



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
24.11.2021 Bulletin 2021/47

(51) Int Cl.:
F25B 1/00 (2006.01) F25B 31/00 (2006.01)

(21) Application number: **21185466.6**

(22) Date of filing: **21.12.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(72) Inventor: **ITO, Masahiro**
Tokyo, 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner mbB**
Patent- und Rechtsanwälte
Theresienhöhe 11a
80339 München (DE)

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
16924560.2 / 3 561 410

(71) Applicant: **mitsubishi electric corporation**
Chiyoda-ku
Tokyo 100-8310 (JP)

Remarks:

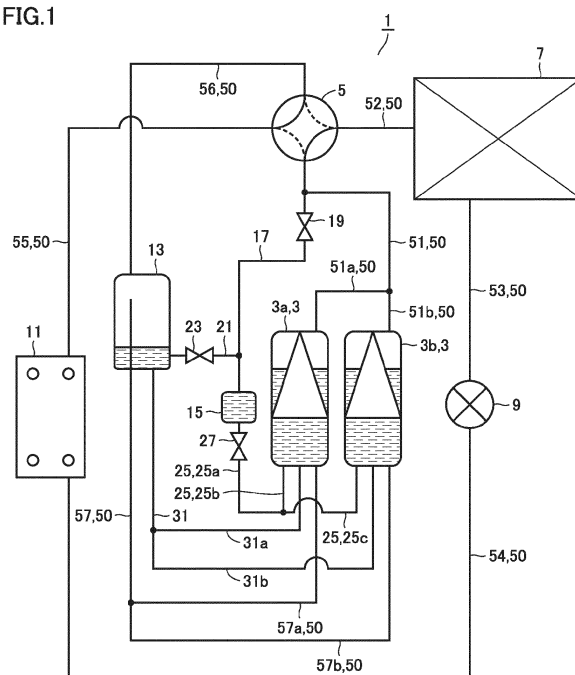
This application was filed on 14-07-2021 as a divisional application to the application mentioned under INID code 62.

(54) **REFRIGERATION CYCLE APPARATUS**

(57) A refrigeration cycle apparatus (1) includes a compressor group (3), a four-way valve (5), a first heat exchanger (7), an expansion valve (9), a second heat exchanger (11), an accumulator (13), and an oil storage (15). The oil storage (15) is connected to the discharge side of the compressor group (3) via a discharge gas

bypass pipe (17) provided with a first solenoid valve (19). The oil storage (15) is connected to the accumulator (13) via a first oil bypass piping (21) provided with a second solenoid valve (23). The oil storage (15) is connected to the compressor group (3) via a second oil bypass pipe (25) provided with a third solenoid valve (27).

FIG.1



Description

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration cycle apparatus, and more particularly to a refrigeration cycle apparatus including a compressor group in which a plurality of compressors are connected in parallel.

BACKGROUND ART

[0002] Conventionally, a refrigeration cycle apparatus is provided with a refrigerant circuit in which refrigerant is circulated by a plurality of compressors. In such a refrigeration cycle apparatus, when the refrigerant is being circulated in the refrigerant circuit, the amount of oil in one compressor and the amount of oil in another compressor may become unequal. For example, when the amount of oil is insufficient in one compressor, the compressor may suffer from galling.

[0003] In order to prevent the problem from occurring, it is known to utilize the difference between the oil level of one compressor and the oil level of another compressor to supply the oil in one compressor with more oil to another compressor with less oil so as to equalize the amount of oil in each compressor. PTL 1 discloses such a refrigeration cycle apparatus.

CITATION LIST

PATENT LITERATURE

[0004] PTL 1: Japanese Patent Laying-Open No. 2007-139215 (Japanese Patent No. 4130676)

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] In a refrigeration cycle apparatus, when a refrigerator is in a transient operation, for example, when the refrigerator is started or restarted after defrosting, the refrigerant may not be sufficiently gasified, and thereby, the refrigerant containing liquid state refrigerant (liquid refrigerant) may be sucked into the compressor. This phenomenon is called a liquid back.

[0006] Suppose that a liquid back has occurred in one compressor. Thus, the liquid refrigerant is fed into the one compressor together with oil, the actual amount of oil in the compressor is reduced, which lowers the concentration of the oil. When the oil level of the one compressor is substantially the same as the oil level of the other compressors, despite that the one compressor has a lower oil concentration, and no oil will be supplied from the other compressors, the one compressor may suffer from galling.

[0007] The present invention has been made to solve the above problem, and an object thereof is to provide a

refrigeration cycle apparatus capable of preventing a compressor from suffering from galling even when a liquid back occurs.

5 SOLUTION TO PROBLEM

[0008] The refrigeration cycle apparatus according to the present invention is provided with a refrigerant circuit which is formed by connecting a compressor group in which a plurality of compressors including a first compressor and a second compressor are connected in parallel, a four-way valve, a condenser, an expansion valve, an evaporator, and an accumulator via a refrigerant pipe, and further includes an oil storage. The oil storage is connected to the discharge side of the compressor group via a first on-off valve, connected to the accumulator via a second on-off valve, and connected to the suction side of the compressor group via a third on-off valve.

20 ADVANTAGEOUS EFFECTS OF INVENTION

[0009] According to the refrigeration cycle apparatus of the present invention, when a liquid back occurs, the oil stored in the oil storage is fed to the compressor group, which makes it possible to prevent the compressor group from suffering from galling.

BRIEF DESCRIPTION OF DRAWINGS

30 **[0010]**

Fig. 1 is a diagram illustrating a structure including a refrigerant circuit of a refrigeration cycle apparatus including a compressor group according to an embodiment;

Fig. 2 is a diagram for explaining a position relationship of an accumulator, an oil storage, and a compressor group in the refrigeration cycle apparatus according to an embodiment;

Fig. 3 is a diagram for explaining the flow of refrigerant when the refrigeration cycle apparatus according to an embodiment is performing a cooling operation;

Fig. 4 is a diagram for explaining the flow of refrigerant when the refrigerating cycle apparatus according to an embodiment is performing a heating operation;

Fig. 5 is a flowchart illustrating the normal operation of the refrigeration cycle apparatus according to an embodiment;

Fig. 6 is a flowchart illustrating the operations of the refrigeration cycle apparatus according to an embodiment when a liquid back occurs;

Fig. 7 is a diagram illustrating a configuration of a refrigeration cycle apparatus according to a comparative example;

Fig. 8 is a first diagram for explaining the operations of the refrigeration cycle apparatus according to the

comparative example;

Fig. 9 is a second diagram for explaining the operations of the refrigeration cycle apparatus according to the comparative example;

Fig. 10 is a first diagram for explaining the operations of the refrigeration cycle apparatus according to an embodiment when a liquid back occurs;

Fig. 11 is a second diagram for explaining the operations of the refrigeration cycle apparatus according to an embodiment when a liquid back occurs;

Fig. 12 is a first diagram for explaining an operation for fully filling an oil storage in the refrigeration cycle apparatus according to an embodiment with oil;

Fig. 13 is a second diagram for explaining an operation for fully filling an oil storage in the refrigeration cycle apparatus according to an embodiment with oil;

Fig. 14 is a first diagram for explaining an oil equalizing operation for equalizing the amount of oil in the compressor group of the refrigeration cycle apparatus according to an embodiment;

Fig. 15 is a second diagram for explaining an oil equalizing operation for equalizing the amount of oil in the compressor group of the refrigeration cycle apparatus according to an embodiment; and

Fig. 16 is a diagram illustrating a partial structure of a refrigeration cycle apparatus according to a modification of an embodiment.

DESCRIPTION OF EMBODIMENTS

[0011] A refrigeration cycle apparatus according to an embodiment will be described. First, the basic components of the refrigeration cycle apparatus will be described. As illustrated in Fig. 1, the refrigeration cycle apparatus 1 includes a compressor group 3, a four-way valve 5, a first heat exchanger 7, an expansion valve 9, a second heat exchanger 11, and an accumulator 13 as the basic components. In the refrigeration cycle apparatus 1, the second heat exchanger 11 is a water heat exchanger.

[0012] The compressor group 3, the four-way valve 5, the first heat exchanger 7, the expansion valve 9, the second heat exchanger 11, and the accumulator 13 are connected in this order via a refrigerant pipe 50 to form a refrigerant circuit. The compressor group 3 is connected to the four-way valve 5 via a refrigerant pipe 51 (50). The four-way valve 5 is connected to the first heat exchanger 7 via a refrigerant pipe 52 (50). The first heat exchanger 7 is connected to the expansion valve 9 via a refrigerant pipe 53 (50).

[0013] The expansion valve 9 is connected to the second heat exchanger 11 via a refrigerant pipe 54 (50). The second heat exchanger 11 is connected to the four-way valve 5 via a refrigerant pipe 55 (50). The four-way valve 5 is connected to the accumulator 13 via a refrigerant pipe 56 (50). The accumulator 13 is connected to the compressor group 3 via a refrigerant pipe 57 (50).

[0014] The compressor group 3 includes a first com-

pressor 3a and a second compressor 3b. The first compressor 3a and the second compressor 3b are connected in parallel. The discharge side of the first compressor 3a is connected to the refrigerant pipe 51 via a refrigerant pipe 51a. The discharge side of the second compressor 3b is connected to the refrigerant pipe 51 via a refrigerant pipe 51b. The suction side of the first compressor 3a is connected to the refrigerant pipe 57 via a refrigerant pipe 57a. The suction side of the second compressor 3b is connected to the refrigerant pipe 57 via a refrigerant pipe 57b.

[0015] The refrigeration cycle apparatus 1 according to the embodiment further includes an oil storage 15 configured to supply oil stored therein to the compressor group 3 (the first compressor 3a and the second compressor 3b). The oil storage 15 is connected to the discharge side of the compressor group 3 via a discharge gas bypass pipe (first pipe) 17. One end of the discharge gas bypass pipe 17 is connected to the refrigerant pipe 51 as if it is branched from the refrigerant pipe 51. The other end of the discharge gas bypass pipe 17 is connected to an upper end of the oil storage 15. The discharge gas bypass pipe 17 is provided with a first solenoid valve (first on-off valve) 19.

[0016] The oil storage 15 is connected to the accumulator 13 via a first oil bypass pipe (second pipe) 21. One end of the first oil bypass pipe 21 is connected to a side portion of the accumulator 13 close to the bottom face thereof. The other end of the first oil bypass pipe 21 is connected to the upper end of the oil storage 15. The first oil bypass pipe 21 is provided with a second solenoid valve (second on-off valve) 23.

[0017] The oil storage 15 is connected to the compressor group 3 (the first compressor 3a and the second compressor 3b) via a second oil bypass pipe (third pipe) 25. The second oil bypass pipe 25 includes a main pipe 25a, and a first branch pipe 25b and a second branch pipe 25c which are branched from the main pipe 25a.

[0018] The oil storage 15 is connected to the first compressor 3a via the main pipe 25a and the first branch pipe 25b. The first branch pipe 25b is connected to a lower end of the first compressor 3a. The oil storage 15 is connected to the second compressor 3b via the main pipe 25a and the second branch pipe 25c. The second branch pipe 25c is connected to a lower end of the second compressor 3b. The main pipe 25a is provided with a third solenoid valve 27.

[0019] Further, the accumulator 13 is connected to the compressor group 3 via a first oil pipe (fourth pipe) 31a and a second oil pipe (fourth pipe) 31b. One end of the first oil pipe 31a and one end of the second oil pipe 31b join together as one end of a common oil pipe 31 connected to a lower end of the accumulator 13. The other end of the first oil pipe 31a is connected to a lower end of the first compressor 3a. The other end of the second oil pipe 31b is connected to a lower end of the second compressor 3b.

[0020] Hereinafter, the position relationship between

the oil storage 15, the accumulator 13 and the compressor group 3 in the vertical direction (gravity direction) will be described. As illustrated in Fig. 2, the oil storage 15 is arranged relative to the compressor group 3 in such a manner that the bottom of the oil stored in the oil storage 15, in other words, the bottom surface of a space for storing oil in the oil storage 15 is located at a position with a height H1 from the bottom of the oil in the compressor group 3, in other words, the bottom surface of a space for storing oil in the compressor group 3, and the oil level of the oil maximally stored in the oil storage 15 is located at a position with a height H3 from the bottom of the oil in the compressor group 3. Meanwhile, the accumulator 13 is arranged relative to the compressor group 3 in such a manner that the bottom of the oil stored in the accumulator 13, in other words, the bottom surface of a space for storing oil in the accumulator 13 is located at a position with a height H2 from the bottom of the oil in the compressor group 3, and the height H2 is higher than the oil level of the oil maximally stored in the oil storage 15.

[0021] The position relationship of the oil storage 15, the accumulator 13 and the compressor group 3 is configured so as to facilitate an oil equalizing operation for equalizing oil in the compressor group 3, an oil returning operation for returning oil to the compressor group 3 when a liquid back occurs, and an oil filling operation for fully filling the oil storage 13 with oil when a liquid back occurs. These operations will be described later.

[0022] Hereinafter, as the normal operation of the refrigeration cycle apparatus described above, a cooling operation thereof will be described with reference to Fig. 3. In Fig. 3, the flow of the refrigerant circulated in the refrigerant circuit is indicated by the arrows. The high temperature and high pressure gas refrigerant discharged from the first compressor 3a flows through the refrigerant pipe 51a. The high temperature and high pressure gas refrigerant discharged from the second compressor 3b flows through the refrigerant pipe 51b. The refrigerant flowing through the refrigerant pipe 51a and the refrigerant flowing through the refrigerant pipe 51b join together and flow through the refrigerant pipe 51. The refrigerant flowing through the refrigerant pipe 51 is fed to the first heat exchanger 7 which functions as a condenser via the four-way valve 5 and the refrigerant pipe 52.

[0023] In the first heat exchanger 7, heat is exchanged between the refrigerant and the outside air. Due to the heat exchange, the gas refrigerant is condensed and liquefied to a high pressure liquid refrigerant. The high pressure liquid refrigerant discharged from the first heat exchanger 7 flows through the refrigerant pipe 53, and is converted by the expansion valve 9 into a two-phase refrigerant including a low pressure gas refrigerant and a liquid refrigerant. The two-phase refrigerant is fed to the second heat exchanger 11 which functions as an evaporator via the refrigerant pipe 54.

[0024] The second heat exchanger 11 is a water heat

exchanger. In the second heat exchanger 11, heat is exchanged between the refrigerant and water. Due to the heat exchange, the water is cooled, and the liquid refrigerant in the two-phase refrigerant is vaporized into a low pressure gas refrigerant. The low pressure gas refrigerant discharged from the second heat exchanger 11 is fed to the accumulator 13 via the refrigerant pipe 55, the four-way valve 5 and the refrigerant pipe 56. The oil contained in the refrigerant is separated in the accumulator 13, and the separated oil is stored in the accumulator 13.

[0025] The refrigerant separated from the oil flows through the refrigerant pipe 57 and then flows through each of the refrigerant pipe 57a and the refrigerant pipe 57b which are branched from the refrigerant pipe 57. The refrigerant flowing through the refrigerant pipe 57a is fed to the first compressor 3a where the refrigerant is compressed into a high temperature and high pressure gas refrigerant and discharged from the first compressor 3a thereafter. The refrigerant flowing through the refrigerant pipe 57b is fed to the second compressor 3b where the refrigerant is compressed into a high temperature and high pressure gas refrigerant and discharged from the second compressor 3b thereafter. This cycle is repeated subsequently.

[0026] Hereinafter, as the normal operation of the refrigeration cycle apparatus, a heating operation thereof will be described with reference to Fig. 4. In Fig. 4, the flow of the refrigerant is indicated by the arrows. The high temperature and high pressure gas refrigerant discharged from the first compressor 3a flows through the refrigerant pipe 51a, and the high temperature and high pressure gas refrigerant discharged from the second compressor 3b flows through the refrigerant pipe 51b, and then join together and flow through the refrigerant pipe 51. The refrigerant flowing through the refrigerant pipe 51 is fed to the second heat exchanger 11 (water heat exchanger) which functions as a condenser via the four-way valve 5 and the refrigerant pipe 55.

[0027] In the second heat exchanger 11, heat is exchanged between the refrigerant and water. Due to the heat exchange, the water is heated, and the high temperature and high pressure gas refrigerant is condensed and liquefied to a high pressure liquid refrigerant. The high pressure liquid refrigerant discharged from the second heat exchanger 11 flows through the refrigerant pipe 54, and is converted by the expansion valve 9 into a two-phase refrigerant including a low pressure gas refrigerant and a liquid refrigerant. The two-phase refrigerant is fed to the first heat exchanger 7 which functions as an evaporator via the refrigerant pipe 53.

[0028] In the first heat exchanger 7, heat is exchanged between the refrigerant and the outside air. Due to the heat exchange, the liquid refrigerant in the two-phase refrigerant is vaporized into a low pressure gas refrigerant. The low pressure gas refrigerant discharged from the first heat exchanger 7 is fed to the accumulator 13 via the refrigerant pipe 52, the four-way valve 5 and the refrigerant pipe 56.

[0029] The refrigerant separated from the oil in the accumulator 13 is fed to the first compressor 3a via the refrigerant pipe 57 and the refrigerant pipe 57a, and meanwhile is fed to the second compressor 3b via the refrigerant pipe 57 and the refrigerant pipe 57b. The refrigerant fed to each of the first compressor 3a and the second compressor 3b is compressed into a high temperature and high pressure gas refrigerant and discharged from each of the first compressor 3a and the second compressor 3b thereafter. This cycle is repeated subsequently.

[0030] In the refrigeration cycle apparatus 1 according to the embodiment, while the above-described normal operation is being performed, whether or not the oil storage 15 is full of oil is determined regularly in preparation for a liquid back. A flowchart of such operation will be described with reference to Fig. 5.

[0031] Firstly, in step S1, the compressor group 3 is activated. In step S2, the first solenoid valve 19, the second solenoid valve 23 and the third solenoid valve 27 are closed. In step S3, whether or not the oil storage 15 is full of oil is determined. If it is determined in step S3 that the oil storage is full of oil, the second solenoid valve 23 and the third solenoid valve 27 are kept close in step S4.

[0032] On the other hand, if it is determined in step S3 that the oil storage is not full of oil, the second solenoid valve 23 and the third solenoid valve 27 are opened so as to supply the oil stored in the accumulator 13 to the oil storage 15 until the oil storage 15 is full of oil. After the oil storage 13 is full of oil, the second solenoid valve 23 and the third solenoid valve 27 are closed in step S4.

[0033] In step S5, whether or not a command to stop the compressor group 3 is issued is determined. If it is determined that a command to stop the compressor group 3 is issued in step S5, the compressor group 3 is stopped in step S6. On the other hand, if it is determined that a command to stop the compressor group 3 is not issued in step S5, the procedure returns to step S3, the operations of steps S3 to S5 are repeated.

[0034] In the refrigeration cycle apparatus 1 according to the embodiment, while the series of operations are being performed, an operation of detecting the concentration of the oil in the compressor group 3 is performed repeatedly. A flowchart of such operation will be described with reference to Fig. 6. The operation starts from step LB1. In step LB2, if the second solenoid valve 23 is closed, then it is kept close; and if the second solenoid valve 23 is open, then the second solenoid valve 23 is closed. In step LB3, whether or not the concentration of the oil in the compressor group is equal to or greater than a reference value (first value) is determined. If it is determined that the concentration of the oil in the compressor group 3 is equal to or greater than the reference value (first value) in step LB3, the first solenoid valve 19 and the third solenoid valve 27 are kept close in step LB4.

[0035] On the other hand, when a liquid back occurs, the refrigerant containing the liquid refrigerant flows into the compressor group 3, which will lower the concentra-

tion of the oil in the compressor group 3. If it is determined that the concentration of the oil in the compressor group 3 is lower than the reference value, the first solenoid valve 19 and the third solenoid valve 27 are opened in step LB6. When the second solenoid valve 23 is closed (step LB2), if the first solenoid valve 19 and the third solenoid valve 27 are opened, the oil stored in the oil storage 15 is fed to the compressor group 3 via the second oil bypass pipe 25 by the discharge pressure of the compressor group 3.

[0036] The oil in the oil storage 15 is fed to the compressor group 3 until the concentration of the oil in the compressor group 3 becomes equal to or higher than the reference value. When the concentration of the oil in the compressor group 3 becomes equal to or higher than the reference value, the first solenoid valve 19 and the third solenoid valve 27 are closed in step LB4. The series of operations in steps LB 1 to LB5 are repeated subsequently.

[0037] The refrigeration cycle apparatus 1 described above is provided with the oil storage 15 configured to store oil for the compressor group 3, and when a liquid back occurs, the oil stored in the oil storage 15 is fed to the compressor group 3 so as to prevent the compressor group 3 from suffering from galling. The effect will be described in comparison with a refrigeration cycle apparatus according to a comparative example.

[0038] As illustrated in Fig. 7, a refrigeration cycle apparatus 101 according to a comparative example includes a compressor group 103 including a first compressor 103a and a second compressor 103b, a four-way valve 105, an outdoor heat exchanger 107, an outdoor decompressor 109a, an indoor decompressor 109b, an indoor heat exchanger 111, and an accumulator 113. The compressor group 103 and the like are connected via a refrigerant pipe 150 to form a refrigerant circuit.

[0039] The refrigeration cycle apparatus 101 according to the comparative example further includes an oil equalizing device 151 configured to equalize the oil in the compressor group 103. The oil equalizing device 151 includes a connection pipe 141, a gas-liquid separation unit 143, an oil pipe 145, and an oil pipe 147. The connection pipe 141 is connected between the compressor group 103 and the gas-liquid separation unit 143. The oil pipe 145 is connected between the gas-liquid separation unit 143 and the refrigerant pipe 150 of the refrigerant circuit. The oil pipe 147 is connected between the gas-liquid separation unit 143 and the accumulator 113.

[0040] The operation of the refrigeration cycle apparatus 101 according to the comparative example will be briefly described hereinafter. During the cooling operation, the refrigerant discharged from the compressor group 103 passes through the four-way valve 105, the outdoor heat exchanger 107, the outdoor decompressor 109a, the indoor decompressor 109b, the indoor heat exchanger 111, the four-way valve 105, and the accumulator 113 in order and flows back to the compressor group 103. This cycle is repeated subsequently.

[0041] During the heating operation, the refrigerant discharged from the compressor group 103 passes through the four-way valve 105, the indoor heat exchanger 111, the indoor decompressor 109b, the outdoor decompressor 109a, the outdoor heat exchanger 107, the four-way valve 105, and the accumulator 113 in order and flows back to the compressor group 103. This cycle is repeated subsequently.

[0042] As illustrated in Fig. 8, suppose that during the normal operation, the oil 171 in the first compressor 103a of the compressor group 103 becomes excessive, and thus, the oil level of the oil 171 in the first compressor 103a exceeds the position at which the connection pipe 141 is connected to the first compressor 103a.

[0043] In this case, the oil 171 in the first compressor 103a flows into the gas-liquid separation unit 143 via the connection pipe 141, and thereby, the gas-liquid separation unit 143 is filled with the oil 171. A part of the oil 171 in the gas-liquid separation unit 143 flows back to the first compressor 103a via the oil pipe 147, and the rest of the oil 171 in the gas-liquid separation unit 143 flows into the refrigerant pipe 150 via the oil pipe 145. Eventually, the oil 171 flowing into the refrigerant pipe 150 is fed to the compressor group 103 together with the refrigerant.

[0044] Due to the operation mentioned above, the oil 171 in the first compressor 103a with excessive oil may be gradually reduced, and similarly, the oil in a compressor (not shown) with less oil may be gradually increased. As described above, the oil equalizing operation for equalizing the amount of the oil 171 in the compressor group 103 is carried out in the refrigeration cycle apparatus 101 according to the comparative example.

[0045] Next, suppose that a liquid back occurs in the refrigeration cycle apparatus 101 according to the comparative example. In this case, since the oil and the refrigerant including the liquid refrigerant are fed to the compressor, the amount of the oil 73 with a low concentration increases in the first compressor 103 (see Fig. 9).

[0046] As illustrated in Fig. 9, suppose that the oil level of the oils 71 and 73 in the first compressor 103a becomes higher than the position at which the connection pipe 141 is connected to the compressor 103a. In this case, despite that the concentration of the oil 73 is low, since the oil level is the same as the oil level when the oil 71 is excessive, the oil 73 with a low concentration flows into the gas-liquid separation unit 143.

[0047] The low concentration oil 73 flowing into the gas-liquid separation unit 143 is fed to the compressor group 103 including the first compressor 103a via the oil pipes 145, 147 and the like. Since the oil 73 with a low concentration is fed to the first compressor 103a, the oil 71 can not be sufficiently supplied to the first compressor 103a, whereby the first compressor 103a may suffer from galling.

[0048] Compared with the refrigeration cycle apparatus 101 according to the comparative example, in the refrigeration cycle apparatus 1 according to the embod-

iment, when a liquid back occurs, the oil in the oil storage 15 is supplied to the compressor group 103. The detail thereof will be described hereinafter.

[0049] First, as described above, while the series of operations are being performed in step S1 to step S6 (see Fig. 5), the concentration of oil in the compressor group 3 is repeatedly detected (see Fig. 6). As illustrated in Fig. 10, when a liquid back occurs due to the transient operation or the like, the refrigerant containing the liquid refrigerant is fed to the accumulator 13 together with the oil. Therefore, the amount of the oil 73 with a low concentration increases in the accumulator 13.

[0050] Since the refrigerant containing the liquid refrigerant is fed to the compressor group 3 together with the oil 73, the amount of the oil 73 with a low concentration increases in the compressor group 3. At the time when the liquid back occurs, the first solenoid valve 19, the second solenoid valve 23 and the third solenoid valve 27 are all closed.

[0051] When it is detected that the concentration of the oils 71 and 73 in the compressor group 3 is lower than the reference value (step LB3), as illustrated in Fig. 11, the first solenoid valve 19 and the third solenoid valve 27 are opened with the second solenoid valve 23 being kept close (step LB6). As a result, the refrigerant discharged from the compressor group 3 flows through the discharge gas bypass pipe 17 which is branched from the refrigerant pipe 51 (and through the first solenoid valve 19).

[0052] Due to the discharge pressure of the refrigerant acting on the oil storage 15, the oil 71 stored in the oil storage 15 is fed to the compressor group 3. The oil 71 is fed to the first compressor 3a via the main pipe 25a (the third solenoid valve 27) and the first branch pipe 25b of the second oil bypass pipe 25. Similarly, the oil 71 is fed to the second compressor 3b via the main pipe 25a and the second branch pipe 25c.

[0053] This operation is repeated until the concentration of the oils 71 and 73 in the compressor group 3 reaches the reference value (step LB3). When it is detected that the concentration of the oil 71 in the compressor group 3 is equal to (or greater than) the reference value (step LB3), the first solenoid valve 19 and the third solenoid valve 27 are closed (step LB4). Thereafter, the normal operation (see Fig. 5) is performed while regularly detecting whether or not a liquid back occurs.

[0054] Thus, in the refrigeration cycle apparatus 1 according to the embodiment, the oil 71 preliminarily stored in the oil storage 15 is fed to the compressor group 3 when a liquid back occurs, which makes it possible to prevent the compressor group 3 from suffering from galling.

[0055] Hereinafter, examples of a method for detecting the concentration of the oils 71 and 73 in the compressor group 3 will be described. As an example, a method for detecting the degree of superheat (overheat) on the discharge side or the suction side of the compressor group 3 may be given. The degree of superheat refers to the difference between the temperature of superheated va-

por and the temperature of saturated dry vapor. When a liquid back occurs, the liquid refrigerant is fed to the compressor group 3, and thus, the temperature of the refrigerant discharged from the compressor group 3 will decrease, which consequently causes the degree of superheat to decrease. Therefore, a reference value for the degree of superheat may be set in advance, and if the degree of superheat becomes lower than the reference value, it is determined that the liquid back has occurred.

[0056] As another example, a method for detecting the surface temperature of a compressor in the compressor group 3 may be given. When a liquid back occurs, the liquid refrigerant is fed to the compressor group 3, which may cause the temperature of the compressor to decrease. Therefore, a reference value for the surface temperature may be set in advance, and if the surface temperature becomes lower than the reference value, it is determined that the liquid back has occurred. Furthermore, an oil sensor may be provided in the compressor group 3 to detect the concentration of oil directly. If the concentration of the detected oil is lower than a reference value set in advance for the oil concentration, it is determined that the liquid back has occurred.

[0057] In the refrigeration cycle apparatus 1 according to the embodiment, when a liquid back occurs, the oil 71 stored in the oil storage 15 is fed to the compressor group 3. Thereby, the oil storage 15 is not full of the oil 71. In the refrigeration cycle apparatus 1, it is necessary to keep the oil storage 15 full of the oil 71 in preparation for a liquid back. Hereinafter, when the oil 71 in the oil storage 15 decreases, an operation for fully filling the oil storage 15 with the oil 71 will be explained.

[0058] First, as illustrated in Fig. 12, when a liquid back occurs, the oil 71 stored in the oil storage 15 is fed to the compressor group 3, whereby the oil storage 15 is not full of the oil 71. Note that after the operation of feeding the oil 71 to the compressor group 3 is completed, the first solenoid valve 19, the second solenoid valve 23 and the third solenoid valve 27 will be closed (step LB4).

[0059] Next, as illustrated in Fig. 13, an operation of feeding the oil 71 stored in the accumulator 13 to the oil storage 15 is performed. The second solenoid valve 23 and the third solenoid valve 27 are opened with the first solenoid valve 19 being kept close. As a result, the oil 71 in the accumulator 13 is fed to the oil storage 15 via the first oil bypass pipe 21 (and the first solenoid valve 23). After the oil storage 15 is full of the oil 71, the second solenoid valve 23 and the third solenoid valve 27 are closed. In this way, the operation for fully filling the oil storage 15 with the oil 71 is completed in preparation for a liquid back.

[0060] Hereinafter, examples of a method for detecting that the oil storage 15 is full of the oil 71 will be described. First, as an example, an oil level sensor may be disposed in the oil storage 15. By detecting the oil level of the oil fed from the accumulator 13 to the oil storage 15 with the oil level sensor, it is possible to determine that the oil storage is full of oil.

[0061] In addition, the second solenoid valve 23 and the third solenoid valve 27 may be opened for a preset duration. The pressure loss from the accumulator 13 to the oil storage 15 may be estimated based on the position relationship between the accumulator 13 and the oil storage 15 and the structural configurations such as the length and the inner diameter of the first oil bypass pipe 21 and the like. Based on the pressure loss, the duration required to fully fill the oil storage 15 with oil may be calculated. By setting the duration in advance, it is possible to fully fill the oil storage 15 with oil.

[0062] Hereinafter, the equalizing operation performed during the normal operation in the refrigeration cycle apparatus 1 according to the embodiment will be described. The compressor group 3 of the refrigeration cycle apparatus 1 includes a first compressor 3a and a second compressor 3b. An induction motor for each of the first compressor 3a and the second compressor 3b is driven at a desired frequency (rotational speed) according to the operation environment. The refrigerant discharged from the compressor group 3 flows through the refrigerant pipe 50 together with the oil.

[0063] When the operation environment changes, the frequency should be changed accordingly. For example, as illustrated in Fig. 14, when the frequency suddenly drops, the amount of the oil 71 in the second compressor 3b may become less than the amount of the oil 71 in the first compressor 3a. In addition, even when there is no change in the frequency, due to the arrangement and connection of the refrigerant pipes 50 in the refrigerant circuit, the amount of the oil 71 in the first compressor 3a and the amount of the oil 71 in the second compressor 3b may become unequal.

[0064] When the amount of the oil 71 becomes unequal, the equalizing operation is performed so as to make the amount of the oil 71 in the first compressor 3a and the amount of the oil 71 in the second compressor 3b substantially equal to each other based on the difference in the oil level of the oil 71.

[0065] First, due to the difference between the oil level P3 of the oil 71 stored in the accumulator 13 and the oil level P2 of the oil 71 in the second compressor 3b, the oil 71 in the accumulator 13 is fed to the second compressor 3b via the oil pipe 31 and the second oil pipe 31b (indicated by the arrows). Similarly, due to the difference between the oil level P1 of the oil 71 in the first compressor 3a and the oil level P2 of the oil 71 in the second compressor 3b, the oil 71 in the first compressor 3a is fed to the second compressor 3b via the first oil pipe 31a and the second oil pipe 31b (indicated by the arrows).

[0066] As illustrated in Fig. 15, according to the oil equalizing operation, the amount of the oil 71 in the first compressor 3a and the amount of the oil 71 in the second compressor 3b are made substantially equal. The equalizing operation may be performed regularly during the operation of the refrigeration cycle apparatus 1.

[0067] Thus, when the above-described refrigeration cycle apparatus 1 is operating as a refrigeration cycle

apparatus, the oil equalizing operation is performed so as to make the amount of the oil 71 in the first compressor 3a and the amount of the oil 71 in the second compressor 3b of the compressor group 3 equal to each other. When a liquid back occurs, the oil 71 stored in the oil storage 15 is fed to the first compressor 3a or the second compressor 3b containing the oil 73 with a low concentration, which makes it possible to prevent the first compressor 3a or the second compressor 3b from suffering from galling. After the liquid back, the oil 71 is fed from the accumulator 13 to the oil storage 15 so as to fully fill the oil storage 15 with the oil 71 in preparation for another liquid back.

(Modification)

[0068] As illustrated in Fig. 16, in the refrigeration cycle apparatus according to the modification, specifically, a third solenoid valve 27a is provided in the first branch pipe 25b of the second oil bypass pipe 25, and a third solenoid valve 27b is provided in the second branch pipe 25c of the second oil bypass pipe 25. The other configurations are the same as those of the refrigeration cycle apparatus 1 illustrated in Fig. 1.

[0069] According to the refrigeration cycle apparatus of the modification, the third solenoid valve 27a is provided for the first compressor 3a and the third solenoid valve 27b is provided for the second compressor 3b, so that it is possible to selectively feed the oil 71 stored in the oil storage 15 to the first compressor 3a and/or the second compressor 3b containing the oil 71, 73 with a low concentration.

[0070] In the above-described refrigeration cycle apparatus 1, a compressor group in which two compressors, that is, a first compressor 3a and a second compressor 3b are connected in parallel is given as an example of the compressor group 3. However, the number of compressors in the compressor group 3 is not limited to two, it may be three or more.

[0071] Further, the refrigeration cycle apparatus described in the embodiment may be configured in various combination where necessary.

[0072] The embodiments disclosed herein are merely by way of example and not limited thereto. The scope of the present invention is defined by the terms of the claims, rather than the description above, and is intended to include any modifications within the meaning and scope equivalent to the terms of the claims.

INDUSTRIAL APPLICABILITY

[0073] The present invention is effectively used in a refrigeration cycle apparatus including a compressor group in which a plurality of compressors are connected in parallel.

[0074] The present invention further comprises the following embodiments:

EMBODIMENTS

[0075]

1. A refrigeration cycle apparatus provided with a refrigerant circuit which is formed by connecting a compressor group in which a plurality of compressors including a first compressor and a second compressor are connected in parallel, a four-way valve, a condenser, an expansion valve, an evaporator, and an accumulator via a refrigerant pipe, comprising:

an oil storage which is connected to the discharge side of the compressor group via a first on-off valve, connected to the accumulator via a second on-off valve, and connected to the suction side of the compressor group via a third on-off valve.

2. The refrigeration cycle apparatus according to embodiment 1, wherein the bottom surface of a space for storing oil in the accumulator is located at a position higher than the bottom surface of a space for storing oil in the oil storage, and the bottom surface of the space for storing oil in the oil storage is located at a position higher than the bottom surface of a space for storing oil in the compressor.

3. The refrigeration cycle apparatus according to embodiment 1 or 2, wherein when the concentration of oil in the first compressor is lower than a first value, the oil stored in the oil storage is supplied to the first compressor.

4. The refrigeration cycle apparatus according to embodiment 1 or 2, wherein when the oil in the compressor group which is a part of the total oil circulating in the refrigerant circuit together with refrigerant has a concentration lower than a first value, the second on-off valve is kept close and the first on-off valve and the third on-off valve are opened so as to allow the oil stored in the oil storage to be fed to the compressor group by a pressure on the discharge side of the compressor group.

5. The refrigeration cycle apparatus according to any one of embodiments 1 to 3, wherein when the oil storage is not full of the oil which a part of the total oil circulating in the refrigerant circuit together with refrigerant, the first on-off valve is kept close and the second on-off valve and the third on-off valve are opened so as to allow the oil in the accumulator to be fed to the oil storage until the oil storage is full of the oil.

6. The refrigeration cycle apparatus according to embodiment 1 further comprising:

a first pipe for connecting the discharge side of

the compressor group to the oil storage and provided with the first on-off valve;
 a second pipe for connecting the accumulator to the oil storage and provided with the second on-off valve; and
 a third pipe for connecting the oil storage to the compressor group and provided with the third on-off valve,
 wherein the first pipe and the second pipe are connected to an upper end of the oil storage, and the third pipe is connected to a lower end of the oil storage.

7. The refrigeration cycle apparatus according to embodiment 6, wherein
 the third pipe includes a main pipe which is connected to the oil storage, a first branch pipe which is branched from the main pipe and connected to the first compressor, and a second branch pipe which is branched from the main pipe and connected to the second compressor, and
 the third on-off valve is provided in the main pipe.

8. The refrigeration cycle apparatus according to embodiment 6, wherein
 the third pipe includes a main pipe which is connected to the oil storage, a first branch pipe which is branched from the main pipe and connected to the first compressor, and a second branch pipe which is branched from the main pipe and connected to the second compressor, and
 the third on-off valve is provided in each of the first branch pipe and the second branch pipe.

9. The refrigeration cycle apparatus according to embodiment 1, wherein when a first oil level of the oil in the first compressor which is a part of the total oil circulating in the refrigerant circuit together with refrigerant is higher than a second oil level of the oil in the second compressor which is a part of the total oil circulating in the refrigerant circuit together with refrigerant, the first on-off valve, the second on-off valve and the third on-off valve are kept close so as to allow the oil in the accumulator and the oil in the first compressor to be fed to the second compressor until the first oil level is the same as the second oil level.

10. The refrigeration cycle apparatus according to embodiment 9 further comprising a fourth pipe for connecting the accumulator to the compressor group and for connecting the first compressor and the second compressor,
 wherein the oil in the accumulator is fed to the second compressor via the fourth pipe, and
 the oil in the first compressor is fed to the second compressor via the fourth pipe.

REFERENCE SIGNS LIST

[0076] 1: refrigeration cycle apparatus; 3: compressor group; 3a: first compressor; 3b: second compressor; 5: four-way valve; 7: condenser (first heat exchanger); 9: expansion valve; 11: evaporator (second heat exchanger); 13: accumulator; 15: oil storage; 17: discharge gas bypass pipe; 19: first solenoid valve; 21: first oil bypass pipe; 23: second solenoid valve; 25: second oil bypass pipe; 25a: main pipe; 25b: first branch pipe; 25c: second branch pipe; 27, 27a, 27b: third solenoid valve; 31: oil pipe; 31a: first oil pipe; 31b: second oil pipe; 50, 51, 51a, 51b, 52, 53, 54, 55, 56, 57, 57a, 57b: refrigerant pipe; 71, 73: oil

Claims

1. A refrigeration cycle apparatus (1) provided with a refrigerant circuit which is formed by connecting a compressor group (3) in which a plurality of compressors including a first compressor (3a) and a second compressor (3b) are connected in parallel, a four-way valve (5), a condenser (7), an expansion valve (9), an evaporator (11), and an accumulator (13) via a refrigerant pipe (50), **characterized by** comprising:
 an oil storage (15) which is connected to the discharge side of the compressor group (3) via a first on-off valve (19), connected to the accumulator (13) via a second on-off valve (23), and connected to the suction side of the compressor group (3) via a third on-off valve (27), wherein when the oil in the compressor group (3) which is a part of the total oil circulating in the refrigerant circuit together with refrigerant has a concentration lower than a first value, the second on-off valve (23) is kept close and the first on-off valve and the third on-off valve (27) are opened so as to allow the oil stored in the oil storage (15) to be fed to the compressor group (3) by a pressure on the discharge side of the compressor group (3).
2. The refrigeration cycle apparatus (1) according to claim 1, wherein the bottom surface of a space for storing oil in the accumulator (13) is located at a position higher than the bottom surface of a space for storing oil in the oil storage (15), and the bottom surface of the space for storing oil in the oil storage (15) is located at a position higher than the bottom surface of a space for storing oil in the compressor group (3).
3. The refrigeration cycle apparatus (1) according to claim 1 further comprising:
 a first pipe (17) for connecting the discharge side of the compressor group (3) to the oil storage (15) and provided with the first on-off valve (19);

a second pipe (21) for connecting the accumulator (13) to the oil storage (15) and provided with the second on-off valve (23); and
 a third pipe (25) for connecting the oil storage (15) to the compressor group (3) and provided with the third on-off valve (27),
 wherein the first pipe (17) and the second pipe (21) are connected to an upper end of the oil storage (15), and the third pipe (25) is connected to a lower end of the oil storage (15).

the oil in the first compressor (3a) is fed to the second compressor (3b) via the fourth pipe (31a, 31b).

4. The refrigeration cycle apparatus (1) according to claim 3, wherein
 the third pipe (25) includes a main pipe (25a) which is connected to the oil storage (15), a first branch pipe (25b) which is branched from the main pipe (25a) and connected to the first compressor (3a), and a second branch pipe (25c) which is branched from the main pipe (25a) and connected to the second compressor (3b), and
 the third on-off valve (27) is provided in the main pipe (25a).
5. The refrigeration cycle apparatus (1) according to claim 3, wherein
 the third pipe (25) includes a main pipe (25a) which is connected to the oil storage (15), a first branch pipe (25b) which is branched from the main pipe (25a) and connected to the first compressor (3a), and a second branch pipe (25c) which is branched from the main pipe (25a) and connected to the second compressor (3b), and
 the third on-off valve (27a, 27b) is provided in each of the first branch pipe (25b) and the second branch pipe (25c).
6. The refrigeration cycle apparatus (1) according to claim 1, wherein when a first oil level of the oil in the first compressor (3a) which is a part of the total oil circulating in the refrigerant circuit together with refrigerant is higher than a second oil level of the oil in the second compressor (3b) which is a part of the total oil circulating in the refrigerant circuit together with refrigerant, the first on-off valve (19), the second on-off valve (23) and the third on-off valve (27) are kept close so as to allow the oil in the accumulator and the oil in the first compressor (3a) to be fed to the second compressor (3b) until the first oil level is the same as the second oil level.
7. The refrigeration cycle apparatus (1) according to claim 6 further comprising a fourth pipe (31, 31a, 31b) for connecting the accumulator (13) to the compressor group (3) and for connecting the first compressor (3a) and the second compressor (3b), wherein the oil in the accumulator (13) is fed to the second compressor (3b) via the fourth pipe (31, 31b), and

FIG.1

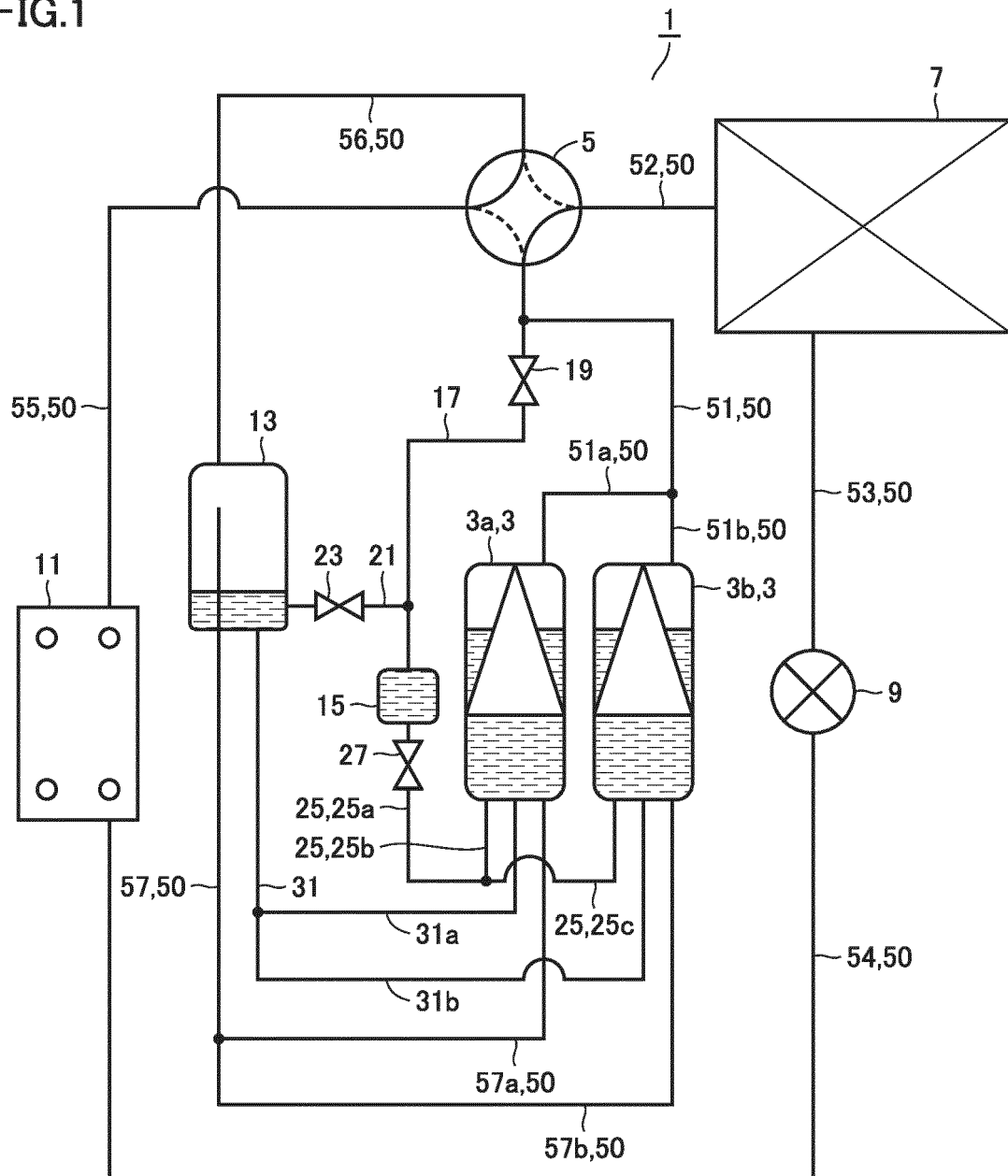


FIG.2

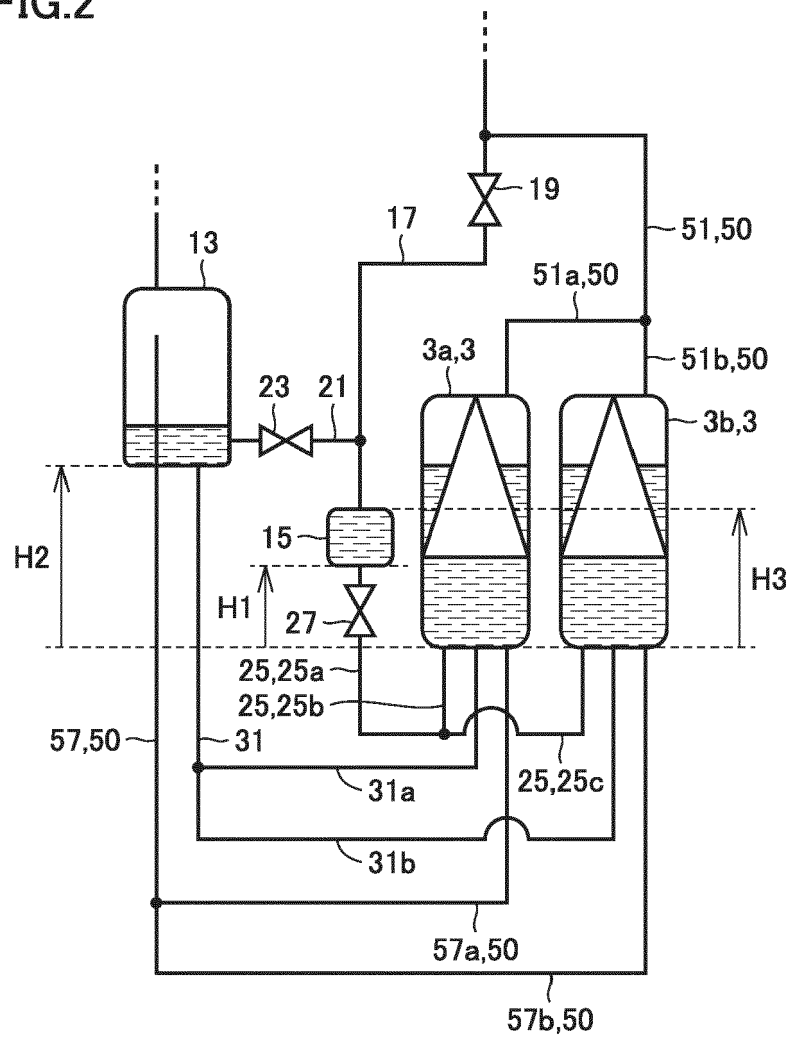


FIG.3

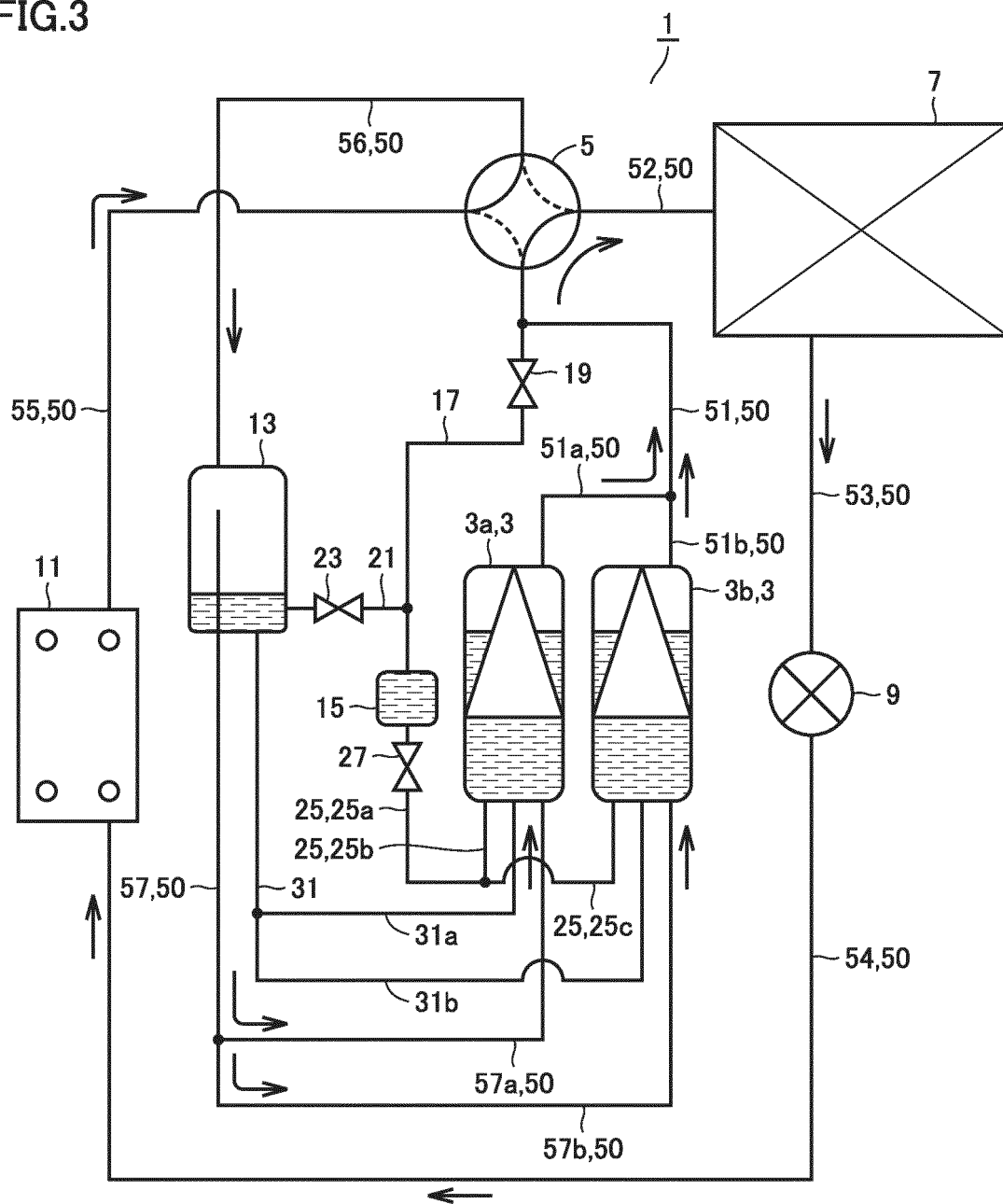


FIG.4

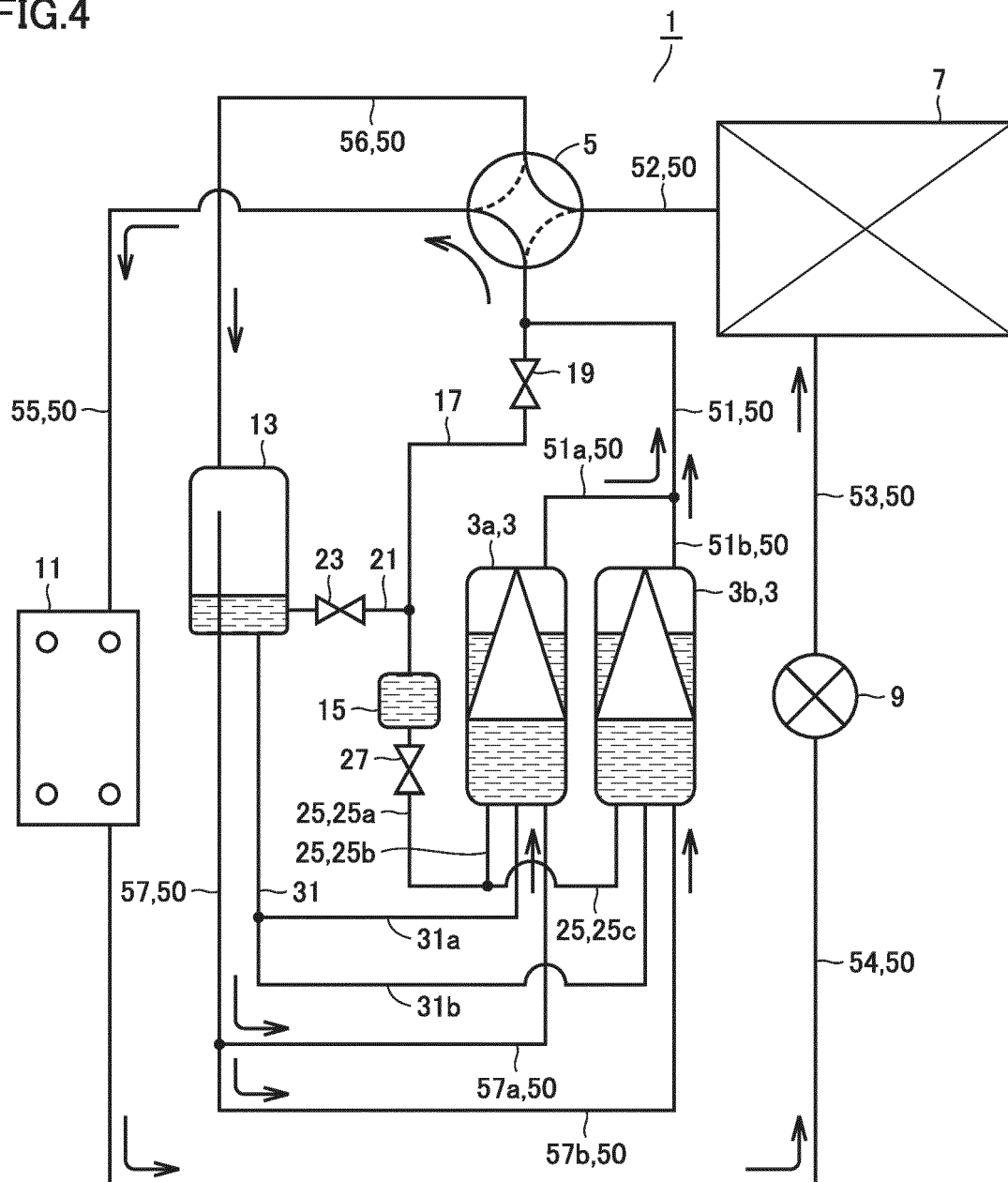


FIG.5

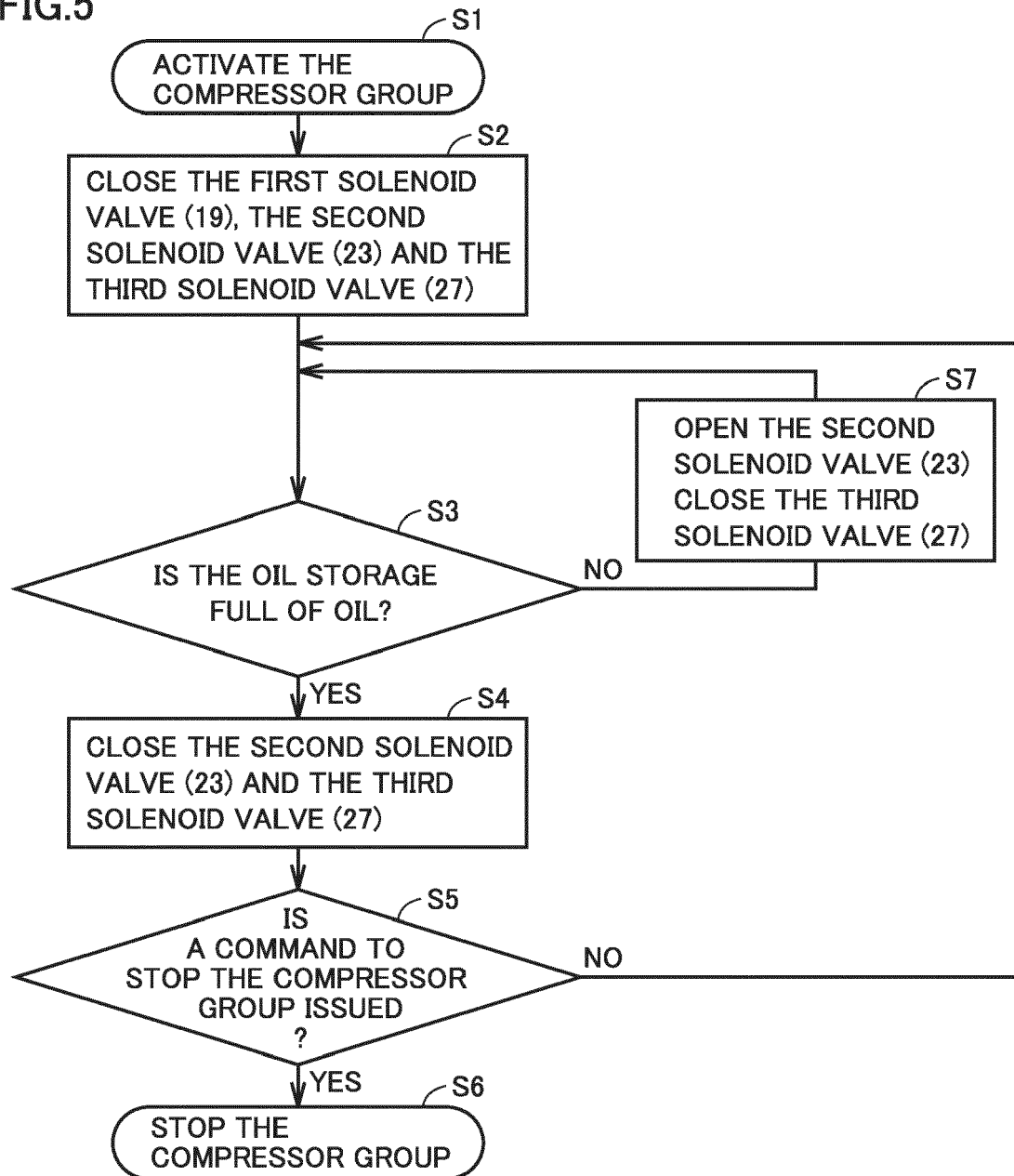


FIG.6

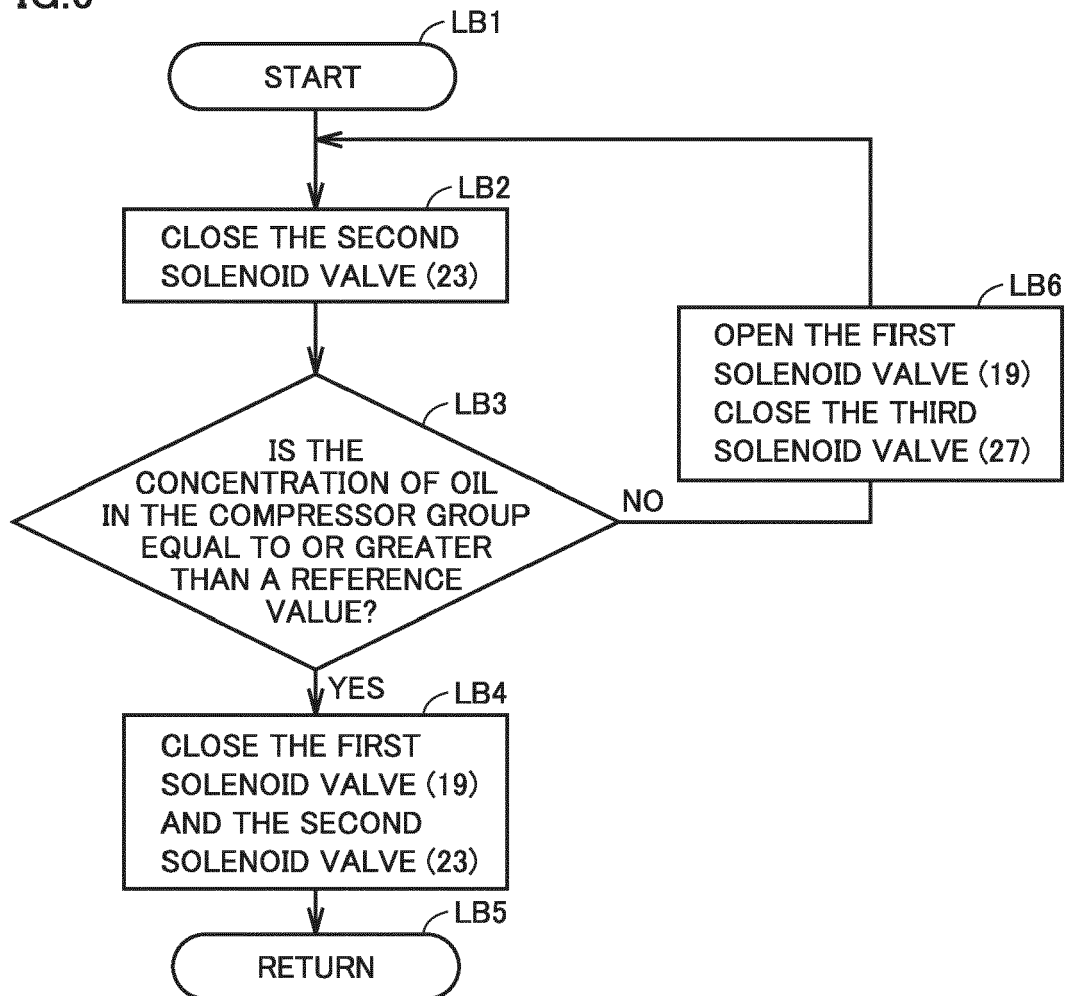


FIG.7

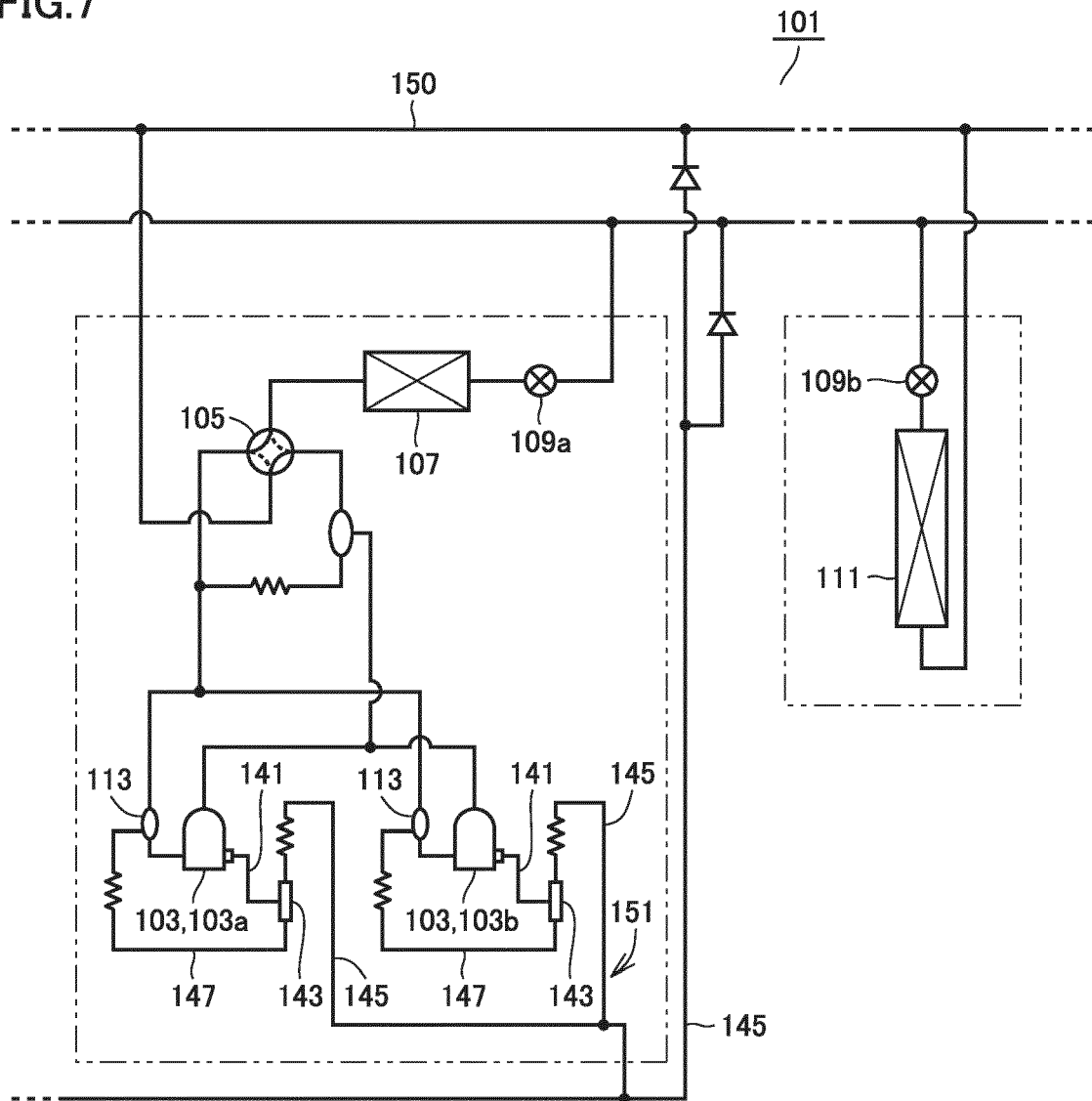


FIG.8

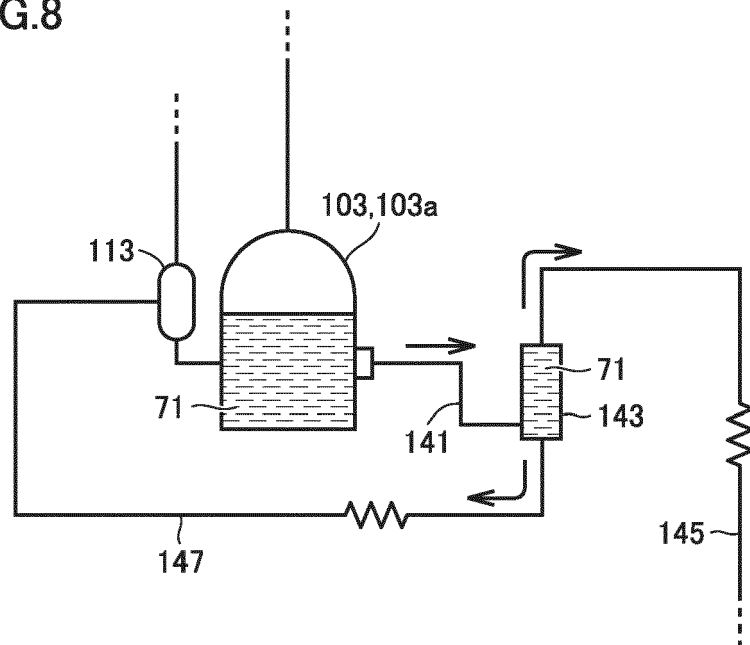


FIG.9

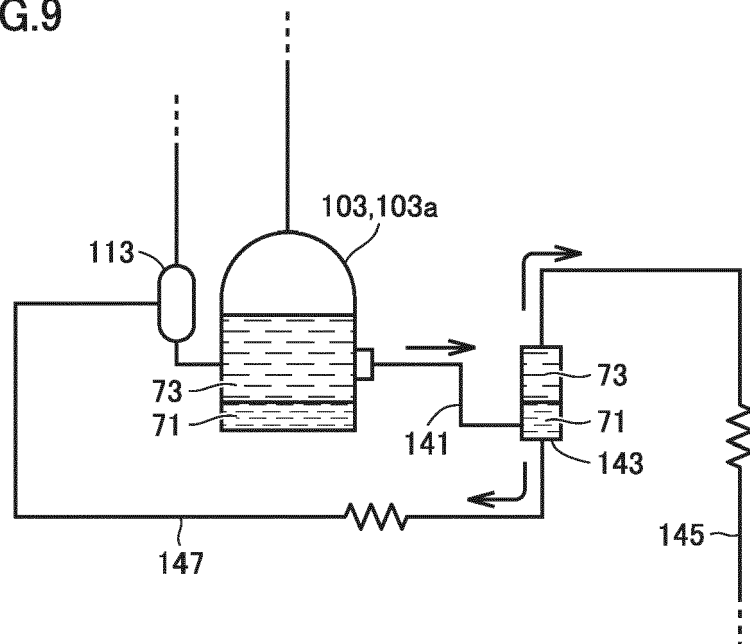
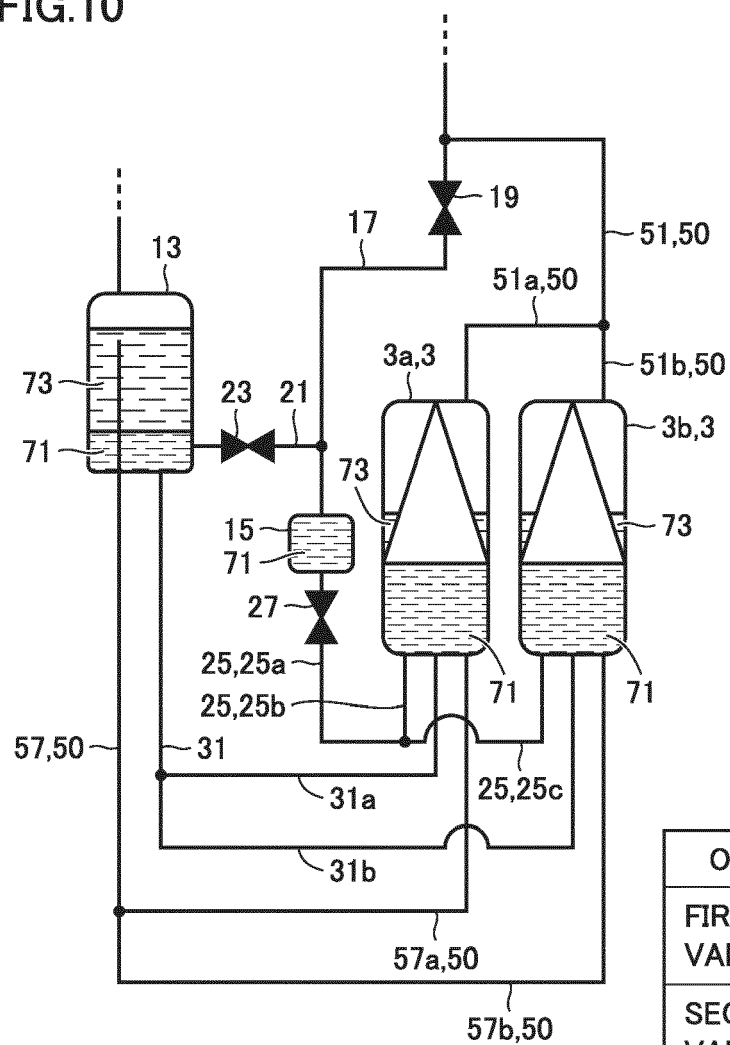
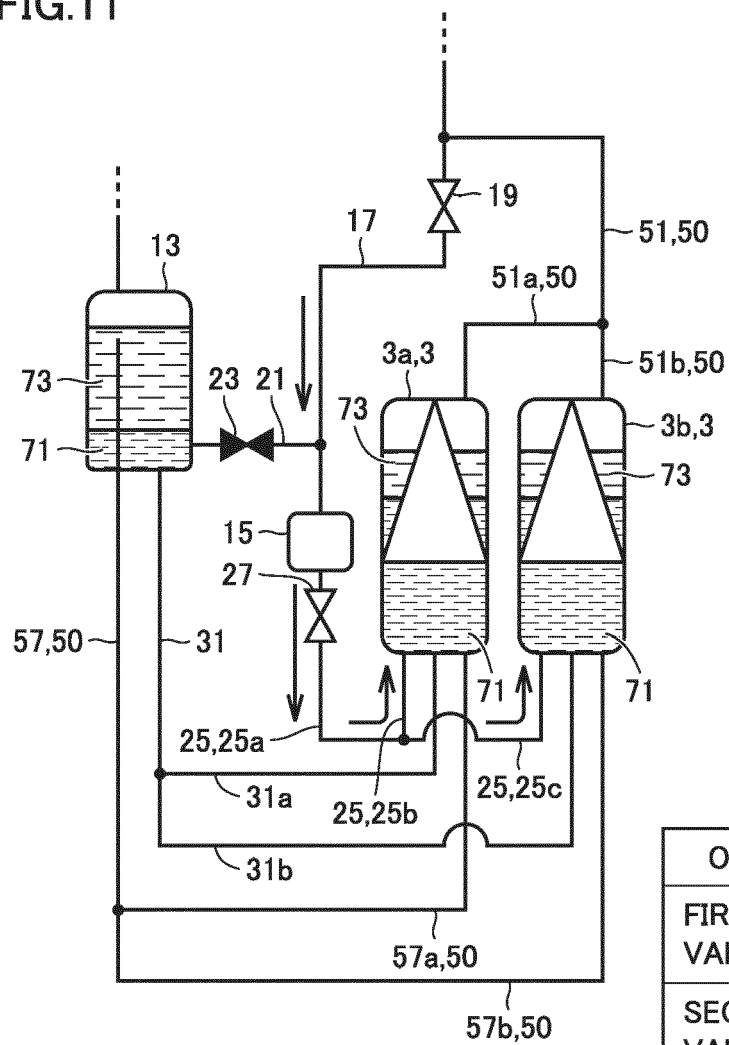


FIG.10



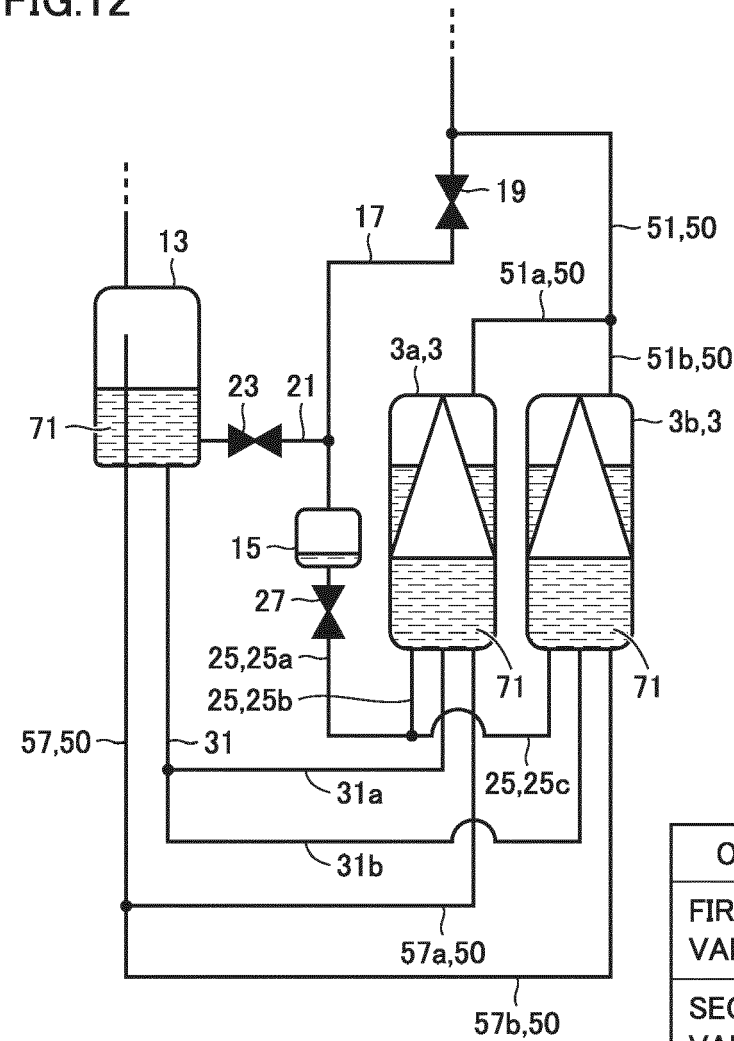
ON-OFF VALVE	STATE
FIRST SOLENOID VALVE (19)	CLOSED
SECOND SOLENOID VALVE (23)	CLOSED
THIRD SOLENOID VALVE (27)	CLOSED

FIG.11



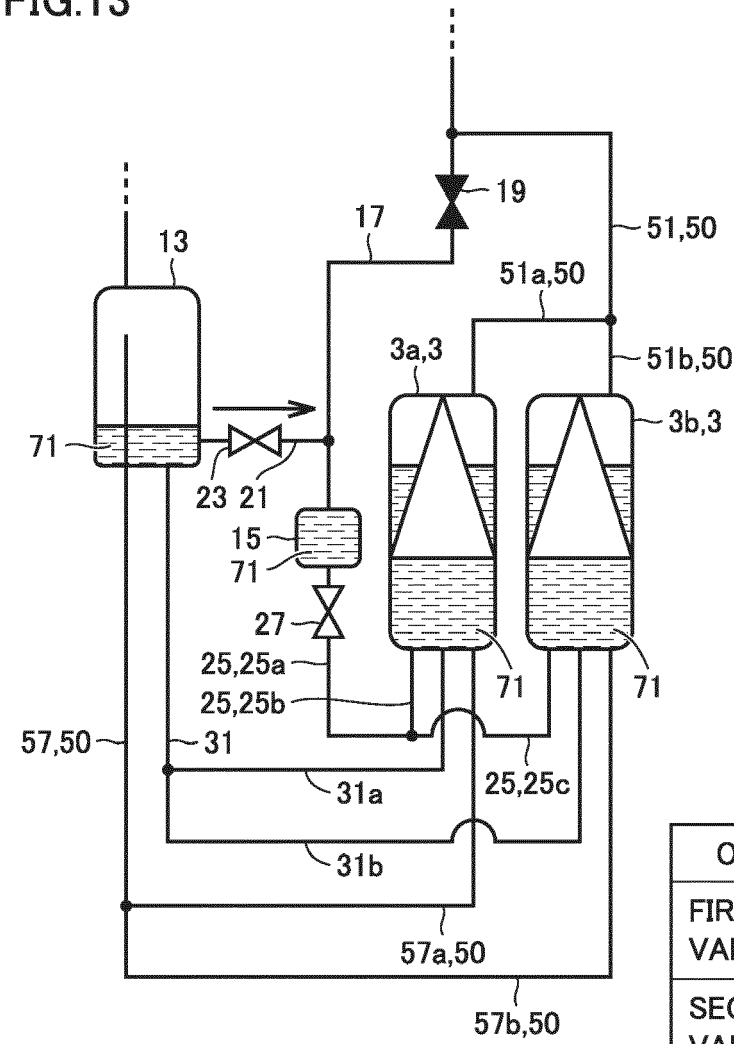
ON-OFF VALVE	STATE
FIRST SOLENOID VALVE (19)	OPENED
SECOND SOLENOID VALVE (23)	CLOSED
THIRD SOLENOID VALVE (27)	OPENED

FIG.12



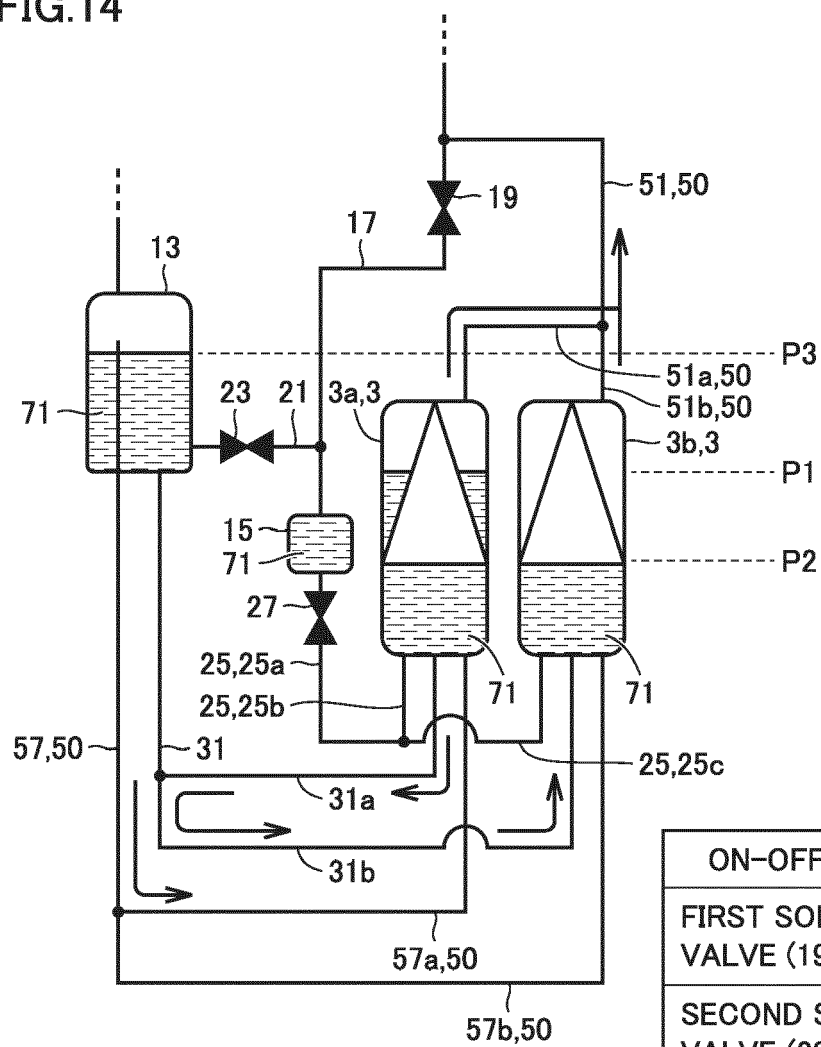
ON-OFF VALVE	STATE
FIRST SOLENOID VALVE (19)	CLOSED
SECOND SOLENOID VALVE (23)	CLOSED
THIRD SOLENOID VALVE (27)	CLOSED

FIG.13



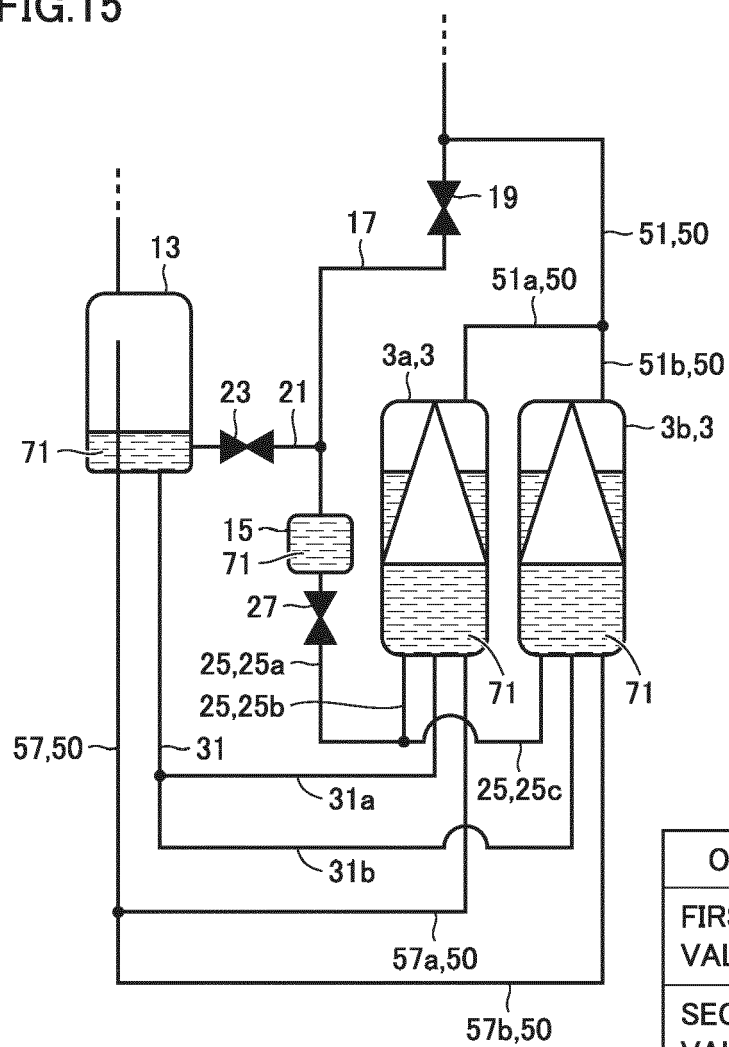
ON-OFF VALVE	STATE
FIRST SOLENOID VALVE (19)	CLOSED
SECOND SOLENOID VALVE (23)	OPENED
THIRD SOLENOID VALVE (27)	OPENED

FIG.14



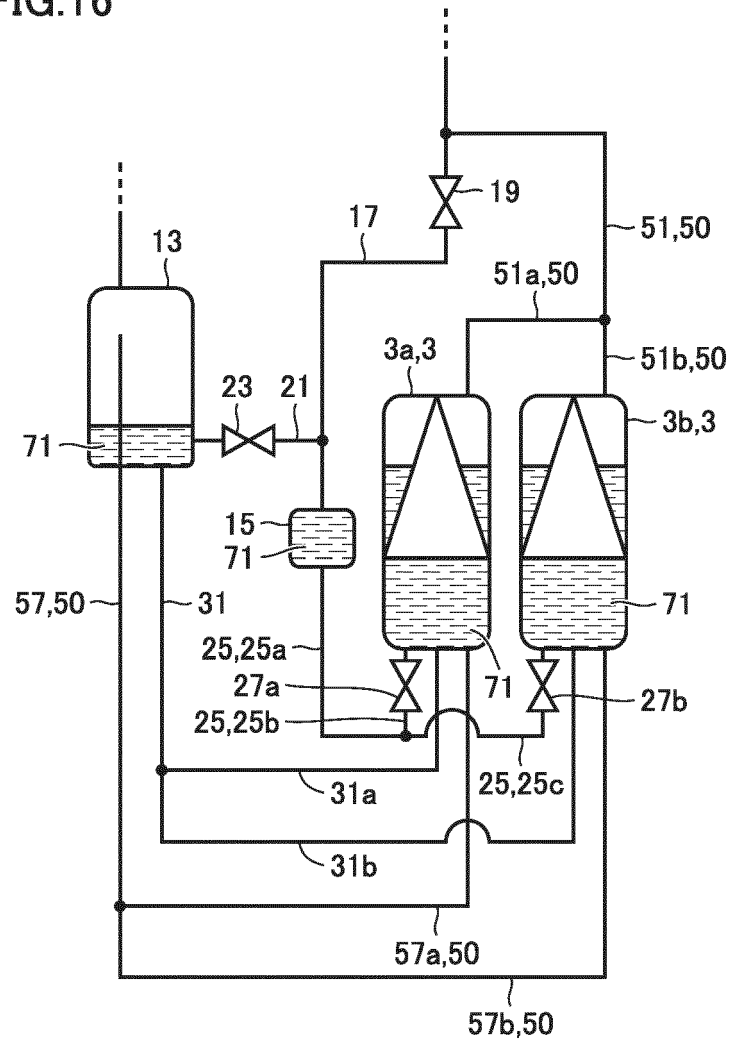
ON-OFF VALVE	STATE
FIRST SOLENOID VALVE (19)	CLOSED
SECOND SOLENOID VALVE (23)	CLOSED
THIRD SOLENOID VALVE (27)	CLOSED

FIG.15



ON-OFF VALVE	STATE
FIRST SOLENOID VALVE (19)	CLOSED
SECOND SOLENOID VALVE (23)	CLOSED
THIRD SOLENOID VALVE (27)	CLOSED

FIG.16





EUROPEAN SEARCH REPORT

Application Number
EP 21 18 5466

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 2 336 681 A1 (JOHNSON CONTROLS TECH CO [US] ET AL.) 22 June 2011 (2011-06-22) * paragraphs [0064] - [0070]; figures * -----	1-7	INV. F25B1/00 F25B31/00
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 October 2021	Examiner Ritter, Christoph
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

 1
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 21 18 5466

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

19-10-2021

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2336681 A1	22-06-2011	CN 101676564 A	24-03-2010
		EP 2336681 A1	22-06-2011
		US 2011162746 A1	07-07-2011
		WO 2010031250 A1	25-03-2010

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2007139215 A [0004]
- JP 4130676 B [0004]