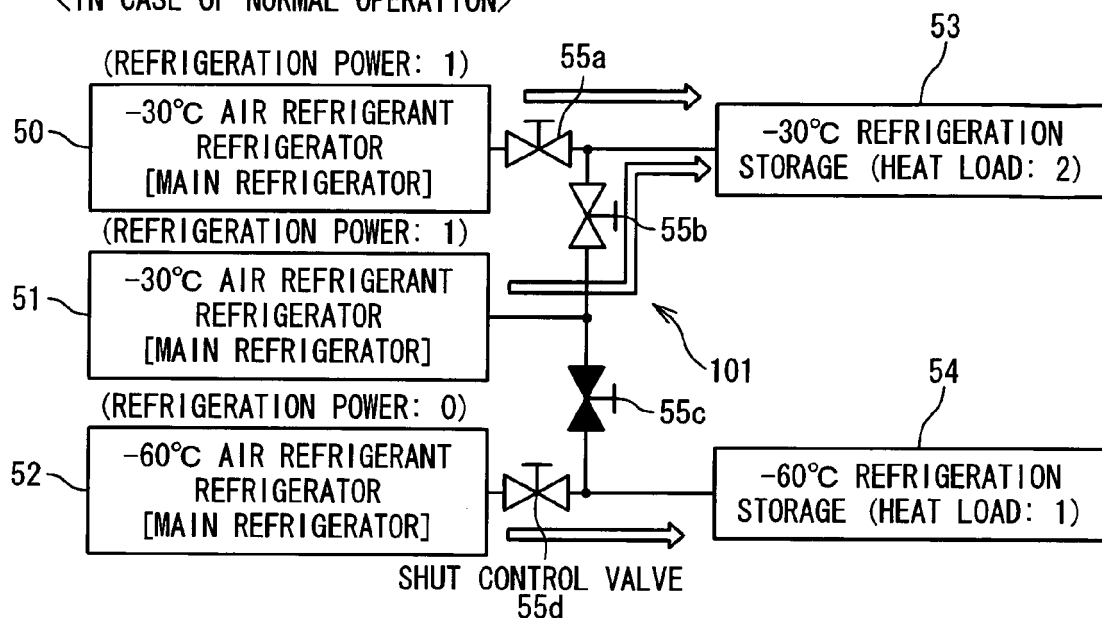


Fig. 6B

<IN CASE OF FAILURE OF -60°C REFRIGERATOR>

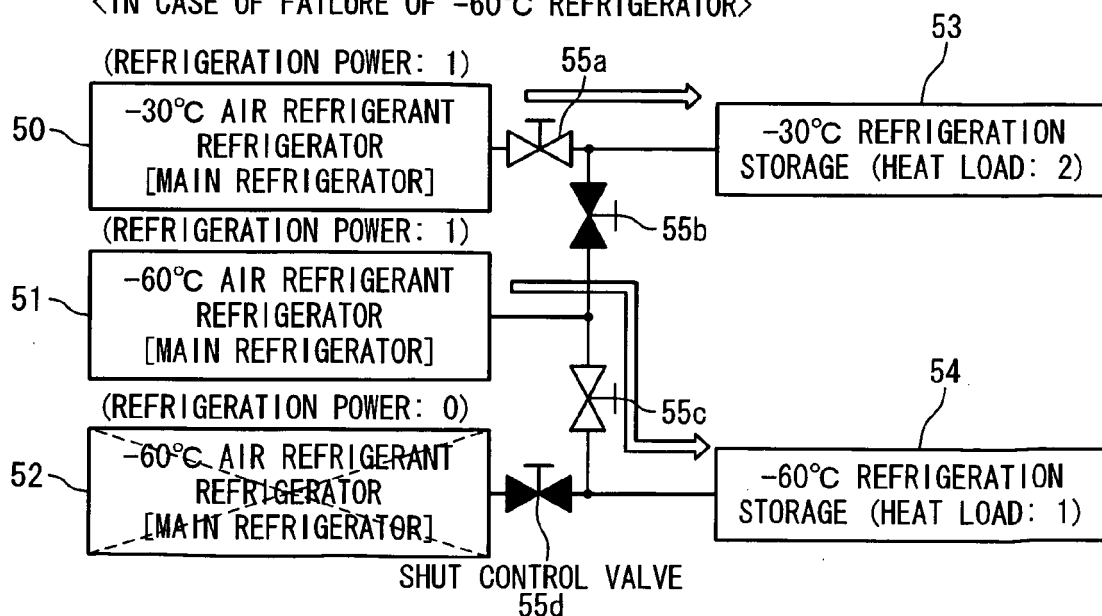


Fig. 6C

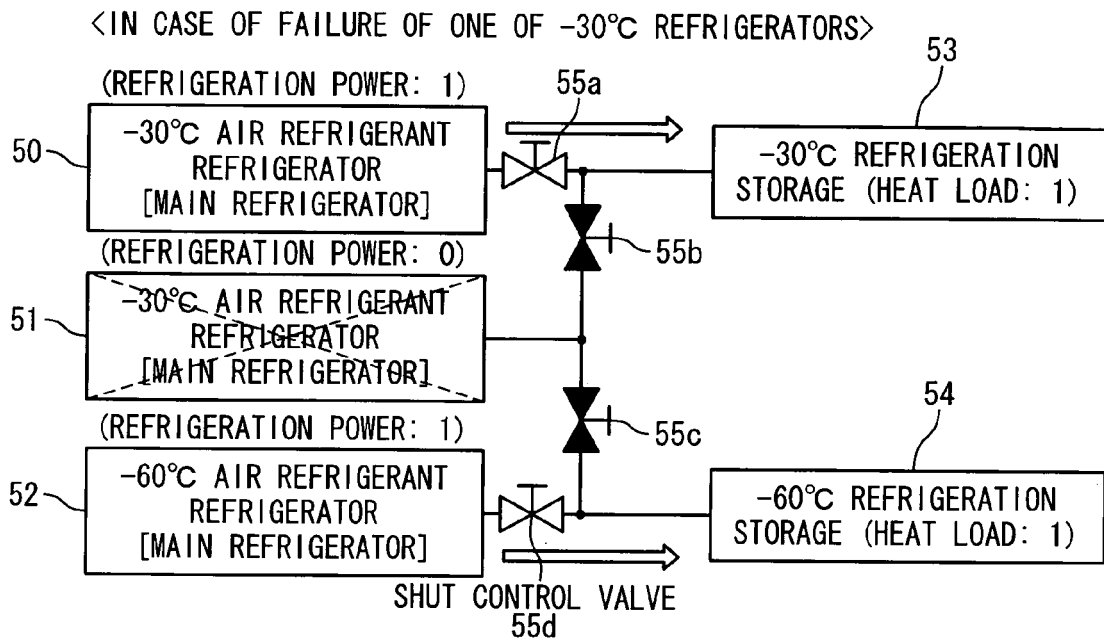


Fig. 7A

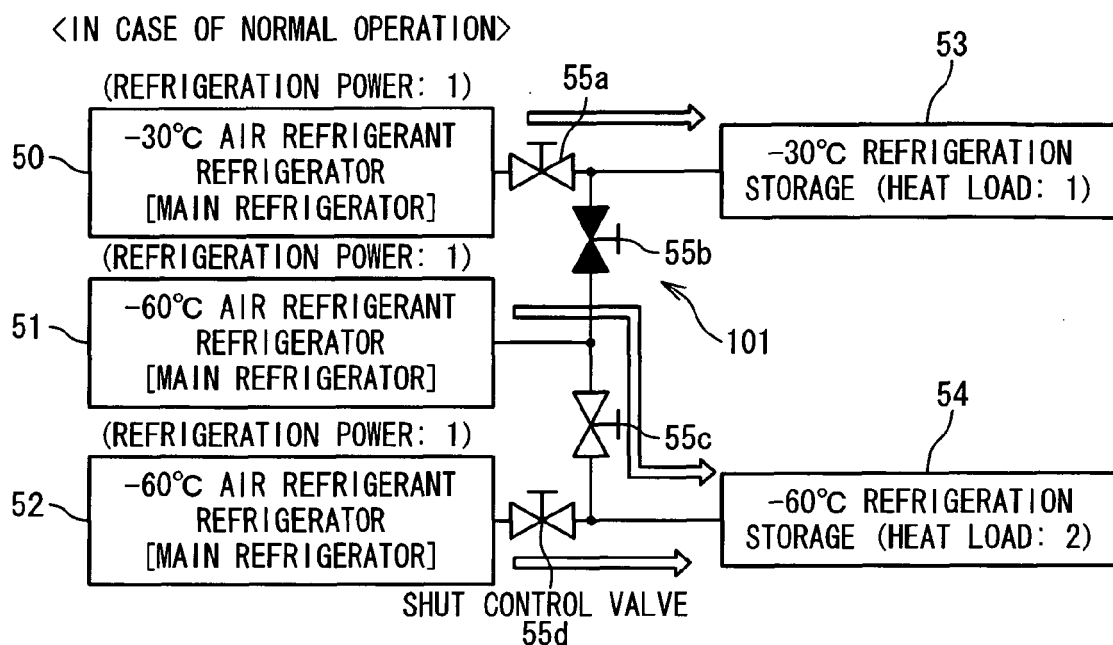


Fig. 7B

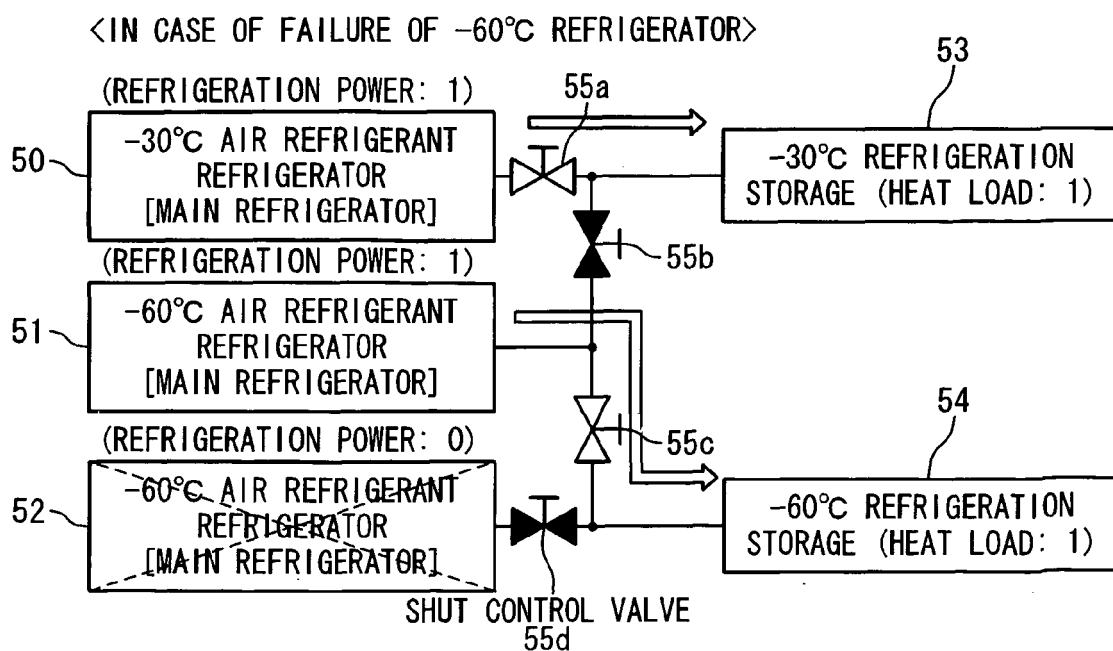


Fig. 7C

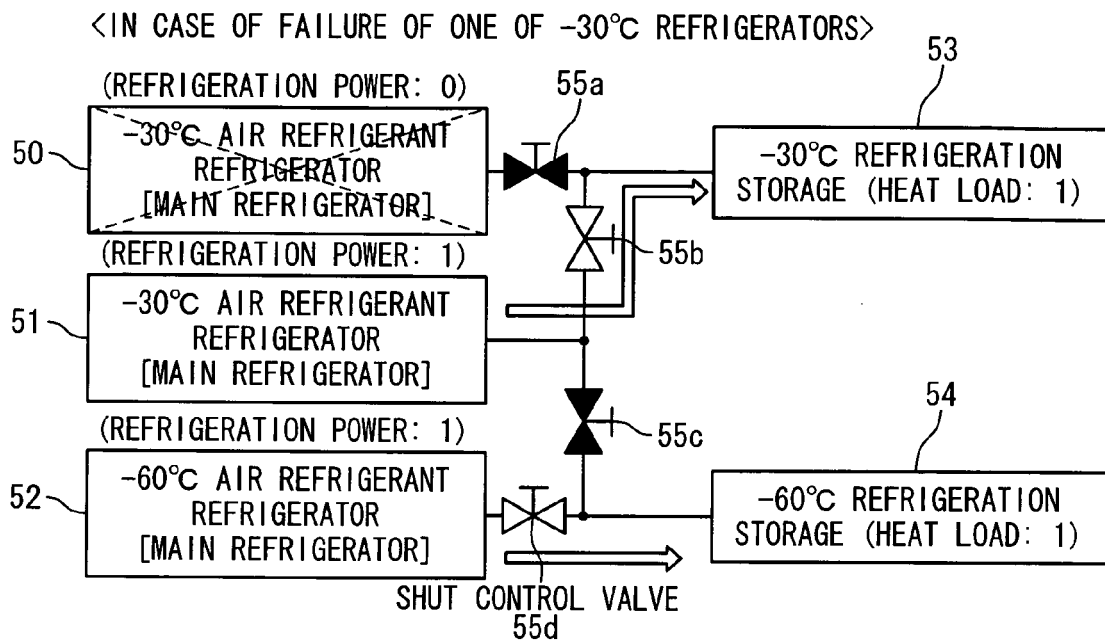


Fig. 8

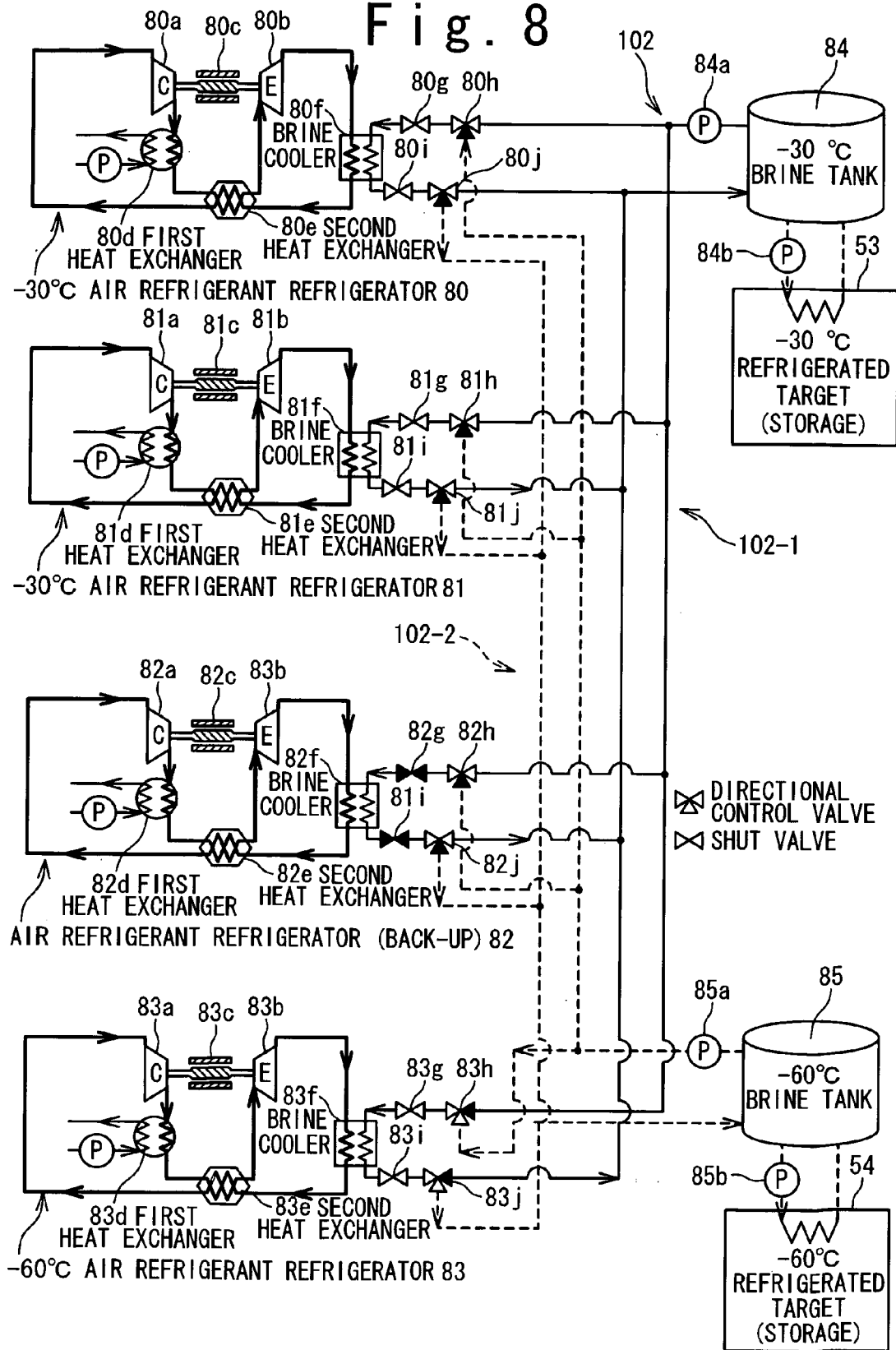


Fig. 9A

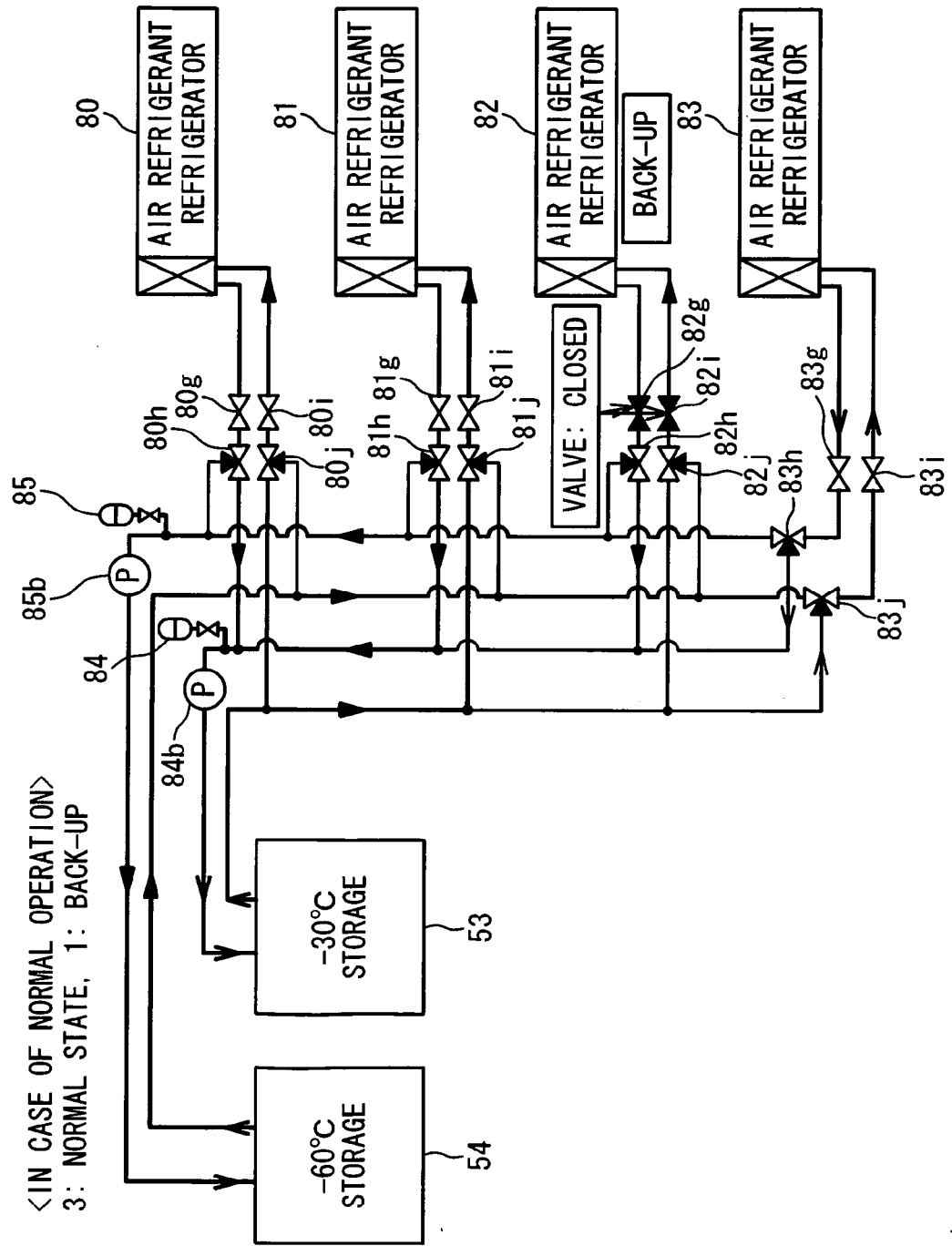
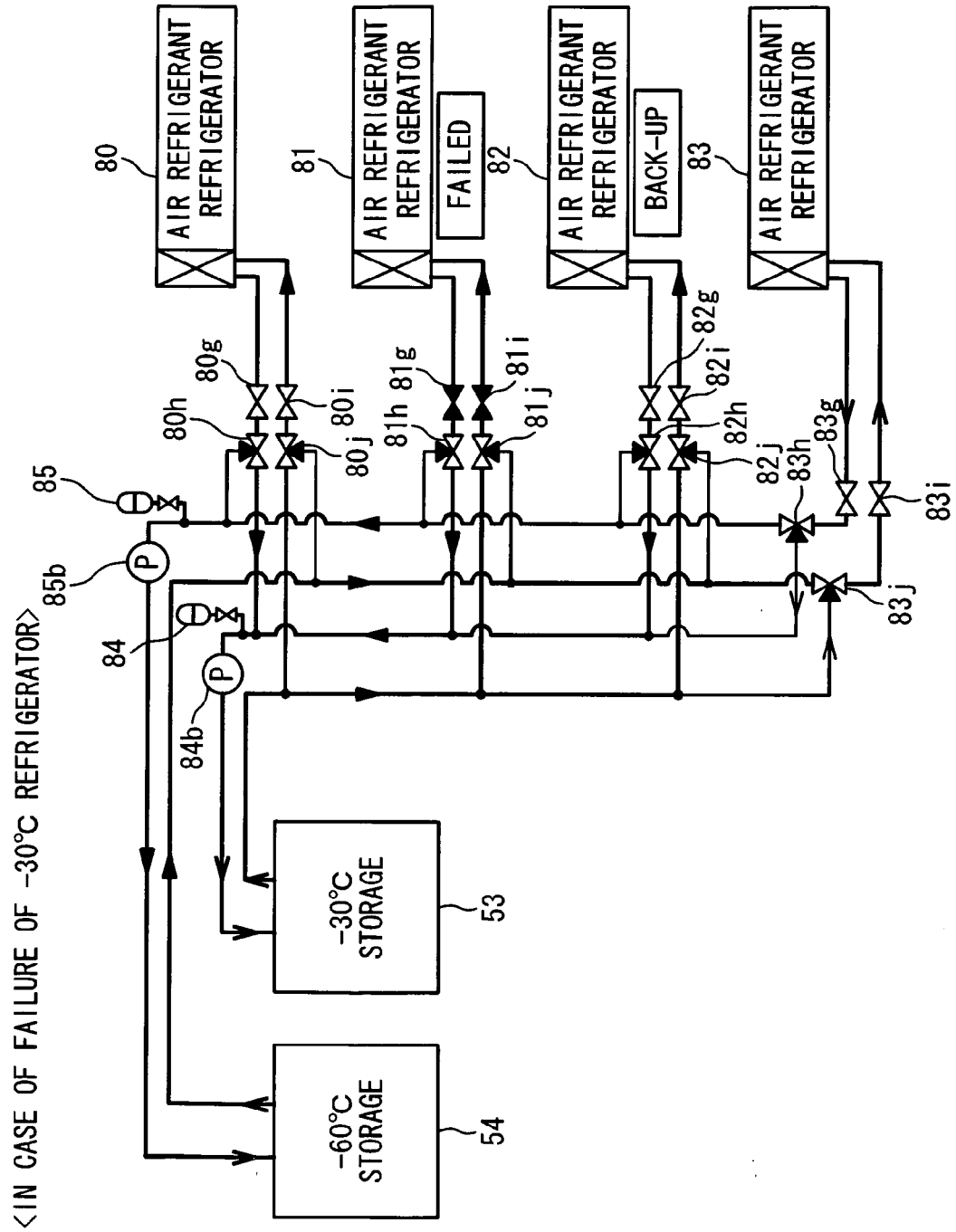


Fig. 9B



IN CASE OF FAILURE OF -60°C REFRIGERATOR>

Fig. 9C

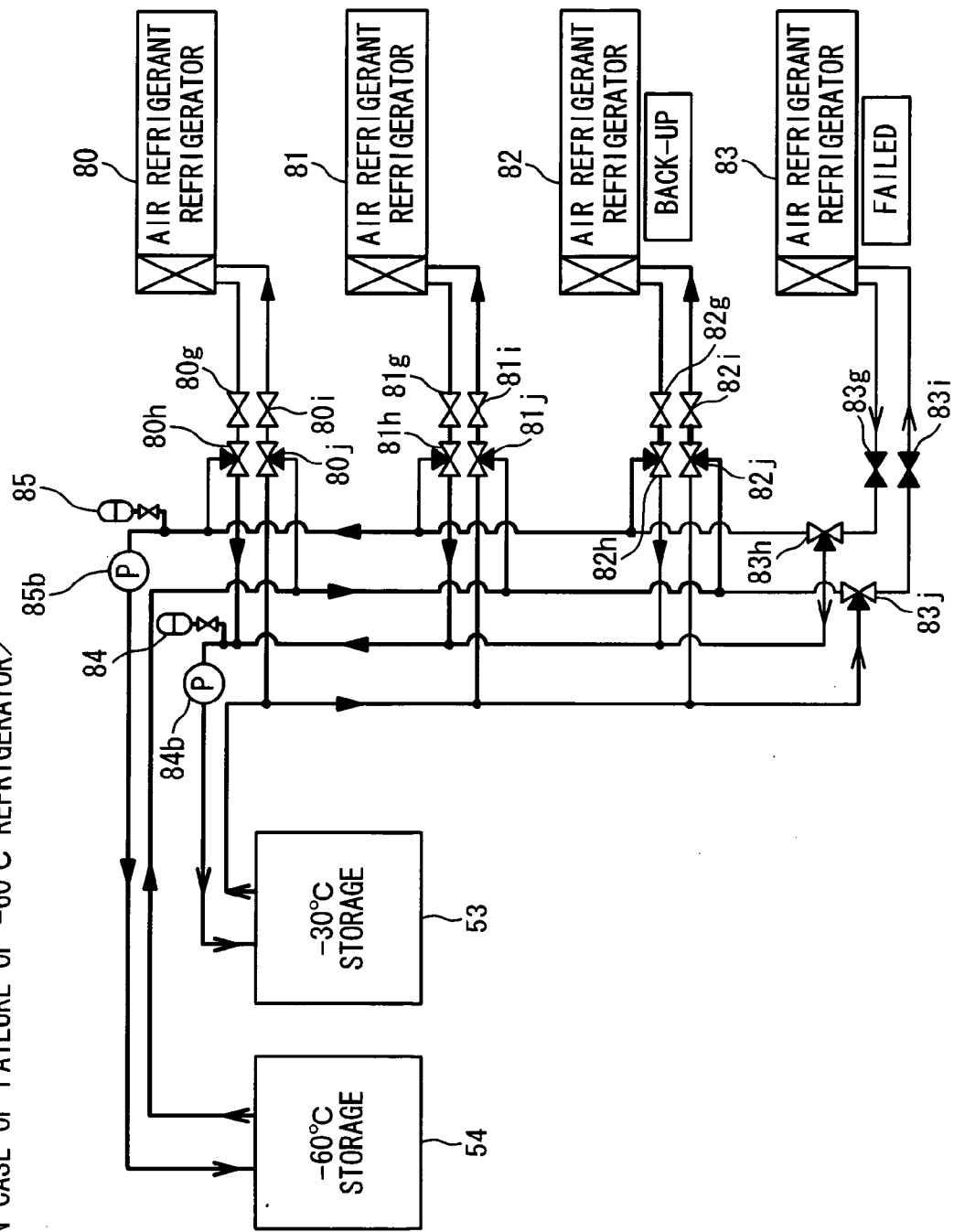


Fig. 10

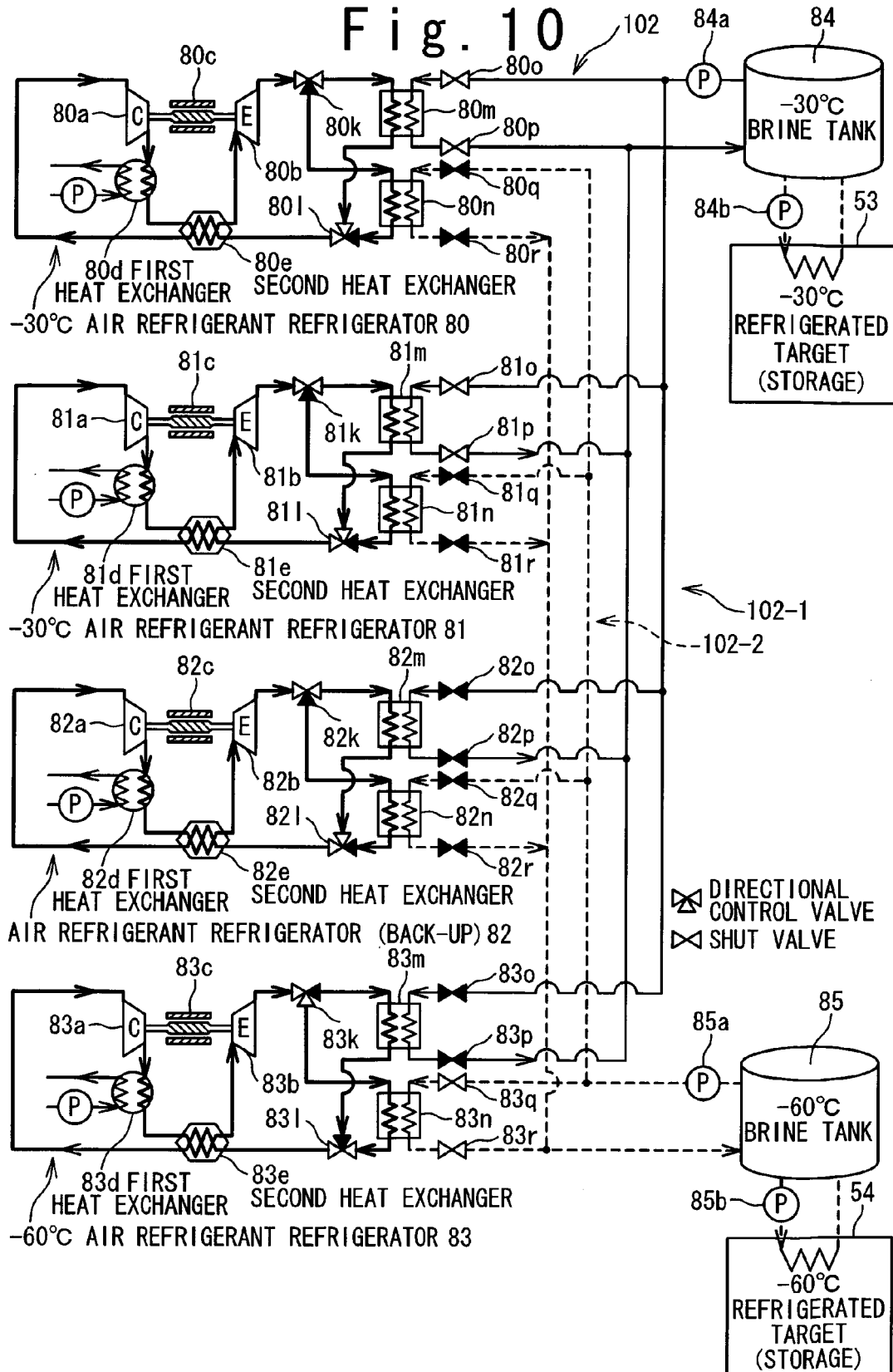
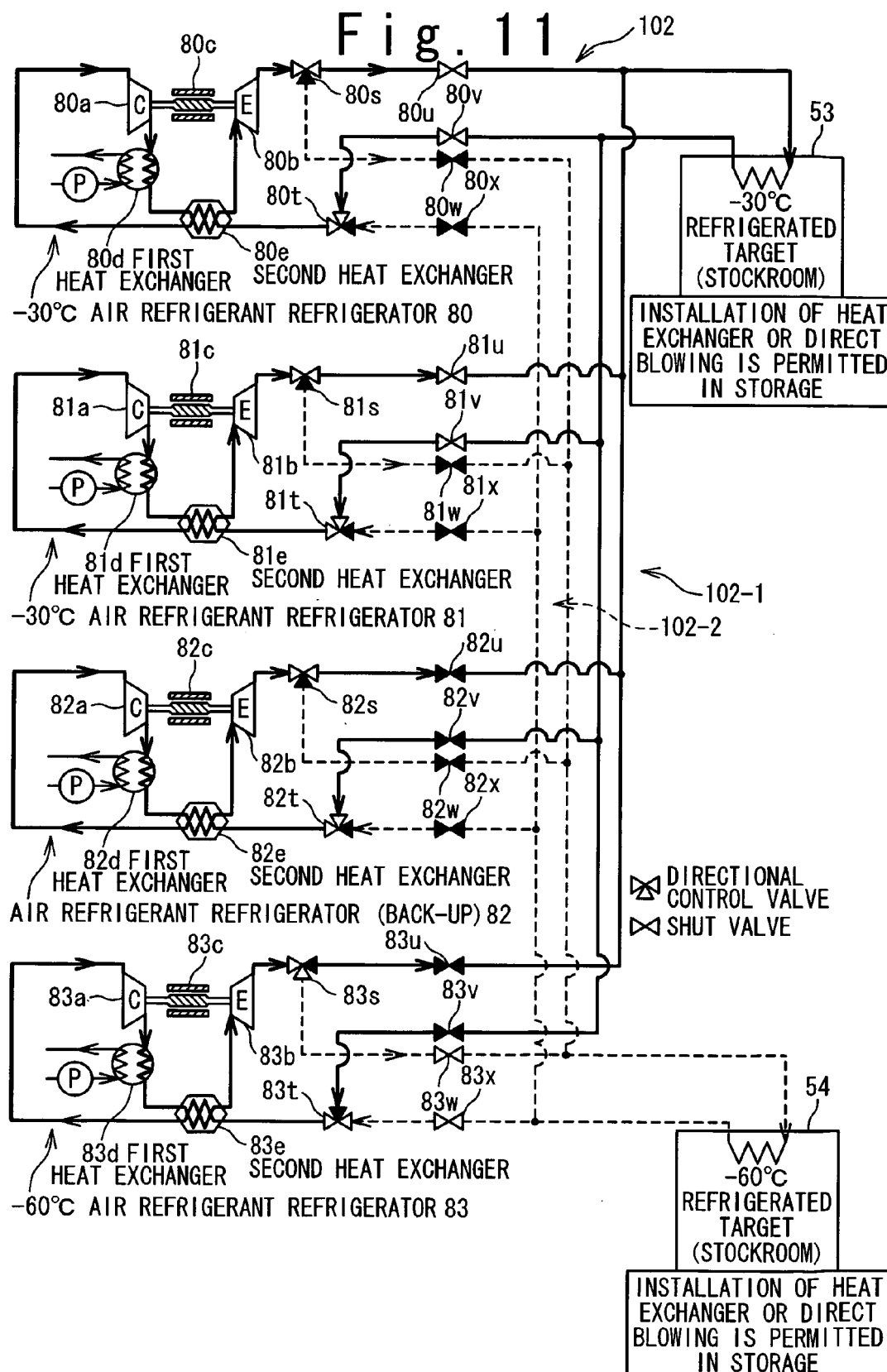


Fig. 11



REFERENCES CITED IN THE DESCRIPTION

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