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(72) Inventors:
• **TEZUKA, Satoshi**
Takasago-shi, Hyogo 676-8670 (JP)
• **SEYAMA, Katsuhiro**
Takasago-shi, Hyogo 676-8670 (JP)
• **AKAMO, Naoki**
Takasago-shi, Hyogo 676-8670 (JP)

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(74) Representative: **TBK**
Bavariaring 4-6
80336 München (DE)

(71) Applicant: **Kabushiki Kaisha Kobe Seiko Sho**
(Kobe Steel, Ltd.)
Kobe-shi, Hyogo 651-8585 (JP)

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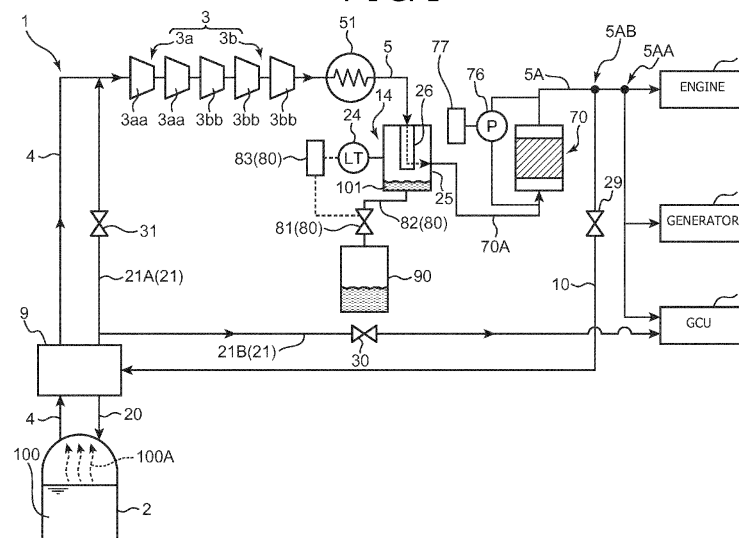
(54) **BOIL-OFF GAS RECOVERY SYSTEM**

(57) A boil-off gas recovery system capable of suppressing performance deterioration of a heat exchanger in a boil-off gas re-liquefying system is provided.

A boil-off gas recovery system includes a tank where a liquefied gas is stored, a reciprocating compressor to which lubricating oil is supplied, the compressor that compresses a boil-off gas generated by vaporization of part of the liquefied gas in the tank, a first separator that separates the lubricating oil contained in the boil-off gas

which is discharged from the compressor, an activated carbon filter that absorbs the lubricating oil contained in the boil-off gas already passing through the first separator, and a re-liquefying system having a heat exchanger that cools the boil-off gas already passing through the activated carbon filter by heat exchange with the boil-off gas supplied to the compressor from the tank, the re-liquefying system where the liquefied boil-off gas is returned to the tank.

FIG. 1



Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a boil-off gas recovery system.

(DESCRIPTION OF THE RELATED ART)

[0002] In a liquefied natural gas transportation ship, since a liquefied natural gas stored in a tank is gasified by heat coming from the outside when transferred at sea, a boil-off gas is generated. This boil-off gas is effectively utilized as fuel for an engine, a steam boiler, or a generator in the ship, and an extra gas is re-liquefied and then returned to the tank. As a technique to re-liquefy the boil-off gas generated in the tank and to return the boil-off gas to the tank in such a way, a boil-off gas recovery system described in JP 2015-158263 A is known.

[0003] In the boil-off gas recovery system of JP 2015-158263 A, as described in FIG. 9, a boil-off gas generated in a tank 11 is compressed by an oil supply type compressor 15, and part of the compressed boil-off gas is re-liquefied through cooling by a heat exchanger 14 and expansion by an expansion valve 17 and then returned to the tank 11. Lubricating oil used in the compressor 15 can be mixed into the boil-off gas discharged from the compressor 15. Therefore, in the boil-off gas recovery system of JP 2015-158263 A, a filter for removing oil content contained in the boil-off gas is arranged in a second pipe 16.

[0004] In the boil-off gas recovery system of JP 2015-158263 A, the oil content contained in the boil-off gas is removed by the filter. However, it is sometimes difficult to sufficiently remove the oil content contained in the boil-off gas by this filter. Therefore, since the oil content passing through the filter is coagulated and precipitated in a flow passage of the heat exchanger 14, the flow passage is narrowed down. As a result, there is a problem that a heat exchange performance is deteriorated.

SUMMARY OF THE INVENTION

[0005] The present invention is achieved in consideration with the above problem, and an object of the present invention is to provide a boil-off gas recovery system capable of suppressing performance deterioration of a heat exchanger in a boil-off gas re-liquefying system.

[0006] A boil-off gas recovery system according to one aspect of the present invention includes a tank where a liquefied gas is stored, a reciprocating compressor to which lubricating oil is supplied, the compressor that compresses a boil-off gas generated by vaporization of part of the liquefied gas in the tank, an oil separation unit that separates the lubricating oil contained in the boil-off

gas which is discharged from the compressor, an absorption filter that absorbs the lubricating oil contained in the boil-off gas already passing through the oil separation unit, and a re-liquefying system having a heat exchanger that cools the boil-off gas already passing through the absorption filter by heat exchange with the boil-off gas supplied to the compressor from the tank, the re-liquefying system where the liquefied boil-off gas is returned to the tank. The above absorption filter is preferably an activated carbon filter.

[0007] In the above boil-off gas recovery system, after the lubricating oil contained in the boil-off gas which is discharged from the compressor is separated by the oil separation unit, the lubricating oil contained in the boil-off gas can be further absorbed by the absorption filter. In such a way, by two-step operations of separation of the lubricating oil with the oil separation unit and absorption of the lubricating oil with the absorption filter, an amount of the lubricating oil contained in the boil-off gas can be reduced to a great extent. Therefore, an amount of oil content flowing into the heat exchanger in the re-liquefying system can be reduced to a great extent. Thus, since precipitation of the oil content in a flow passage of the heat exchanger is suppressed, performance deterioration of the heat exchanger can be suppressed. In particular, the activated carbon filter is preferable due to a high ability of absorbing the lubricating oil.

[0008] The above boil-off gas recovery system may further include a monitoring means that monitors whether or not the lubricating oil is contained in the boil-off gas already passing through the absorption filter.

[0009] With this configuration, it can be confirmed whether or not the lubricating oil contained in the boil-off gas is sufficiently removed by the oil separation unit and the absorption filter.

[0010] The above boil-off gas recovery system may further include a differential pressure meter that detects a pressure difference before and after the absorption filter, and an alarm issuing unit that issues an alarm when the pressure difference detected by the differential pressure meter exceeds a preliminarily fixed reference value.

[0011] With this configuration, the end of the life of the absorption filter can be recognized by the alarm. Thus, a replacement task of the absorption filter can be promptly performed.

[0012] The above boil-off gas recovery system may further include a level sensor that detects whether or not a liquid level of the lubricating oil in the oil separation unit exceeds a preliminarily fixed reference level, a lead-out means that leads the lubricating oil out of the oil separation unit when the liquid level exceeds the reference level, and a drain tank that stores the lubricating oil led out by the lead-out means.

[0013] With this configuration, at timing when the liquid level of the lubricating oil exceeds the reference level, the lubricating oil can be led out of the oil separation unit. Thus, maintenance of the oil separation unit is easily performed.

[0014] As clear from the above description, according to the present invention, the boil-off gas recovery system capable of suppressing the performance deterioration of the heat exchanger in the boil-off gas re-liquefying system can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

FIG. 1 is a diagram schematically showing a configuration of a boil-off gas recovery system according to a first embodiment of the present invention.

FIG. 2 is a diagram schematically showing a configuration of an activated carbon filter in the above boil-off gas recovery system.

FIG. 3 is a diagram schematically showing a configuration of a re-liquefying system in the above boil-off gas recovery system.

FIG. 4 is a diagram schematically showing a configuration of a boil-off gas recovery system according to a second embodiment of the present invention.

FIG. 5 is a diagram schematically showing a configuration of a boil-off gas recovery system according to a modified example of the above second embodiment.

FIG. 6 is a diagram schematically showing a configuration of a boil-off gas recovery system according to a third embodiment of the present invention.

FIG. 7 is a diagram schematically showing a configuration of a boil-off gas recovery system according to a fourth embodiment of the present invention.

FIG. 8 is a diagram schematically showing a configuration of a boil-off gas recovery system according to one of other embodiments of the present invention.

FIG. 9 is a diagram schematically showing a configuration of a boil-off gas recovery system according to the conventional example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] Hereinafter, a boil-off gas recovery system according to embodiments of the present invention will be described in detail on the basis of the drawings.

(FIRST EMBODIMENT)

[0017] Firstly, a boil-off gas recovery system 1 according to a first embodiment of the present invention will be described with reference to FIGS. 1 to 3. FIG. 1 is a schematic configuration diagram showing the boil-off gas recovery system 1 according to the first embodiment. FIG. 2 is a schematic configuration diagram showing an activated carbon filter 70 (absorption filter) in the boil-off gas recovery system 1 according to the first embodiment. FIG. 3 is a schematic configuration diagram showing a re-liquefying system 9 in the boil-off gas recovery system

1 according to the first embodiment.

[0018] The boil-off gas recovery system 1 is installed in a ship that transports a liquefied gas such as a liquefied natural gas. As shown in FIG. 1, the boil-off gas recovery system 1 mainly includes a tank 2, a compressor group 3, a cooler 51, a first separator 14 (oil separation unit), the activated carbon filter 70 (absorption filter), the re-liquefying system 9, pipes connecting these constituent elements to each other, and various control valves provided in the pipes.

[0019] The tank 2 is to store a liquefied gas 100 such as a liquefied natural gas. The liquefied natural gas is stored in the tank 2 in a temperature state of about -160°C . In the tank 2, by vaporization of part of the liquefied gas 100 due to in-coming of heat from the outside, a boil-off gas 100A is generated. The tank 2 is not limited to the one to store the liquefied natural gas but may be the one to store other types of the liquefied gas 100 such as a liquefied petroleum gas.

[0020] The compressor group 3 is connected to the tank 2 via a first pipe 4. The boil-off gas 100A generated in the tank 2 passes through the inside of the first pipe 4 and is supplied to the compressor group 3. The compressor group 3 includes a non-oil supply type compressor 3a that does not require lubricating oil, and an oil supply type compressor 3b to which the lubricating oil is supplied. The non-oil supply type and oil supply type compressors 3a, 3b compress the boil-off gas 100A generated due to vaporization of part of the liquefied gas 100 in the tank 2. The oil supply type compressor 3b is arranged in a subsequent part of the non-oil supply type compressor 3a. The non-oil supply type compressor 3a may be omitted.

[0021] The non-oil supply type compressor 3a has two compression stages 3aa. The oil supply type compressor 3b has three compression stages 3bb. The number of the compression stages can be set in accordance with the types of the liquefied gas 100 so that pressure of the boil-off gas can be boosted to be pressure required for re-liquefaction. Therefore, the number of the compression stages is not limited to five of the present embodiment but may be four or less or may be six or more.

[0022] Each of the non-oil supply type and oil supply type compressors 3a, 3b is a reciprocating compressor. That is, the compressors 3a, 3b boost the pressure of the boil-off gas suctioned into a cylinder via a suction port by reciprocating motion of a piston and discharge the boil-off gas whose pressure is boosted from a discharge port. A check valve is provided in each of the suction port and the discharge port.

[0023] The cooler 51 is to cool the boil-off gas compressed by the compressors 3a, 3b, and is arranged in a subsequent part of the compressor group 3. The cooler 51 cools the boil-off gas by heat exchange with using sea water, for example. By cooling in the cooler 51, a temperature of the boil-off gas supplied to an engine 6 and the like can be adjusted to be a predetermined temperature. The lubricating oil used in the compressor 3b can

be mixed into the boil-off gas discharged from the compressor 3b. For this, by cooling in the cooler 51, the lubricating oil in a vaporous state (oil content) contained in the boil-off gas can also be condensed.

[0024] The first separator 14 is to separate the lubricating oil (lubricating oil used in the oil supply type compressor 3b) in a liquid state or a mist state contained in the boil-off gas which is discharged from the compressor 3b, and is arranged in a subsequent part of the cooler 51. The first separator 14 is connected to the compressor 3b via a second pipe 5. The cooler 51 is provided in the middle of the second pipe 5. As shown in FIG. 1, the first separator 14 has a main body portion 25 having a cylindrical shape, and a small diameter portion 26 having a cylindrical shape whose diameter is smaller than that of the main body portion 25, the small diameter portion being arranged in the main body portion 25. An outer surface of this small diameter portion 26 is formed in a mesh shape.

[0025] The boil-off gas cooled by the cooler 51 passes through the inside of the second pipe 5 and flows into the small diameter portion 26 from the upper end side of the small diameter portion 26 of the first separator 14. As shown by a broken line in FIG. 1, the boil-off gas flows from an upper end toward a lower end in the small diameter portion 26 and then passes through the mesh on the outer surface of the small diameter portion 26. At this time, the lubricating oil in a liquid state or a mist state contained in the boil-off gas does not pass through the mesh but is accumulated on a bottom of the small diameter portion 26. The boil-off gas passes through the mesh of the small diameter portion 26 and then flows out of the first separator 14 from a gas outlet provided on a side surface of the main body portion 25. In such a way, by using a mesh structure of the small diameter portion 26, the lubricating oil contained in the boil-off gas can be separated. The oil content accumulated on the bottom of the small diameter portion 26 passes through mesh holes and drips down to a bottom of the main body portion 25 (reference numeral 101 in FIG. 1).

[0026] The above boil-off gas recovery system 1 further includes a level sensor 24 provided in the first separator 14, a lead-out means 80 that leads the lubricating oil out of the first separator 14, and a drain tank 90 that stores the lubricating oil led out by the lead-out means 80.

[0027] The level sensor 24 detects whether or not a liquid level of the lubricating oil in the first separator 14 (main body portion 25) exceeds a preliminarily fixed reference level. Specifically, the level sensor 24 has a pair of electrodes, and when the liquid level of the lubricating oil reaches the reference level, a portion between the pair of electrodes is filled with the lubricating oil. At this time, electric resistance between the pair of electrodes is changed. By detecting the change in the electric resistance, the level sensor 24 detects the fact that the liquid level of the lubricating oil in the first separator 14 exceeds the preliminarily fixed reference level.

[0028] The lead-out means 80 leads the lubricating oil

out of the first separator 14 when the liquid level of the lubricating oil in the first separator 14 exceeds the reference level. The lead-out means 80 has a drain pipe 82, a drain valve 81 provided in the drain pipe 82, and a control unit 83 that controls open/close of the drain valve 81.

[0029] As shown in FIG. 1, the drain pipe 82 has one end connected to a bottom portion of the first separator 14 (main body portion 25), and the other end connected to an upper portion of the drain tank 90. The control unit 83 receives a detection signal indicating the fact that the liquid level of the lubricating oil in the first separator 14 exceeds the reference level from the level sensor 24. Upon receiving this detection signal, the control unit 83 performs control of opening the drain valve 81. Thereby, when the liquid level of the lubricating oil in the first separator 14 exceeds the reference level, the lubricating oil can be guided from the inside of the first separator 14 to the drain tank 90 via the drain pipe 82.

[0030] The activated carbon filter 70 is to absorb the lubricating oil contained in the boil-off gas already passing through the first separator 14, and is arranged in a subsequent part of the first separator 14. The activated carbon filter 70 is connected to the first separator 14 by a third pipe 70A. Thereby, the boil-off gas already passing through the first separator 14 can flow into the activated carbon filter 70 via the third pipe 70A.

[0031] FIG. 2 is a vertically sectional diagram showing a detailed configuration of the activated carbon filter 70. As shown in FIG. 2, the activated carbon filter 70 mainly has a casing 71, a lid 73, an activated carbon cartridge 72, and fastening members 74, 75. In the present embodiment, the activated carbon filter 70 is arranged in a posture along the vertical direction (vertically placed). However, the posture of the activated carbon filter 70 to be arranged is not limited to this but the activated carbon filter may be arranged in a posture along the horizontal direction (horizontally placed).

[0032] The casing 71 has a cylindrical shape inside which the activated carbon cartridge 72 can be housed, and an upper end of the casing is opened. In substantially center of a bottom portion 71C of the casing 71, a gas inflow port 71A for the boil-off gas flowing into the casing 71 is provided. The lid 73 has a disc shape of the substantially same diameter as that of the casing 71, and is fixed to an upper end of the casing 71 by the fastening members 74, 75. In substantially center of the lid 73, a gas outflow port 73A for the boil-off gas flowing out to the outside is provided.

[0033] The activated carbon cartridge 72 is housed in the casing 71 and can be taken out of the casing 71. Specifically, after the fastening members 74, 75 are removed and the lid 73 is detached from the casing 71, the activated carbon cartridge 72 can be taken out from the upper end opening portion of the casing 71. In such a way, a replacement task of the activated carbon cartridge 72 can be performed.

[0034] The activated carbon cartridge 72 has a large

number of particulate activated carbon particles 72A, and a housing portion 72B that houses the activated carbon particles 72A. The activated carbon particles 72A can absorb the lubricating oil in a liquid state or a mist state contained in the boil-off gas. As shown in FIG. 2, a space 71B is provided between the activated carbon cartridge 72 and the bottom portion 71C of the casing 71. By providing this space 71B, the boil-off gas flowing into the casing 71 can flow in throughout the inside of the activated carbon cartridge 72.

[0035] The boil-off gas already passing through the first separator 14 flows into the casing 71 from the gas inflow port 71A. As shown by broken arrows in FIG. 2, the boil-off gas spreads in the radial direction in the space 71B and then passes through the inside of the activated carbon cartridge 72. At this time, the lubricating oil in a liquid state or a mist state contained in the boil-off gas (lubricating oil which is not completely separated by the first separator 14) can be absorbed by the activated carbon particles 72A. The boil-off gas passes through the activated carbon cartridge 72 and then flows out to the outside from the gas outflow port 73A. In such a way, by performing a separation operation of the lubricating oil with the first separator 14 and an absorption operation of the lubricating oil with the activated carbon filter 70, an amount of the lubricating oil contained in the boil-off gas can be reduced to a great extent.

[0036] As shown in FIG. 1, the above boil-off gas recovery system 1 further includes a differential pressure meter 76 and an alarm issuing unit 77. The differential pressure meter 76 detects a pressure difference before and after the activated carbon filter 70. The alarm issuing unit 77 issues an alarm when the pressure difference detected by the differential pressure meter 76 exceeds a preliminarily fixed reference value. The alarm issuing unit 77 may be for example of a sound type or a lighting type. Thereby, a difference between pressure of the boil-off gas flowing into the activated carbon filter 70 (pressure of the boil-off gas on the upstream side of the activated carbon filter 70) and pressure of the boil-off gas flowing out of the activated carbon filter 70 (pressure of the boil-off gas on the downstream side of the activated carbon filter 70) is increased. Thus, by the alarm issuing unit 77, a worker can be notified of the fact that the replacement time for the activated carbon cartridge 72 has come.

[0037] One end of a gas outlet pipe 5A is connected to the gas outflow port 73A of the activated carbon filter 70. As shown in FIG. 1, the gas outlet pipe 5A branches into three at a first part 5AA. The branching pipes are connected to the engine 6, a gas combustion unit 7, and a generator 8, respectively. Thereby, the boil-off gas already passing through the activated carbon filter 70 can be respectively supplied to the engine 6, the gas combustion unit 7, and the generator 8.

[0038] Control valves (not shown) may be respectively provided in the branching pipes. By controlling open/close of these control valves, supply amounts of the boil-off gas to the engine 6, the gas combustion unit

7, and the generator 8 can be adjusted.

[0039] The engine 6 generates propulsion force for a ship by combusting the supplied boil-off gas. The generator 8 generates electric power required for driving various devices of the ship by performing power generation with the supplied boil-off gas as fuel. The gas combustion unit 7 combusts and safely processes an extra boil-off gas in a case where a generation amount of the boil-off gas exceeds an amount required as fuel for the engine 6 and the generator 8.

[0040] Next, the re-liquefying system 9 provided in the above boil-off gas recovery system 1 will be described mainly with reference to FIGS. 1 and 3. The re-liquefying system 9 cools and expands to re-liquefy the boil-off gas whose pressure is boosted by the compressors 3a, 3b. The re-liquefying system 9 mainly has a fourth pipe 10, a heat exchanger 16, a fifth pipe 17, an expansion valve 18, a gas-liquid separation unit 19, a sixth pipe 21, and a seventh pipe 20.

[0041] The fourth pipe 10 has one end connected to a second part 5AB of the gas outlet pipe 5A placed on the upstream side of the first part 5AA, and the other end connected to the heat exchanger 16. Thereby, the boil-off gas already passing through the activated carbon filter 70 passes through the gas outlet pipe 5A, flows into the fourth pipe 10 from the second part 5AB, and is supplied to the heat exchanger 16. As shown in FIG. 1, a first control valve 29 is provided in the fourth pipe 10. By controlling open/close of this first control valve 29, an amount of the boil-off gas flowing into the fourth pipe 10 from the gas outlet pipe 5A can be adjusted.

[0042] The heat exchanger 16 cools the boil-off gas to a liquefiable temperature (for example, -100°C). As shown in FIG. 3, the heat exchanger 16 has a low-temperature side passage 16a through which the boil-off gas fed to the compressors 3a, 3b from the tank 2 passes, and a high-temperature side passage 16b through which the boil-off gas already passing through the activated carbon filter 70 passes.

[0043] The heat exchanger 16 performs heat exchange between the boil-off gas supplied to the compressors 3a, 3b from the tank 2 (boil-off gas passing through the low-temperature side passage 16a) and the boil-off gas already passing through the activated carbon filter 70 (boil-off gas passing through the high-temperature side passage 16b). By this heat exchange, the boil-off gas passing through the high-temperature side passage 16b is cooled. At this time, part of the boil-off gas may be liquefied. The boil-off gas passing through the low-temperature side passage 16a is heated, for example, from -160°C to -50°C .

[0044] As shown in FIG. 3, the first pipe 4 is connected to an inlet and an outlet of the low-temperature side passage 16a. The other end of the fourth pipe 10 is connected to an inlet of the high-temperature side passage 16b. One end of the fifth pipe 17 is connected to an outlet of the high-temperature side passage 16b.

[0045] The fifth pipe 17 has the one end connected to

the heat exchanger 16, and the other end connected to the gas-liquid separation unit 19. The expansion valve 18 is to expand the boil-off gas cooled in the heat exchanger 16 to reduce the pressure, and is provided in the middle of the fifth pipe 17. By this expansion valve 18, part of the boil-off gas is liquefied.

[0046] The gas-liquid separation unit 19 is to separate the partly liquefied boil-off gas into a liquid component and a gas component. One end of the sixth pipe 21 and one end of the seventh pipe 20 are respectively connected to the gas-liquid separation unit 19.

[0047] The seventh pipe 20 has the one end connected to a bottom portion of the gas-liquid separation unit 19, and the other end connected to the tank 2. Thereby, the liquid component of the boil-off gas separated in the gas-liquid separation unit 19 can be returned to the tank 2 via the seventh pipe 20.

[0048] The sixth pipe 21 connects the gas-liquid separation unit 19 and the first pipe 4 to each other, and also connects the gas-liquid separation unit 19 and the gas combustion unit 7 to each other. Specifically, the sixth pipe 21 branches into two branching pipes 21A, 21B at a first part 21AA. One branching pipe 21A is connected to the first pipe 4 on the outlet side of the heat exchanger 16, and the other branching pipe 21B is connected to the gas combustion unit 7. Thereby, the gas component of the boil-off gas separated in the gas-liquid separation unit 19 can respectively flow into the first pipe 4 and the gas combustion unit 7 via the sixth pipe 21.

[0049] As shown in FIG. 3, a second control valve 31 and a third control valve 30 are respectively provided in the branching pipes 21A, 21B. By these valves, opening degrees of flow passages of the boil-off gas in the branching pipes 21A, 21B can be adjusted. Thereby, an amount of the boil-off gas flowing into the side of the first pipe 4 and an amount of the boil-off gas flowing into the side of the gas combustion unit 7 can be respectively adjusted.

[0050] Characteristic configurations and operations and effects of the boil-off gas recovery system 1 according to the above first embodiment will be described.

[0051] The above boil-off gas recovery system 1 includes the tank 2, the compressor 3b to which the lubricating oil is supplied, the compressor that compresses the boil-off gas, the first separator 14 that separates the lubricating oil contained in the boil-off gas which is discharged from the compressor 3b, the activated carbon filter 70 that absorbs the lubricating oil contained in the boil-off gas already passing through the first separator 14, and the re-liquefying system 9 having the heat exchanger 16 that cools the boil-off gas already passing through the activated carbon filter 70, the re-liquefying system where the liquefied boil-off gas is returned to the tank 2.

[0052] In the above boil-off gas recovery system 1, after the lubricating oil contained in the boil-off gas which is discharged from the compressor 3b is separated by the first separator 14, the lubricating oil contained in the boil-off gas can be further absorbed by the activated car-

bon filter 70. In such a way, by two-step operations of separation of the lubricating oil with the first separator 14 and absorption of the lubricating oil with the activated carbon filter 70, the amount of the lubricating oil contained in the boil-off gas can be reduced to a great extent. Specifically, concentration of the lubricating oil in the boil-off gas can be reduced to 0.5 ppm or less by the first separator 14, and the concentration can be further reduced to 0.1 ppm or less by the activated carbon filter 70. Therefore, an amount of the oil content flowing into the heat exchanger 16 in the re-liquefying system 9 can be reduced to a great extent. Thus, since precipitation of the oil content in a flow passage of the heat exchanger 16 is suppressed, performance deterioration of the heat exchanger 16 can be suppressed.

[0053] The above boil-off gas recovery system 1 includes the differential pressure meter 76 that detects the pressure difference before and after the activated carbon filter 70, and the alarm issuing unit 77 that issues the alarm when the pressure difference exceeds the preliminarily fixed reference value. Thereby, the end of the life of the activated carbon filter 70 can be recognized by the alarm. Thus, the replacement task of the activated carbon cartridge 72 can be promptly performed.

[0054] The above boil-off gas recovery system 1 includes the level sensor 24 that detects whether or not the liquid level of the lubricating oil in the first separator 14 exceeds the preliminarily fixed reference level, the lead-out means 80 that leads the lubricating oil out of the first separator 14 when the liquid level exceeds the reference level, and the drain tank 90 that stores the lubricating oil led out by the lead-out means 80. Thereby, at timing when the liquid level of the lubricating oil exceeds the reference level, the lubricating oil can be led out of the first separator 14. Thus, maintenance of the first separator 14 is easily performed.

(SECOND EMBODIMENT)

[0055] Next, a boil-off gas recovery system 1A according to a second embodiment of the present invention will be described with reference to FIG. 4. The boil-off gas recovery system 1A according to the second embodiment basically has the same configuration as the boil-off gas recovery system 1 according to the above first embodiment but is different in terms of a point that a monitoring means that monitors whether or not the lubricating oil is contained in the boil-off gas already passing through the activated carbon filter 70 is further provided. Hereinafter, only the point which is different from the above first embodiment will be described. In FIG. 4, the configurations of the cooler 51, the first separator 14, and the like arranged between the compressor 3b and the activated carbon filter 70 are omitted.

[0056] As shown in FIG. 4, the boil-off gas recovery system 1A according to the second embodiment includes a monitoring means 65. This monitoring means 65 has a second separator 60 arranged in a subsequent part of

the activated carbon filter 70, and a controlling unit 63 that controls actions of the compressors 3a, 3b.

[0057] More specifically, the above boil-off gas recovery system 1A has a gas branching pipe 61 whose one end is connected to a third part 5AC of the gas outlet pipe 5A on the upstream side of the second part 5AB. The other end of this gas branching pipe 61 is connected to an inlet of the second separator 60. Thereby, the boil-off gas already passing through the activated carbon filter 70 can flow into the gas branching pipe 61 from the third part 5AC and can be supplied to the second separator 60. A fourth control valve 62 is provided in the gas branching pipe 61. By controlling open/close of this fourth control valve 62, an amount of the boil-off gas flowing into the gas branching pipe 61 from the gas outlet pipe 5A can be adjusted.

[0058] The second separator 60 has the same configuration as the first separator 14 described in the above first embodiment. Therefore, with the second separator 60, in a case where the first separator 14 and the activated carbon filter 70 do not sufficiently function and the lubricating oil in a liquid state or a mist state is still contained in the boil-off gas already passing through the activated carbon filter 70, the lubricating oil can be separated. Thus, by the amount of the lubricating oil separated by the second separator 60 (amount of the lubricating oil accumulated on the bottom of the main body portion 25), it can be confirmed whether or not a large amount of the lubricating oil is contained in the boil-off gas flowing through the subsequent part of the activated carbon filter 70. That is, it can be confirmed whether or not the lubricating oil contained in the boil-off gas is sufficiently removed by the first separator 14 and the activated carbon filter 70 in a prior part of the second separator 60.

[0059] A level sensor 24 is provided in the second separator 60 as well as the first separator 14. When the level sensor 24 detects the fact that a liquid level of the lubricating oil in the second separator 60 exceeds a preliminarily fixed reference level, a detection signal of the level sensor is sent to the controlling unit 63. Upon receiving the detection signal, the controlling unit 63 performs control of stopping the actions of the compressors 3a, 3b. That is, the controlling unit 63 stops the actions of the compressors 3a, 3b when the amount of the lubricating oil separated by the second separator 60 reaches a predetermined amount. Thereby, even in a case where the lubricating oil in the boil-off gas is not sufficiently removed by the first separator 14 and the activated carbon filter 70 for some reasons (failure), the boil-off gas containing a large amount of the lubricating oil can be prevented from flowing to the side of the re-liquefying system 9.

[0060] As shown in FIG. 4, the above boil-off gas recovery system 1A includes an eighth pipe 64 having one end connected to a gas outlet of the second separator 60, and the other end connected to the first pipe 4. Thereby, the boil-off gas flowing out of the second separator 60 can be returned back to a prior part of the compressor 3a.

[0061] The gas branching pipe 61 may be omitted and the second separator 60 may be arranged in the middle of the gas outlet pipe 5A as shown in FIG. 5. The monitoring means 65 may include no controlling unit 63 but only include the second separator 60. In this case, the worker regularly confirms the amount of the lubricating oil separated by the second separator 60, and when the separation amount of the lubricating oil exceeds a predetermined amount, the worker manually stops the actions of the compressors 3a, 3b.

(THIRD EMBODIMENT)

[0062] Next, a boil-off gas recovery system 1B according to a third embodiment of the present invention will be described with reference to FIG. 6. The boil-off gas recovery system 1B according to the third embodiment basically has the same configuration as the boil-off gas recovery system 1 according to the above first embodiment but is different in terms of a point that plural first separators 14 and plural activated carbon filters 70 are provided and respectively arranged in parallel. Hereinafter, only the point which is different from the above first embodiment will be described in detail.

[0063] As shown in FIG. 6, the plural (two in the present embodiment) first separators 14 are provided and arranged in parallel. Specifically, the second pipe 5 branches into two separator upstream pipes 131, 132 at a part 5E. The separator upstream pipes 131, 132 are connected to inlets of the first separators 14. The third pipe 70A has two separator downstream pipes 133, 134 connected to outlets of the first separators 14. The two separator downstream pipes 133, 134 join at a part 5F.

[0064] The above boil-off gas recovery system 1B includes a separator switching means 110 that switches supply of the boil-off gas to the plural first separators 14. The separator switching means 110 includes on-off valves 111, 112 provided before and after (on the upstream side and the downstream side of) one of the first separators 14 (on the upper side in FIG. 6), and on-off valves 113, 114 provided before and after the other first separator 14 (on the lower side in FIG. 6). The separator switching means 110 may further include a controller that controls these on-off valves 111 to 114.

[0065] By controlling the on-off valves 111 to 114, the supply of the boil-off gas to the plural first separators 14 can be switched. Specifically, by closing the on-off valves 111, 112 and opening the on-off valves 113, 114, the boil-off gas can be supplied only to the first separator 14 on the lower side in FIG. 6. Meanwhile, maintenance or the like of the first separator 14 on the upper side in FIG. 6 can be performed. On the other hand, by opening the on-off valves 111, 112 and closing the on-off valves 113, 114, the boil-off gas can be supplied only to the first separator 14 on the upper side in FIG. 6.

[0066] As shown in FIG. 6, the plural (two in the present embodiment) activated carbon filters 70 are provided and arranged in parallel as well as the first separators 14.

Specifically, the third pipe 70A branches into two filter upstream pipes 135, 136 at a part 5G. The two filter upstream pipes 135, 136 are connected to inlets of the activated carbon filters 70. The gas outlet pipe 5A has two filter downstream pipes 137, 138 connected to outlets of the activated carbon filters 70. The two filter downstream pipes 137, 138 join at a part 5H.

[0067] The above boil-off gas recovery system 1B includes a filter switching means 120 that switches supply of the boil-off gas to the plural activated carbon filters 70. The filter switching means 120 includes on-off valves 121, 122 provided before and after one of the activated carbon filters 70 (on the upper side in FIG. 6), and on-off valves 123, 124 provided before and after the other activated carbon filter 70 (on the lower side in FIG. 6). The filter switching means 120 may further include a controller that controls these on-off valves 121 to 124.

[0068] By controlling the on-off valves 121 to 124, the supply of the boil-off gas to the plural activated carbon filters 70 can be switched. Specifically, by closing the on-off valves 121, 122 and opening the on-off valves 123, 124, the boil-off gas can be supplied only to the activated carbon filter 70 on the lower side in FIG. 6. Meanwhile, the replacement task of the activated carbon cartridge 72 or the like can be performed in the activated carbon filter 70 on the upper side in FIG. 6. On the other hand, by opening the on-off valves 121, 122 and closing the on-off valves 123, 124, the boil-off gas can be supplied only to the activated carbon filter 70 on the upper side in FIG. 6.

[0069] In such a way, in the boil-off gas recovery system 1B according to the third embodiment, the plural first separators 14 and the plural activated carbon filters 70 are respectively arranged in parallel, and the means for switching the supply of the boil-off gas to these are provided. Thereby, while continuing an operation of the boil-off gas recovery system 1B, the maintenance of the first separator 14, the replacement task of the activated carbon cartridge 72, and the like can be performed.

[0070] In the third embodiment, the case where the two first separators 14 and the two activated carbon filters 70 are provided is described. However, three or more first separators and three or more activated carbon filters may be arranged in parallel. Only one of the first separators 14 and the activated carbon filters 70 may be arranged in parallel.

(FOURTH EMBODIMENT)

[0071] Next, a boil-off gas recovery system 1C according to a fourth embodiment of the present invention will be described with reference to FIG. 7. The boil-off gas recovery system 1C according to the fourth embodiment basically has the same configuration as the boil-off gas recovery system 1 according to the above first embodiment but is different in terms of a point that plural first separators 14 and plural activated carbon filters 70 are provided and respectively arranged in series. Hereinafter,

only the point which is different from the above first embodiment will be described in detail.

[0072] As shown in FIG. 7, the plural (two in the present embodiment) first separators 14 are provided and arranged in series. The plural (two in the present embodiment) activated carbon filters 70 are provided and arranged in series. Thereby, the boil-off gas discharged from the compressor 3b can pass through the plural first separators 14. The boil-off gas already passing through the first separators 14 can pass through the plural activated carbon filters 70. Thereby, the amount of the lubricating oil contained in the boil-off gas can be further reduced.

(OTHER EMBODIMENTS)

[0073] Finally, other embodiments of the present invention will be described.

[0074] In the above first embodiment, the configuration in which the boil-off gas after passing through the last compression stage 3bb is guided to the re-liquefying system 9 is described. However, the present invention is not limited to this. As shown in FIG. 8, the fourth pipe 10 in the re-liquefying system 9 may be connected to a portion between the compression stages 3bb in the oil supply type compressor 3b. In this case, the cooler 51, the first separator 14, and the activated carbon filter 70 are also arranged in the portion between the compression stages 3bb. Thereby, the boil-off gas extracted from a middle part of the compressor 3b can be guided to the re-liquefying system 9.

[0075] In the above first embodiment, the case where the gas inflow port 71A is provided in a lower portion of the activated carbon filter 70 and the gas outflow port 73A is provided in an upper portion of the activated carbon filter 70 is described. However, the present invention is not limited to this. The gas outflow portion may be provided in the lower portion of the activated carbon filter 70 and the gas outflow port may be provided in the upper portion of the activated carbon filter 70.

[0076] In the above first to fourth embodiments, the differential pressure meter 76 and the alarm issuing unit 77 may be omitted. The level sensor 24, the lead-out means 80, and the drain tank 90 may be omitted.

[0077] In the above first to fourth embodiments, the activated carbon filter 70 is described as one example of the absorption filter in the present invention. However, the present invention is not limited to this. For example, an absorption filter made of a porous material such as zeolite may be used.

[0078] In the boil-off gas recovery system according to the above first to fourth embodiments, the cooler 51 may be omitted.

[0079] In the above embodiments, the first separator 14 having the small diameter portion 26 whose outer surface is formed in a mesh shape is described as one example of the oil separation unit in the present invention. However, the lubricating oil can also be separated by

other oil separation units. For example, an oil separation unit using a baffle plate or an oil separation unit of centrifugal separation may be used. The same is applied to the second separator 60 included in the monitoring means in the present invention.

[0080] In the above first embodiment, a pipe connecting an arbitrary part of the third pipe 70A and the first part 5AA of the gas outlet pipe 5A may be provided. Thereby, the boil-off gas already passing through the first separator 14 can be directly supplied to the engine 6, the gas combustion unit 7, and the generator 8 while bypassing the activated carbon filter 70. A control valve is provided in the pipe.

[0081] In the above first embodiment, the case where the cooler 51 is arranged only in the subsequent part of the fifth compression stage 3bb is described. However, the cooler 51 may be arranged in a subsequent part of each of the compression stages 3aa, 3bb.

[0082] The embodiments disclosed herein should be understood as not restriction but only examples in all aspects. The scope of the present invention is indicated not by the above description but by the claims, and is intended to include equivalent meanings to the claims and all modifications within the scope.

[0083] A boil-off gas recovery system capable of suppressing performance deterioration of a heat exchanger in a boil-off gas re-liquefying system is provided.

[0084] A boil-off gas recovery system includes a tank where a liquefied gas is stored, a reciprocating compressor to which lubricating oil is supplied, the compressor that compresses a boil-off gas generated by vaporization of part of the liquefied gas in the tank, a first separator that separates the lubricating oil contained in the boil-off gas which is discharged from the compressor, an activated carbon filter that absorbs the lubricating oil contained in the boil-off gas already passing through the first separator, and a re-liquefying system having a heat exchanger that cools the boil-off gas already passing through the activated carbon filter by heat exchange with the boil-off gas supplied to the compressor from the tank, the re-liquefying system where the liquefied boil-off gas is returned to the tank.

Claims

1. A boil-off gas recovery system comprising:

a tank where a liquefied gas is stored;
a reciprocating compressor to which lubricating oil is supplied, the compressor that compresses a boil-off gas generated by vaporization of part of the liquefied gas in the tank;
an oil separation unit that separates the lubricating oil contained in the boil-off gas which is discharged from the compressor;
an absorption filter that absorbs the lubricating oil contained in the boil-off gas already passing

through the oil separation unit; and
a re-liquefying system having a heat exchanger that cools the boil-off gas already passing through the absorption filter by heat exchange with the boil-off gas supplied to the compressor from the tank, the re-liquefying system where the liquefied boil-off gas is returned to the tank.

2. The boil-off gas recovery system according to claim 1, further comprising:

a monitoring means that monitors whether or not the lubricating oil is contained in the boil-off gas already passing through the absorption filter.

3. The boil-off gas recovery system according to claim 1 or 2, further comprising:

a differential pressure meter that detects a pressure difference before and after the absorption filter; and
an alarm issuing unit that issues an alarm when the pressure difference detected by the differential pressure meter exceeds a preliminarily fixed reference value.

4. The boil-off gas recovery system according to any one of claims 1 to 3, further comprising:

a level sensor that detects whether or not a liquid level of the lubricating oil in the oil separation unit exceeds a preliminarily fixed reference level;
a lead-out means that leads the lubricating oil out of the oil separation unit when the liquid level exceeds the reference level; and
a drain tank that stores the lubricating oil led out by the lead-out means.

5. The boil-off gas recovery system according to any one of claims 1 to 4, wherein the absorption filter is an activated carbon filter.

Amended claims in accordance with Rule 137(2) EPC.

1. A boil-off gas recovery system (1, 1A, 1B, 1C) comprising:

a tank (2) where a liquefied gas is stored;
a reciprocating compressor (3) to which lubricating oil is supplied, the compressor that compresses a boil-off gas generated by vaporization of part of the liquefied gas in the tank;
an oil separation unit (14) that separates the lubricating oil contained in the boil-off gas which

is discharged from the compressor;
 an absorption filter (70) that absorbs the lubricating oil contained in the boil-off gas that has already passed through the oil separation unit;
 and
 a re-liquefying system (9) having a heat exchanger (16) that cools the boil-off gas that has already passed through the absorption filter by heat exchange with the boil-off gas supplied to the compressor from the tank, the re-liquefying system where the liquefied boil-off gas is returned to the tank.

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2. The boil-off gas recovery system according to claim 1, further comprising:
 a monitoring means (65) that monitors whether or not the lubricating oil is contained in the boil-off gas that has already passed through the absorption filter.

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3. The boil-off gas recovery system according to claim 1 or 2, further comprising:

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a differential pressure meter (76) that detects a pressure difference before and after the absorption filter; and
 an alarm issuing unit (77) that issues an alarm when the pressure difference detected by the differential pressure meter exceeds a preliminarily fixed reference value.

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4. The boil-off gas recovery system according to any one of claims 1 to 3, further comprising:

a level sensor (24) that detects whether or not a liquid level of the lubricating oil in the oil separation unit exceeds a preliminarily fixed reference level;
 a lead-out means (80) that leads the lubricating oil out of the oil separation unit when the liquid level exceeds the reference level; and
 a drain tank (90) that stores the lubricating oil led out by the lead-out means.

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5. The boil-off gas recovery system according to any one of claims 1 to 4,
 wherein the absorption filter is an activated carbon filter.

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FIG. 1

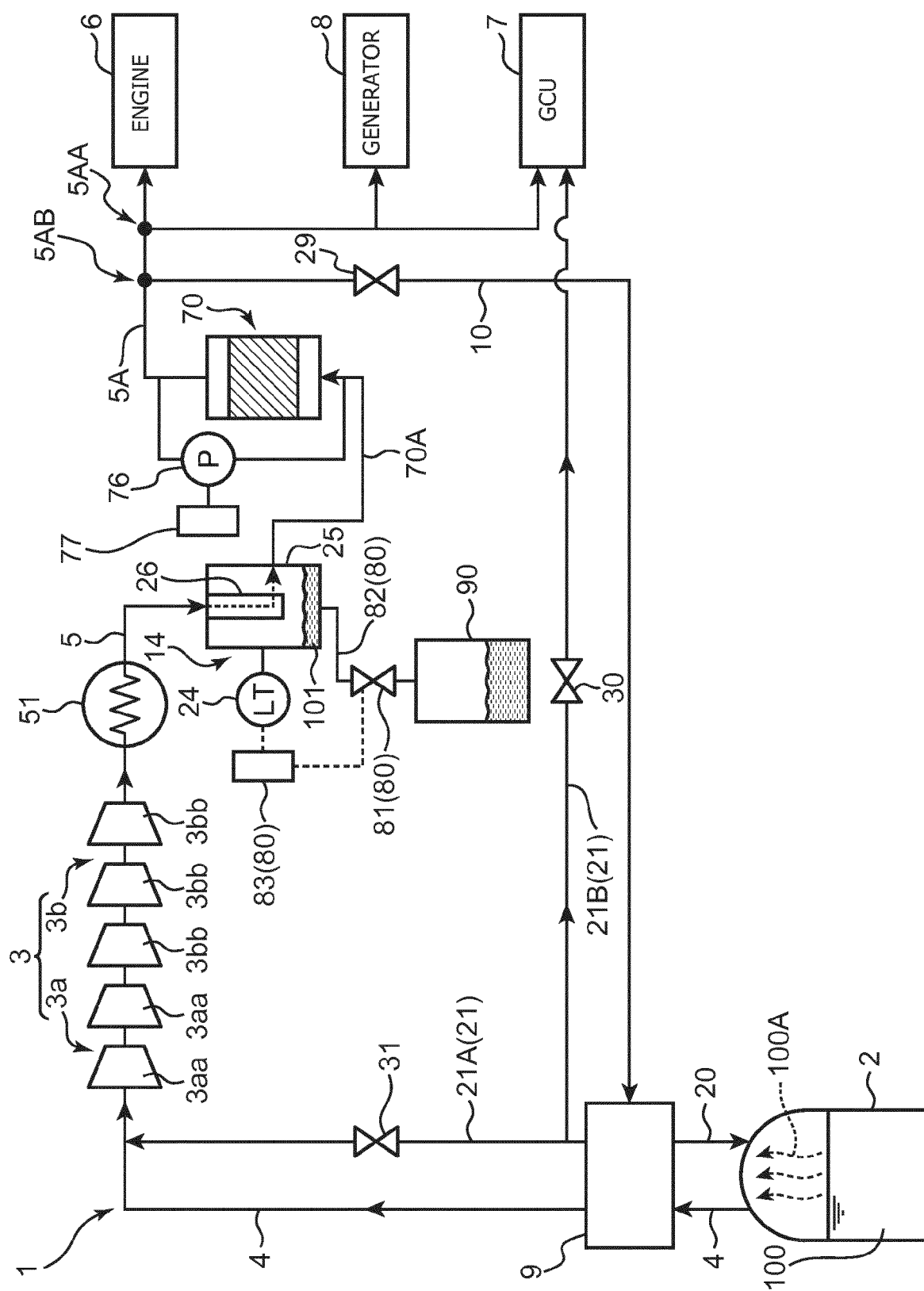


FIG. 2

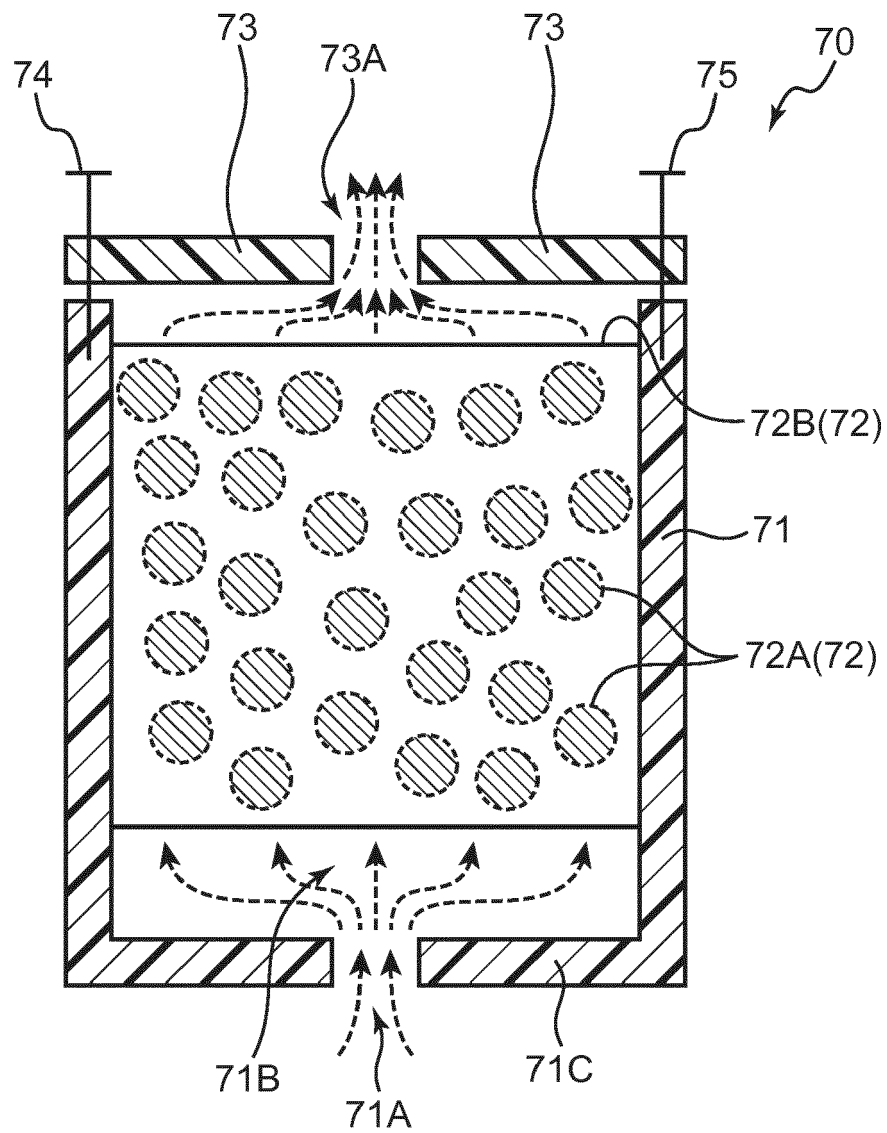


FIG. 3

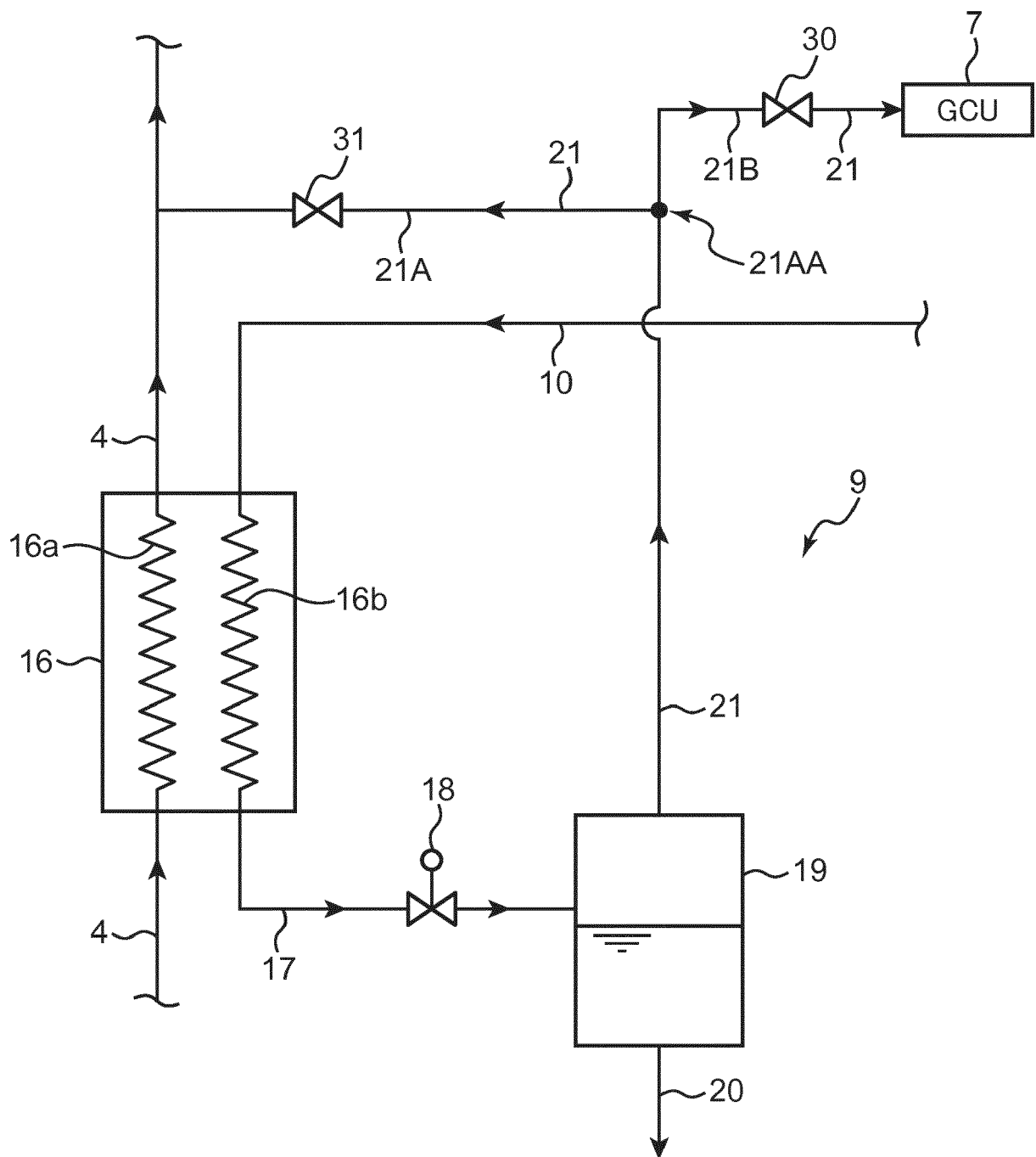


FIG. 4

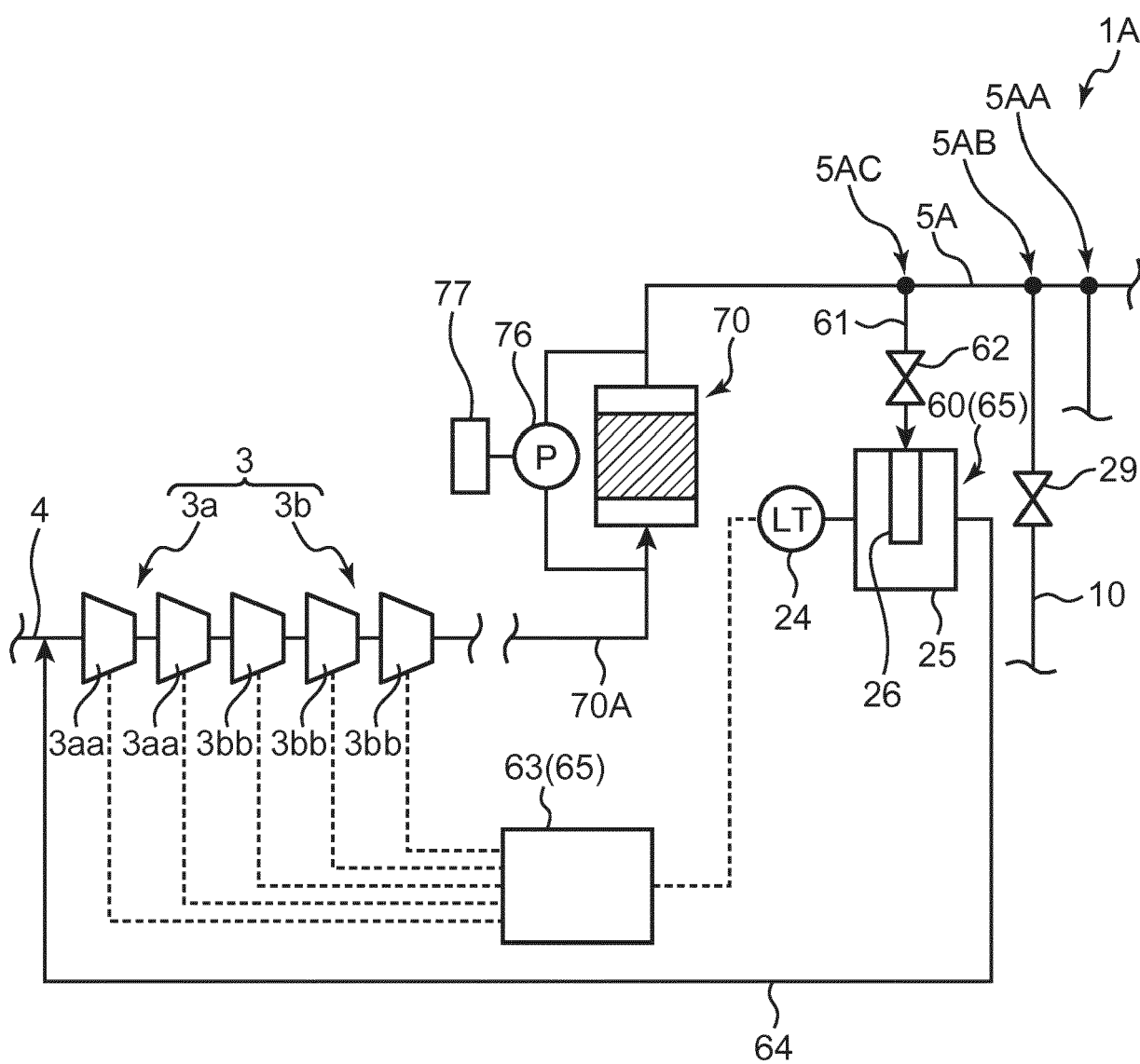


FIG. 5

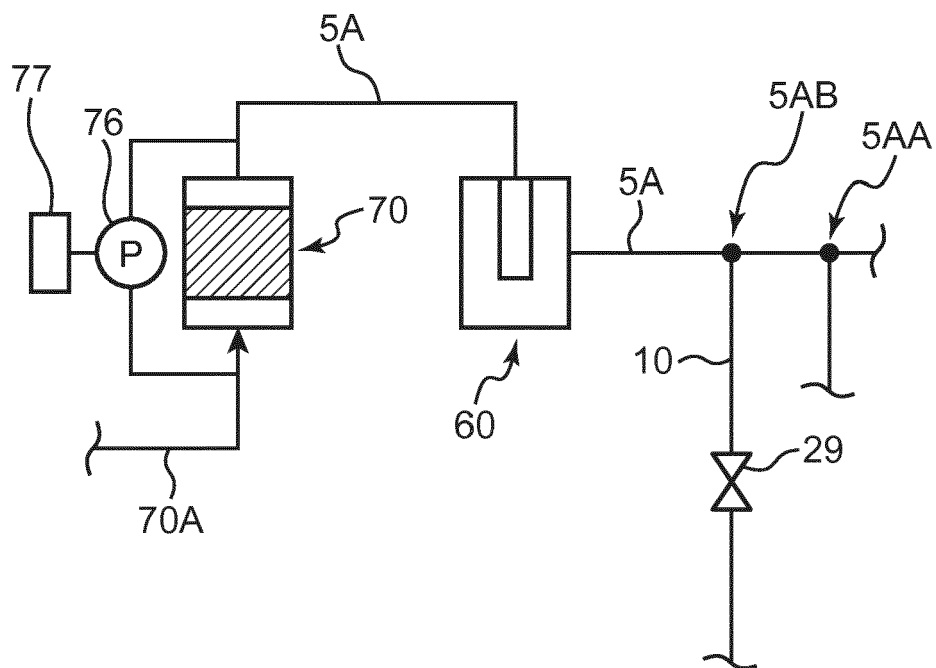


FIG. 6

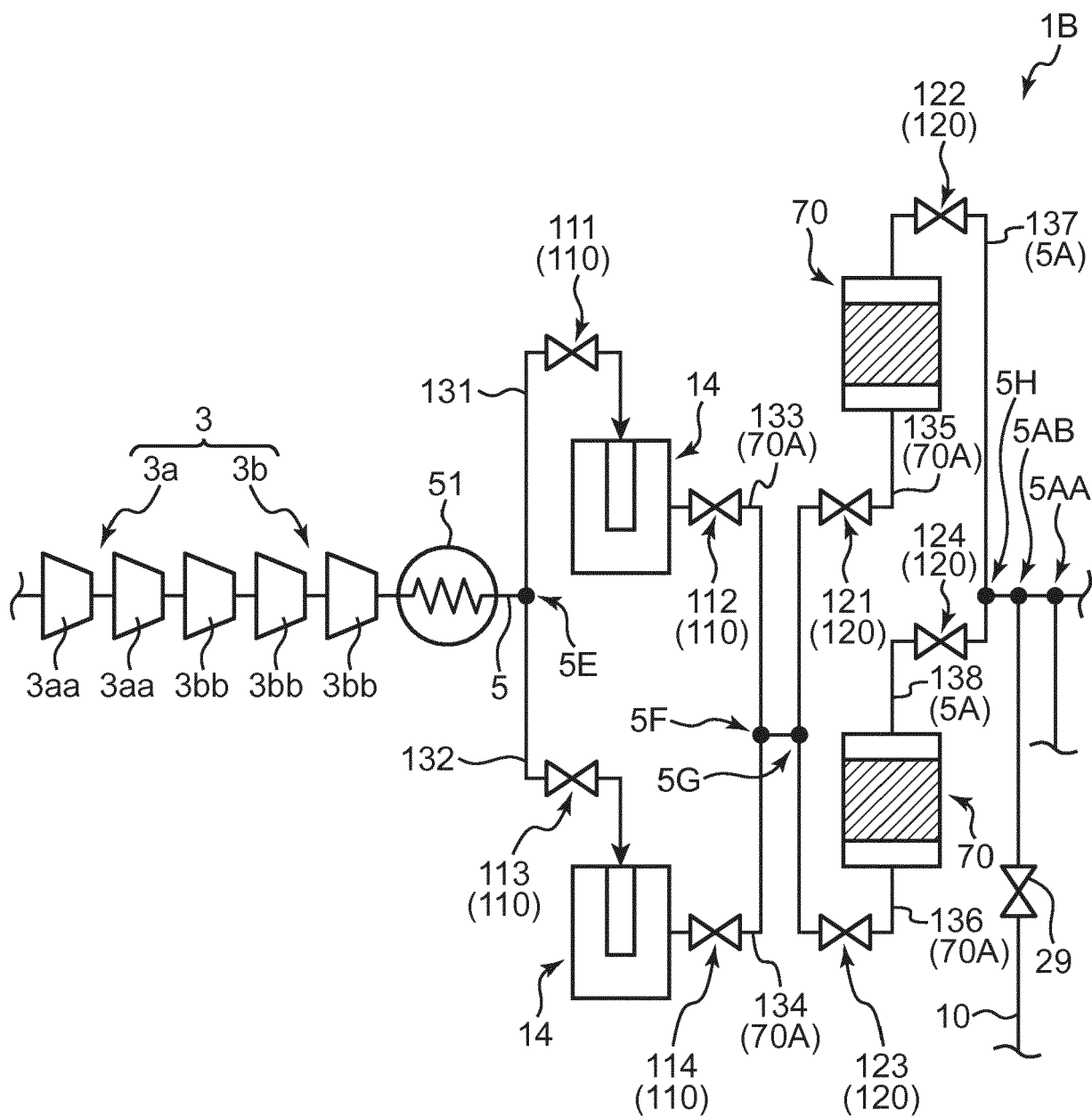


FIG. 7

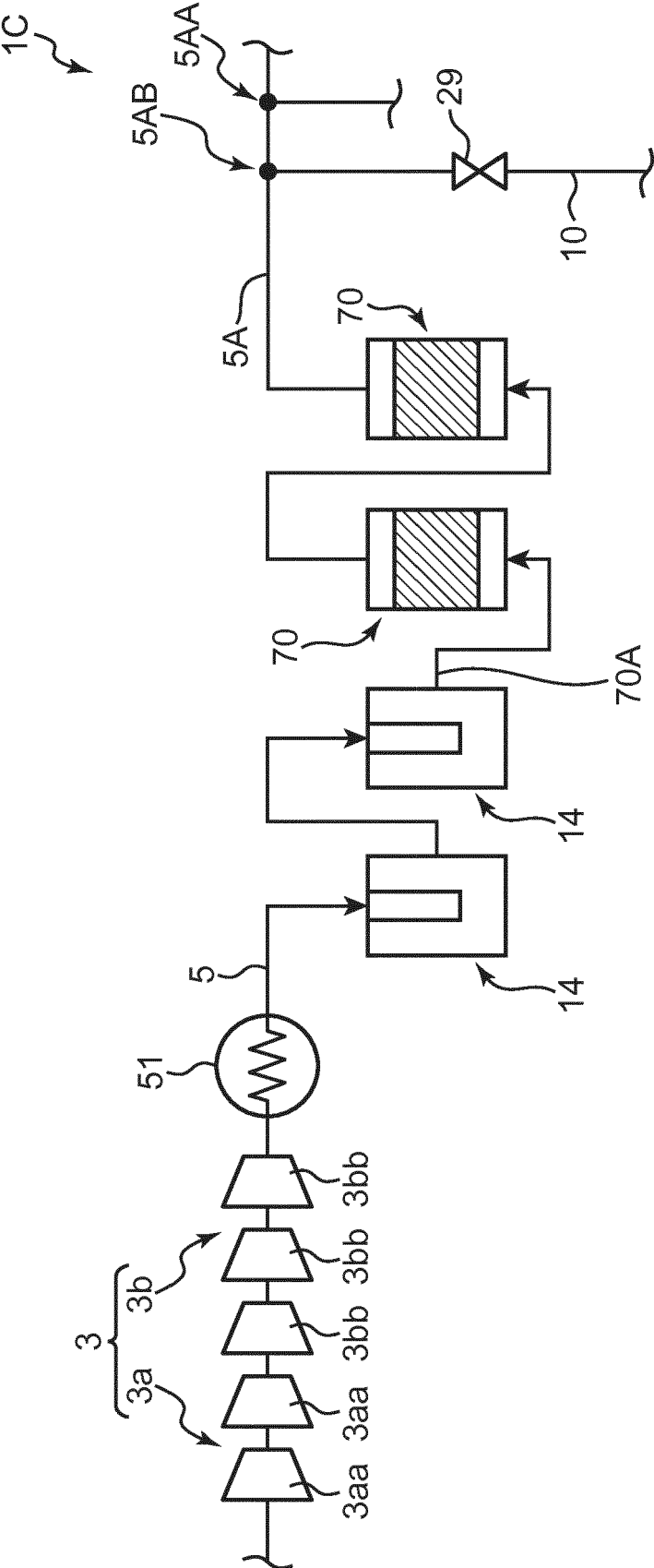


FIG. 8

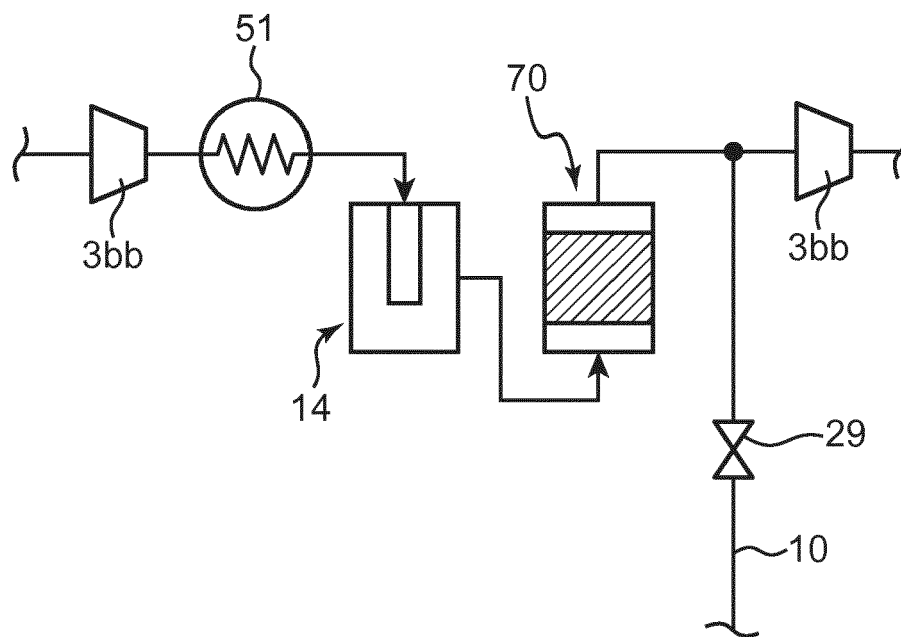
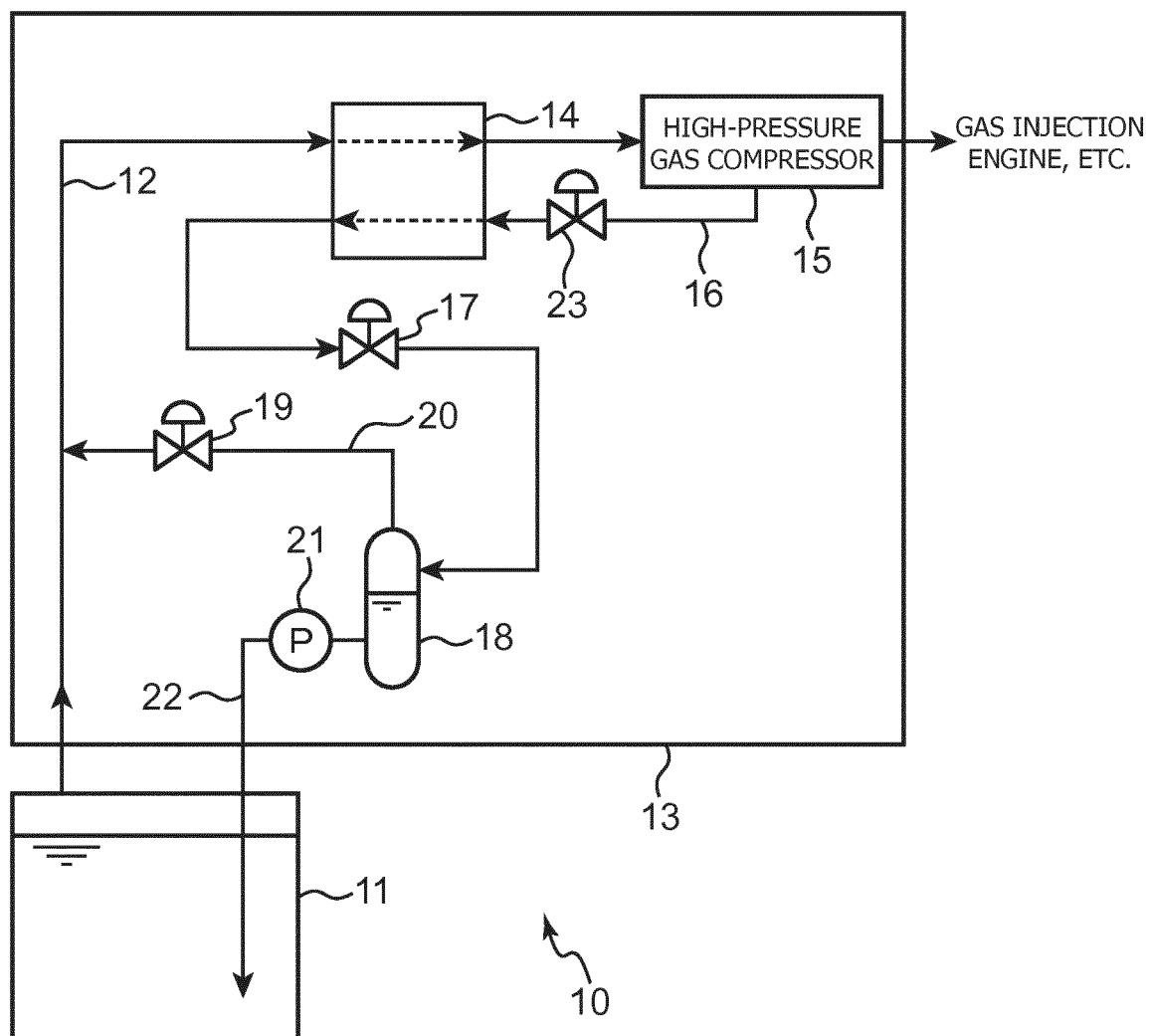


FIG. 9





EUROPEAN SEARCH REPORT

Application Number
EP 17 20 7990

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