



(51) International Patent Classification:

F25J 1/00 (2006.01)

F25J 1/02 (2006.01)

(21) International Application Number:

PCT/JP2017/034766

(22) International Filing Date:

26 September 2017 (26.09.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: **CHIYODA CORPORATION** [JP/JP];
4-6-2, Minatomirai, Nishi-ku, Yokohama-shi, Kanagawa,
2208765 (JP).

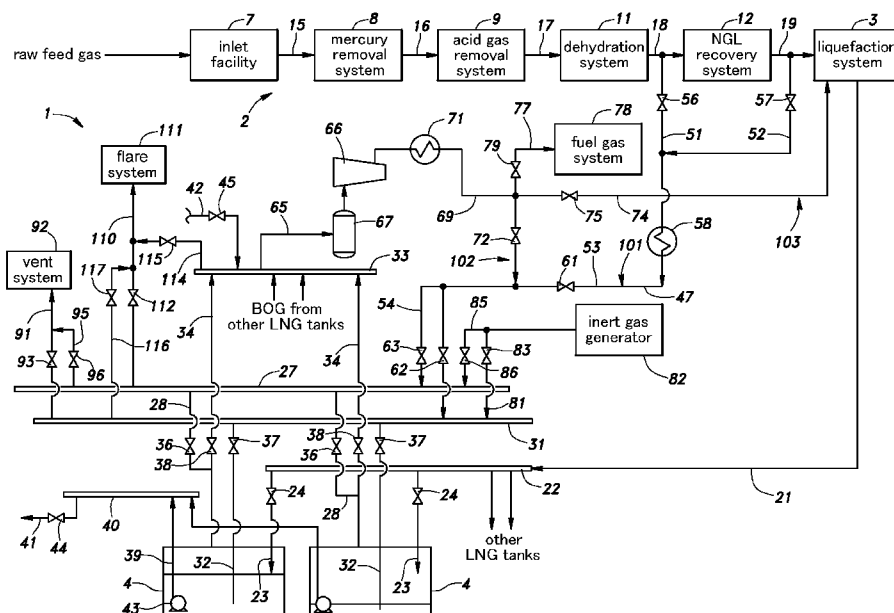
(72) Inventors: **TADANO Kenichi**; c/o Chiyoda Corporation,
4-6-2, Minatomirai, Nishi-ku, Yokohama-shi, Kanagawa,
2208765 (JP). **WATANABE Naoki**; c/o Chiyoda Corpo-
ration, 4-6-2, Minatomirai, Nishi-ku, Yokohama-shi, Kana-
gawa, 2208765 (JP).

(74) Agent: **OSHIMA & PARTNERS**; 2-20, Kanda-Jimbocho,
Chiyoda-ku, Tokyo, 1010051 (JP).

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: FLOATING STRUCTURE FOR PRODUCING LNG AND MAINTENANCE METHOD OF LNG TANK IN THE FLOATING STRUCTURE



(57) Abstract: Provided is a floating structure that is capable of supplying a hydrocarbon gas to an LNG tank during a maintenance work for the LNG tank by utilizing essential facility for LNG production. A floating structure (1) having a dehydration system (11), a liquefaction system (3), an LNG tank (4), a BOG compressor (66), a first line (101) for connecting a downstream portion of the dehydration system with the LNG tank to supply the natural gas from which moisture has been removed to the LNG tank, and a second line (102) connecting the BOG compressor with the LNG tank to supply the compressed BOG to the LNG tank.

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

Description

Title of Invention: FLOATING STRUCTURE FOR PRODUCING LNG AND MAINTENANCE METHOD OF LNG TANK IN THE FLOATING STRUCTURE

Technical Field

[0001] The present invention relates to a floating structure for producing LNG and a maintenance method of an LNG tank in such a floating structure.

Background Art

[0002] A floating structure known as LNG-FPSO (Floating Production, Storage and Off-loading) unit includes LNG production facilities and a plurality of LNG tanks for storing the produced LNG in the hull of the floating structure. The LNG tanks are required to be inspected and repaired if necessary at predetermined intervals according to international regulations. In order to allow an inspector to enter an LNG tank, the LNG in the LNG tank is required to be removed by evaporating the residual LNG by heating the tank, purging the LNG gas in the LNG tank with inert gas, and purging the inert gas with the air. After the inspection of the LNG tank has been completed, the air in the LNG tank is purged by inert gas, the inert gas is then replaced by hydrocarbon gas, and the LNG tank is cooled before supplying LNG to be stored in the LNG tank back into the LNG tank.

[0003] In the technology disclosed in Emi, Hirohiko (1991) "LNG carrier / LNG carrier technical document", Japan, Ship Technology Association, p. 91-94, for heating an LNG tank for maintenance purpose, an LNG carrier has an LNG vaporizer that vaporizes LNG from another LNG carrier or an LNG receiving terminal/production plant, a high duty compressor that compresses natural gas vaporized from the own LNG tanks, and a warming up heater that heats the compressed natural gas. The compressed and heated natural gas is supplied to the LNG tank which is to be subjected to maintenance work and the LNG in the LNG tank is vaporized. Also, the hydrocarbon gas vaporized by the LNG vaporizer is supplied to replace the inert gas with the hydrocarbon gas.

[0004] Since LNG-FPSO has LNG production facilities and LNG supply facilities, the space on the hull is limited. Therefore, it is difficult to find a space for arranging facilities used only for maintenance such as vaporizer and high duty compressor.

[0005] The present invention was made in view of such a background, and has a primary object to provide a floating structure capable of omitting facilities that are used only for maintenance.

A second object of the present invention is to provide a method for performing a

maintenance work for an LNG tank that does not need facilities used only for maintenance.

Summary of Invention

[0006] Such objects can be accomplished by providing a floating structure (1) for producing LNG, comprising:

- a dehydration system (11) for removing moisture from natural gas;
- a liquefaction system (3) for liquefying the natural gas from which moisture is removed to produce LNG;
- an LNG tank (4) for storing the LNG produced by the liquefaction system;
- a BOG compressor (66) for compressing BOG generated in the LNG tank;
- a first line (101) for connecting a downstream portion of the dehydration system with the LNG tank to supply the natural gas from which moisture has been removed to the LNG tank; and
- a second line (102) connecting the BOG compressor with the LNG tank to supply the compressed BOG to the LNG tank.

[0007] According to this aspect of the present invention, it is possible to supply the natural gas from which moisture has been removed via the first line to the LNG tank, and to supply the BOG to the LNG tank via the second line. Thus, at least one of the natural gas from which moisture has been removed and the BOG can be used to vaporize a part of the LNG remaining in the LNG tank during a maintenance work. Since the natural gas and the BOG supplied to the LNG tank do not contain moisture, they do not cause icing in the conduit or in the LNG tank. Because the BOG compressor and the dehydration system are already present in the floating structure as a part of the existing facilities, there is no need to add a new equipment to the floating structure. Therefore, equipment used only for maintenance such as an LNG vaporizer, a high duty compressor and a warming up heater provided in a conventional LNG tanker can be removed.

[0008] The floating structure may further comprise a first heat exchanger (58) provided in the first line to adjust a temperature of the natural gas from which moisture is removed by the dehydration system.

[0009] According to this aspect of the present invention, it is possible to adjust the temperature of the natural gas supplied to the LNG tank with the first heat exchanger.

[0010] According to a preferred embodiment of the present invention, the floating structure may further comprise an NGL recovery system (12) connected between the dehydration system and the liquefaction system to remove heavy hydrocarbons from the natural gas from which moisture has been removed; wherein the first line connects a downstream portion of the NGL recovery system with the LNG tank.

- [0011] According to this aspect of the present invention, since the natural gas freed from the NGL recovery system is supplied to the LNG tank to vaporize residual LNG, it is possible to prevent the heavy hydrocarbons accumulation in the LNG tank.
- [0012] The floating structure may further comprise a first heat exchanger (58) provided in the first line to adjust a temperature of the natural gas from which heavy hydrocarbons have been removed by the NGL recovery system.
- [0013] According to this aspect of the present invention, it is possible to adjust the temperature of the natural gas supplied to the LNG tank by the first heat exchanger (58).
- [0014] The floating structure may further comprise a second heat exchanger (71) provided in the second line to cool the BOG compressed by the BOG compressor.
- [0015] According to this aspect of the present invention, it is possible to cool the BOG compressed by the BOG compressor.
- [0016] The floating structure may further comprise a fuel gas system (78) connected to the second line to burn the BOG compressed by the BOG compressor as a fuel.
- [0017] According to this aspect of the present invention, since the excess BOG can be used in the fuel gas system, the amount of the BOG released to the air can be minimized.
- [0018] The floating structure may further comprise a third line (103) for connecting the second line with the liquefaction system to supply the compressed BOG to the liquefaction system.
- [0019] According to this aspect of the present invention, since the excess BOG can be returned to the liquefaction system, the amount of the BOG released to the air can be minimized.
- [0020] The floating structure may further comprise a flow control valve provided in each of the first line and the second line.
- [0021] According to this aspect of the present invention, it is possible to selectively supply the natural gas and/or the BOG to the LNG tank.
- [0022] The present invention also provides a method for replacing LNG in an LNG tank with the air in a floating structure (1) including a dehydration system (11) for removing moisture from natural gas, a liquefaction system (3) for liquefying the natural gas from which moisture has been removed to produce LNG, an LNG tank (4) for storing the LNG produced by the liquefaction system, and a BOG compressor (66) for compressing BOG generated in the LNG tank, the method comprising:
- a first step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to the LNG tank to vaporize the LNG remaining in the LNG tank;
 - a second step of supplying inert gas to the LNG tank to replace hydrocarbon gas remaining in the LNG tank with the inert gas following the first step; and
 - a third step of supplying the air to the LNG tank to replace the inert gas with the air

following the second step.

- [0023] According to this aspect of the present invention, at least one of the natural gas from which moisture has been removed and the BOG can be used to vaporize the LNG remaining in the LNG tank during a maintenance work. Since the natural gas and the BOG supplied to the LNG tank do not contain moisture, they do not cause icing in the conduit or the LNG tank. Since the present invention uses the BOG compressor and the dehydration system that are essential system for the LNG production facility, it does not require the LNG vaporizer, the high duty compressor, and the warm up heater that were provided by the conventional LNG carrier.
- [0024] Preferably, the first step includes supplying the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are not in operation, and supplying at least one of the natural gas dehydrated in the dehydration system and the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are in operation.
- [0025] According to this aspect of the present invention, it is possible to select the source of the hydrocarbon gas to be supplied to the LNG tank depending on the operating condition of the liquefaction system.
- [0026] The first step may include removing heavy hydrocarbons from the dehydrated natural gas, and supplying the natural gas from which the heavy hydrocarbons are removed to the LNG tank to vaporize the LNG remaining in the LNG tank.
- [0027] According to this aspect of the present invention, since the natural gas from which the heavy hydrocarbons have been removed is supplied to the LNG tank, it is possible to avoid an accumulation of heavy hydrocarbons in the LNG tank.
- [0028] The present invention also provides a method for refilling LNG to an LNG tank initially filled with the air in a floating structure (1) including a dehydration system (11) for removing moisture from natural gas, a liquefaction system (3) for liquefying the natural gas from which moisture has been removed to produce LNG, an LNG tank (4) for storing the LNG produced by the liquefaction system, and a BOG compressor (66) for compressing BOG generated in the LNG tank, the method comprising:
- a first step of supplying inert gas to the LNG tank to replace the air in the LNG tank with the inert gas;
 - a second step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to replace the inert gas with hydrocarbon gas following the first step, and
 - a third step of supplying the LNG produced in the liquefaction system or stored in other LNG tanks to the LNG tank following the second step.
- [0029] According to this aspect of the present invention, at least one of the natural gas from which moisture has been removed and the BOG which is compressed by the BOG

compressor can be used to replace the inert gas in the LNG tank with a hydrocarbon gas to return back to normal tank operation. Because the BOG compressor and the dehydration system are already present in the floating structure as a part of the existing facilities, there is no need to add a new equipment to the floating structure.

- [0030] The second step may include supplying the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are not in operation, and supplying at least one of the natural gas dehydrated in the dehydration system and the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are in operation.
- [0031] According to this aspect of the present invention, it is possible to select the hydrocarbon gas to be supplied to the LNG tank according to the operating condition of the liquefaction system.
- [0032] The first step may include removing heavy hydrocarbons from the dehydrated natural gas, and supplying the natural gas from which the heavy hydrocarbons are removed to the LNG tank to replace the inert gas in the LNG tank with the dehydrated natural gas from which the heavy hydrocarbons are removed.
- [0033] According to this aspect of the present invention, since the natural gas from which the heavy hydrocarbons have been removed is supplied to the LNG tank, it is possible to avoid an accumulation of heavy hydrocarbons in the LNG tank.
- [0034] The present invention further provides a method for replacing and refilling LNG in an LNG tank in a floating structure (1) including a dehydration system (11) for removing moisture from natural gas, a liquefaction system (3) for liquefying the natural gas from which moisture has been removed to produce LNG, an LNG tank (4) for storing the LNG produced by the liquefaction system, and a BOG compressor (66) for compressing BOG generated in the LNG tank, the method comprising:
- a first step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to the LNG tank to vaporize the LNG remaining in the LNG tank;
 - a second step of supplying inert gas to the LNG tank to replace hydrocarbon gas remaining in the LNG tank with the inert gas following the first step; and
 - a third step of supplying the air to the LNG tank to replace the inert gas with the air following the second step;
 - a fourth step of performing maintenance work inside the LNG tank following the third step;
 - a fifth step of supplying inert gas to the LNG tank to replace the air in the LNG tank with the inert gas following the fourth step;
 - a sixth step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to replace the inert gas with hydrocarbon

gas following the fifth step, and

a seventh step of supplying the LNG produced in the liquefaction system or stored in other LNG tanks to the LNG tank following the sixth step.

[0035] According to this aspect of the present invention, at least one of the natural gas from which moisture has been removed and the BOG from which moisture has been removed can be used to vaporize the LNG remaining in the LNG tank, and to replace the inert gas in the LNG tank with a hydrocarbon gas during maintenance work. Since the natural gas and the BOG supplied to the LNG tank do not contain moisture, they do not cause icing in the conduit or the LNG tank. Because the BOG compressor and the dehydration system are already present in the floating structure as a part of the existing facilities, there is no need to newly add equipment to the floating structure.

Brief Description of Drawings

[0036] [fig.1]Figure 1 is a block diagram showing a simplified overall structure of a floating structure embodying the present invention;

[fig.2]Figure 2 is a block diagram showing a stream of dry gas and BOG in the vaporization step; and

[fig.3]Figure 3 is a block diagram showing a stream of dry gas and BOG in the hydrocarbon replacement step.

Description of Embodiments

[0037] A preferred embodiment of the present invention is described in the following with reference to the appended drawing.

[0038] (Floating structure)

Fig. 1 shows an LNG production facility constructed as a floating structure 1 known as FPSO (floating production storage and offloading) unit. Such a unit is also known as FLNG (floating liquefied natural gas) facilities. This floating structure 1 is configured to perform gas treatment, refining, liquefaction, storage and shipping of natural gas on a body of water. The floating structure 1 is provided with a hull that floats on the body of water, and a topside facility on the hull contains a purification system 2 and a liquefaction system 3. The hull contains a plurality of LNG tanks 4.

[0039] The purification system 2 includes an inlet facility 7 that accepts raw feed gas (natural gas), a mercury removal system 8 that removes mercury from the raw feed gas, an acid gas removal system 9 that removes acid gas from the raw feed gas, a dehydration system 11 for removing moisture from the raw feed gas and an NGL recovery system 12 for removing heavy hydrocarbons from the raw feed gas, which are arranged in that order from the upstream end of the feed flow. However, the NGL recovery system 12 is optional for the present invention, and may be omitted if the contents of heavy hydrocarbons in the raw feed gas is low enough.

- [0040] The dehydration system 11 removes moisture from the raw feed gas by contacting an adsorbent agent such as molecular sieve with the raw feed gas. The NGL recovery system 12 liquefies and removes heavy hydrocarbons in the raw feed gas by lowering the temperature and the pressure of the raw feed gas.
- [0041] The inlet facility 7 and the mercury removal system 8 are connected via a conduit 15, the mercury removal system 8 and the acid gas removal system 9 are connected via a conduit 16, the acid gas removal system 9 and the dehydration system 11 are connected via a conduit 17, and the dehydration system 11 and the NGL recovery system 12 are connected via a conduit 18. The raw feed gas passes through the mercury removal system 8, acid gas removal system 9, dehydration system 11, NGL recovery system 12 in order, and is purified. The purified natural gas contains methane as a main component.
- [0042] Liquefaction system 3 liquefies the refined natural gas by cooling, and produces LNG. The liquefaction system 3 may be based on known as mixed refrigerant process, a cascade process or any other liquefaction technologies. An inlet of liquefaction system 3 is connected to an outlet of NGL recovery system 12 via a conduit 19.
- [0043] The downstream end of the liquefaction system 3 is connected to an LNG rundown header 22 via a conduit 21. The LNG rundown header 22 is connected to the plurality of LNG tanks 4 via respective conduits 23. LNG in the liquefaction system 3 is supplied to each LNG tank 4 via the LNG rundown header 22. Each of the conduits 23 is provided with a respective pressure control valves 24 to distribute equally to each LNG tank 4.
- [0044] The plurality of LNG tanks 4 are connected to a gas header 27 via respective conduits 28 and are connected to an inert gas header 31 via respective conduits 32. In addition, the plurality of conduits 28 are connected to the BOG header 33 via respective conduits 34. It is preferable that the end of the conduit 32 connected to the inert gas header 31 on the LNG tank 4 side is disposed at the bottom of the LNG tank 4. Manual valves 36 are provided in each of the conduits 28 on the portion on the side of the gas header 27 from the connecting portion with the conduit 34. Each of the conduits 32 is provided with a respective manual valve 37. Each of the conduits 34 is provided with a respective manual valve 38.
- [0045] Each LNG tank 4 is connected to an offloading header 40 via a corresponding conduit 39. Each LNG tank 4 has a pump 43 which sends the LNG to the offloading header 40. The offloading header 40 is connectable to an LNG tank of an LNG tanker existing around the floating structure 1 via an LNG offloading line 41. The LNG offloading line 41 includes offloading facility. The BOG header 33 is connectable to the LNG tank of the LNG tanker via an LNG tanker BOG return line 42. The LNG stored in the LNG tank 4 of the floating structure 1 is supplied to the LNG tank of the LNG

tanker via the offloading header 40, the LNG offloading line 41. BOG generated in the LNG tank of the LNG tanker flows to the BOG header 33 through the LNG tanker BOG return line 42. The LNG offloading line 41 and the LNG tanker BOG return line 42 may be configured as loading arms or floating hoses floating on the sea. An isolation valve 44 is provided between the offloading header 40 and the LNG offloading line 41, and an isolation valve 45 is provided between the BOG header 33 and the LNG tanker BOG return line 42.

[0046] The conduit 18 between the dehydration system 11 and the NGL recovery system 12 and the conduit 19 between the NGL recovery system 12 and the liquefaction system 3 are connected to the inert gas header 31 via a conduit 47. The conduit 47 includes a first upstream pipe part 51 connected at one end to the conduit 18, a second upstream pipe part 52 connected at one end to the conduit 19, a downstream pipe portion 53 connected to the other end of the first upstream pipe part 51 and the other end of the second upstream pipe part 52 at one end and connected to the inert gas header 31 at the other end. The downstream pipe portion 53 of the conduit 47 is connected to the gas header 27 via a conduit 54.

[0047] A manual valve 56 is provided in the first upstream pipe part 51 and a manual valve 57 is provided in the second upstream pipe part 52. The downstream pipe portion 53 provides a first heat exchanger 58, a flow control valve 61, and a manual valve 62 in order from the first upstream pipe part 51 side. The flow control valve 61 is provided on the first upstream pipe part 51 side from the connection portion with the conduit 54 in the downstream pipe portion 53 and the manual valve 62 is provided in the downstream pipe portion 53 from the connection portion with the conduit 54, inert gas header 31 side. The conduit 54 is provided with a manual valve 63.

[0048] The BOG header 33 is connected to a BOG compressor 66 via a conduit 65. The BOG compressor 66 consists of known as compressor such as a centrifugal compressor and a reciprocating compressor driven by an electric motor. The conduit 65 is provided with a suction drum 67. The suction drum 67 brings the BOG into contact with the LNG inside the suction drum 67, thereby adjusting the temperature of the BOG supplied to the BOG compressor 66 to a predetermined temperature. The processing maximum capacity of the BOG compressor 66 may be 50-60 t/h, for example.

[0049] The discharge port of the BOG compressor 66 is connected via a conduit 69 to the portion between the flow control valve 61 and the conduit 54 in the conduit 47. The conduit 69 is provided with a second heat exchanger 71 and a flow control valve 72 in order from the BOG compressor 66.

[0050] The part between the second heat exchanger 71 and the flow control valve 72 of the conduit 69 is connected to the liquefaction system 3 via a conduit 74. The conduit 74 is provided with a control valve 75.

- [0051] The portion between the second heat exchanger 71 and the flow control valve 72 of the conduit 69 is connected to a fuel gas system 78 via a conduit 77. The fuel gas system 78 consumes the BOG compressed by the BOG compressor 66 as a fuel, and may be an internal combustion engine that generates power. The internal combustion engine may be a gas turbine, for example. The conduit 77 is provided with a control valve 79.
- [0052] The inert gas header 31 is connected to an inert gas generator 82 via a conduit 81. The inert gas generator 82 may produce a flue gas, for example. The inert gas generator 82 burns marine diesel oil or heavy fuel to produce inert gas with oxygen content of 2-4 %. The conduit 81 is provided with a manual valve 83. The portion between the inert gas generator 82 and the manual valve 83 in the conduit 81 is connected to the gas header 27 via a conduit 85. The conduit 85 is provided with a manual valve 86.
- [0053] The inert gas generated by the inert gas generator 82 is supplied to the LNG tank 4 via the inert gas header 31 during maintenance work to be described later, and hydrocarbon gas in the LNG tank 4 is purged with the inert gas.
- [0054] The inert gas header 31 is connected to a vent system 92 via a conduit 91. The conduit 91 is provided with a manual valve 93. The portion between the vent system 92 and the manual valve 93 in the conduit 91 is connected to the gas header 27 via a conduit 95. The conduit 95 is provided with a manual valve 96. The vent system 92 discharges inert gas or air in the LNG tank 4 through the inert gas header 31 and the gas header 27 to the atmosphere.
- [0055] The gas header 27 is connected to the flare system 111 via a conduit 110. The conduit 110 is provided with a manual valve 112. The portion between the flare system 111 and the manual valve 112 in the conduit 110 is connected to the inert gas header 31 via a conduit 116. The conduit 116 is provided with a manual valve 117. The portion between the flare system 111 and the manual valve 112 in the conduit 110 is connected to the BOG header 33 via a conduit 114. The conduit 114 is provided with a manual valve 115. The flare system 111 burns BOG and releases it into the atmosphere.
- [0056] The inert gas generator 82 can also supply the air in addition to the inert gas. The air is supplied from the inert gas generator 82 via conduit 81 to inert gas header 31 and is supplied to gas header 27 via conduit 85. The air supplied to the gas header 27 is supplied to the upper part of the LNG tank 4 via a conduit 28.
- [0057] During normal operation, the BOG generated in the LNG tanks 4 flows to the BOG header 33 via the respective conduits. BOG generated in the LNG tanker flows into the BOG header 33 via the LNG tanker BOG return line 42. The temperature of BOG collected in the BOG header 33 is adjusted by the suction drum 67 and compressed to a

predetermined pressure by the BOG compressor 66. The compressed BOG is cooled in the second heat exchanger 71 and supplied to the liquefaction system 3 or the fuel gas system 78. If the liquefaction system 3 and the fuel gas system 78 are in a maintenance or shutdown, the excess BOG is supplied to the flare system 111 through the conduit 114 from the BOG header 33.

[0058] (Maintenance work for LNG tanks)

Maintenance work is performed to one of the LNG tanks 4 at a time. The maintenance work of the LNG tank 4 in this case includes a preparatory process for enabling a worker to enter the LNG tank 4 so that the interior of the LNG tank may be inspected, and repaired if necessary. The maintenance work also includes a restoration process for bringing the LNG tank 4 back into normal operation.

[0059] The preparatory process includes a vaporization step of vaporizing the LNG remaining in the target LNG tank 4 and raising the temperature of the LNG tank 4 at the same time, an inert gas replacement step of replacing the hydrocarbons in the LNG tank 4 with an inert gas (flue gas, for example), and an air replacement step of replacing the inert gas in the LNG tank 4 with the air, which are performed in this order.

[0060] The vaporization step is preferably carried out when the amount of the LNG in the LNG tank 4 is small such as when the LNG in the LNG tank 4 has been loaded to an LNG tanker or shifted to other LNG tanks 4. In the vaporization step, at least one of the dehydrated natural gas (dry gas) supplied from the dehydration system 11 or the NGL recovery system 12 and the BOG (compressed BOG) compressed by the BOG compressor 66 is selected, and supplied to the LNG tank 4. The line connecting a downstream portion of the dehydration system 11 or the NGL recovery system 12 with the LNG tank 4 is referred to as a first line 101. The first line 101 supplies the natural gas from which moisture has been removed to the LNG tank 4. The first line 101 includes the first upstream pipe part 51, the second upstream pipe part 52, the conduit 47, the inert gas header 31, the conduit 32, the conduit 54, the gas header 27 and the conduit 28. The first line has the first heat exchanger 58 on the conduit 47.

[0061] As shown in FIG. 2, the dry gas sequentially passes through the conduit 18, the conduit 47, the inert gas header 31 and the conduit 32 from the outlet of the dehydration system 11 and is supplied to the LNG tank 4. Also, the dry gas passes through the conduit 19, the conduit 47, the inert gas header 31, and the conduit 32 in order from the outlet of the NGL recovery system 12 and is supplied to the LNG tank 4.

[0062] The compressed BOG passes through the discharge port of the BOG compressor 66, the conduit 69, the conduit 47, the inert gas header 31, and the conduit 32, and is supplied to the LNG tank 4. The conduit 69, the conduit 47, the inert gas header 31,

and the conduit 32 configure a second line 102. The second line 102 supplies compressed BOG to the LNG tank 4.

- [0063] By opening the flow control valve 61 and closing the flow control valve 72, the dry gas is supplied to the LNG tank 4. On the other hand, by opening the flow control valve 72 and closing the flow control valve 61, the compressed BOG is supplied to the LNG tank 4. The selection between the dry gas and the compressed BOG can be made by suitably adjusting the flow control valve 72 and the flow control valve 61.
- [0064] By opening the manual valve 56 and closing the manual valve 57, the dry gas from the outlet of the dehydration system 11 is supplied to the LNG tank 4. By opening the manual valve 57 and closing the manual valve 56, the dry gas from the outlet of the NGL recovery system 12 is supplied to the LNG tank 4. The gas that has passed through the NGL recovery system 12 is used as the dry gas in case the feed gas contains heavy hydrocarbons.
- [0065] In the vaporization step, the compressed BOG is typically selected as the gas to be supplied to the LNG tank 4 at the time of terminating the production of LNG, or when the operation of the dehydration system 11 and the liquefaction system 3 is terminated. On the other hand, during production of LNG, or during the operation of dehydration system 11 and the liquefaction system 3, one of the dry gas and the compressed BOG is selected as the gas to be supplied to LNG tank 4.
- [0066] The dry gas is heated in the first heat exchanger 58 and the compressed BOG is cooled in the second heat exchanger 71. The first heat exchanger 58 function as temperature regulators for adjusting the temperatures of the dry gas to values suitable for vaporizing the residual LNG and increasing the temperature of the LNG tank 4. The second heat exchanger 71 uses cooling water or air as cooling medium, and the temperature of the compressed BOG will be near cooling medium condition which is close to ambient temperature. However, this temperature is enough warmer for vaporizing the residual LNG and increasing the temperature of the LNG tank 4 for maintenance purpose.
- [0067] When the amount of the compressed BOG to be supplied to the LNG tank 4 for maintenance purpose is excessive, a part of the compressed BOG is supplied to the fuel gas system 78 and the liquefaction system 3. The conduit 69 and the conduit 74 connecting the BOG compressor 66 and the liquefaction system 3 and supplying the compressed BOG to the liquefaction system 3 configure a third line 103. If the compressed BOG is excessive even further, the compressed BOG is supplied from the BOG header 33 to the flare system 111 via the conduit 114. Therefore, it is preferable to execute the vaporization step when the amount of the generated BOG does not exceed the processing capacity of the BOG compressor 66.
- [0068] In the inert gas replacement step of the preparatory process, the inert gas generated

by the inert gas generator 82 sequentially passes through the conduit 81, the inert gas header 31 and the conduit 32 and is supplied to the LNG tank 4 for maintenance purpose. As a result, the BOG (hydrocarbon gas) in the LNG tank 4 is replaced with the inert gas, and the purged BOG sequentially passes through the conduit 28, the gas header 27, and the conduit 110 and flows to the flare system 111.

- [0069] In the air replacement step of the preparatory process, the air introduced from the inert gas generator 82 which is able to supply the air is supplied to the LNG tank 4 via the gas header 27, and the conduit 28 for maintenance purpose. As a result, the inert gas in the LNG tank 4 is replaced by the air, and the purged inert gas sequentially passes through the conduit 32, the inert gas header 31, and the conduit 91 and flows to the vent system 92.
- [0070] Upon completion of the air replacement step, the LNG tank 4 is filled with the air so that operators can safely enter the LNG tank 4. In the following work process, the operators are allowed to inspect and maintain the LNG tank 4 from inside the LNG tank 4.
- [0071] Upon completion of the maintenance work, a restoration process for bringing the LNG tank 4 back into operation is performed. The restoration process includes an inert gas replacement step of replacing the air in the LNG tank 4 with an inert gas, a hydrocarbon replacement step of replacing the inert gas in the LNG tank 4 with a hydrocarbon gas, and an LNG filling step of filling LNG into the LNG tank, which are performed in that order.
- [0072] In the inert gas replacement step of the restoration process, the inert gas generated by the inert gas generator 82 is supplied to the LNG tank 4 via the conduit 81, the inert gas header 31, and the conduit 32. As a result, the air in the LNG tank 4 is replaced by the inert gas, and the purged air is forwarded to the vent system 92 via the conduit 28, the gas header 27, and the conduit 95.
- [0073] In the hydrocarbon replacement step of the restoration process, at least one of the dry gas and the compressed BOG is selected and supplied to the LNG tank 4. The dry gas supplied from the outlet of the dehydration system 11 or the outlet of the NGL recovery system 12 is forwarded to the LNG tank 4 via the first line 101. The compressed BOG is supplied from the discharge port of the BOG compressor 66, and is forwarded to the LNG tank 4 via the second line 102.
- [0074] As shown in FIG. 3, in the hydrocarbon replacement step of the restoration process, the dry gas or compressed BOG supplied to conduit 47 is supplied to LNG tank 4 via the conduit 54, the gas header 27 and the conduit 28. The gas which is to be supplied to the LNG tank 4 can be selected by the manual valve 56, the manual valve 57, the flow control valve 61, and the flow control valve 72. As a result, the inert gas in the LNG tank 4 is replaced by the hydrocarbon gas, and the inert gas sequentially passes

through the conduit 32, the inert gas header 31, and the conduit 116 and flows to the flare system 111.

[0075] In the LNG filling step, the LNG generated in the liquefaction system 3 is supplied to the target LNG tank 4 via the conduit 21, the LNG rundown header 22, and the conduit 23. In addition, the LNG from other LNG tanks 4 may be supplied to the target LNG tank 4 via a spray header (not shown). As a result, the hydrocarbon gas in the LNG tank 4 is replaced by the LNG, and the restoration process of the LNG tank 4 is completed. The hydrocarbon gas passes through the conduit 34, the BOG header 33, the conduit 65, and the suction drum 67, is compressed by the BOG compressor 66, and is then supplied to the fuel gas system 78 or liquefaction system 3.

[0076] In the floating structure 1 configured as described above, the dry gas can be supplied to the LNG tank 4 via the first line 101, and the compressed BOG can be supplied to the LNG tank 4 via the second line 102. Thus, at least one of the dry gas and the compressed BOG can be used to vaporize the remaining LNG in the LNG tank 4 during maintenance work. Since the BOG compressor 66 and the dehydration system 11 are conventionally provided in the floating structure 1, there is no need to add new facilities.

[0077] The dry gas adjusted to an appropriate temperature by the first heat exchanger 58 and the compressed BOG cooled to an appropriate temperature by the second heat exchanger 71 are supplied to the LNG tank 4 for maintenance work. Such an appropriate temperature could be a temperature lower than the maximum design temperature of LNG tanks 4 or a temperature near cooling medium condition. This makes it possible to efficiently raise the temperature of the LNG tank in the vaporization step in the preparatory process.

[0078] By using the natural gas or the dry gas that has passed through the NGL recovery system 12, it is possible to minimize the residual heavy hydrocarbons that may remain in the LNG tank 4.

[0079] Since the excess BOG can be supplied to the fuel gas system 78 or the liquefaction system 3 for reuse, the amount of the BOG released to the atmosphere or flared can be minimized, and the energy efficiency can be increased.

[0080] Although the present invention has been described in terms of preferred embodiments thereof, it is obvious to a person skilled in the art that various alterations and modifications are possible without departing from the scope of the present invention. For example, in the vaporization step or the hydrocarbon replacement step, both the dry gas and the compressed BOG may be supplied to the same LNG tank.

List of the Numerals

[0081] 1 floating structure
3 liquefaction system

4 LNG tank
11 dehydration system
12 NGL recovery system
22 LNG rundown header
27 gas header
31 inert gas header
33 BOG header
40 offloading header
41 LNG offloading line
58 first heat exchanger
61 flow control valve
66 BOG compressor
67 suction drum
71 second heat exchanger
72 flow control valve
78 fuel gas system
92 vent system
111 flare system
101 first line
102 second line
103 third line

Claims

- [Claim 1] A floating structure for producing LNG, comprising:
a dehydration system for removing moisture from natural gas;
a liquefaction system for liquefying the natural gas from which moisture is removed to produce LNG;
an LNG tank for storing the LNG produced by the liquefaction system;
a BOG compressor for compressing BOG generated in the LNG tank;
a first line for connecting a downstream portion of the dehydration system with the LNG tank to supply the natural gas from which moisture has been removed to the LNG tank; and
a second line connecting the BOG compressor with the LNG tank to supply the compressed BOG to the LNG tank.
- [Claim 2] The floating structure according to claim 1, further comprising a first heat exchanger provided in the first line to adjust a temperature of the natural gas from which moisture is removed by the dehydration system.
- [Claim 3] The floating structure according to claim 1, further comprising an NGL recovery system connected between the dehydration system and the liquefaction system to remove heavy hydrocarbons from the natural gas from which moisture has been removed;
wherein the first line connects a downstream portion of the NGL recovery system with the LNG tank.
- [Claim 4] The floating structure according to claim 3, further comprising a first heat exchanger provided in the first line to adjust a temperature of the natural gas from which heavy hydrocarbons have been removed by the NGL recovery system.
- [Claim 5] The floating structure according to claim 1, further comprising a second heat exchanger provided in the second line to cool the BOG compressed by the BOG compressor.
- [Claim 6] The floating structure according to claim 1, further comprising a fuel gas system connected to the second line to burn the BOG compressed by the BOG compressor as a fuel.
- [Claim 7] The floating structure according to claim 1, further comprising a third line for connecting the second line with the liquefaction system to supply the compressed BOG to the liquefaction system.
- [Claim 8] The floating structure according to claim 1, further comprising a flow control valve provided in each of the first line and the second line.
- [Claim 9] A method for replacing LNG in an LNG tank with the air in a floating

structure including a dehydration system for removing moisture from natural gas, a liquefaction system for liquefying the natural gas from which moisture has been removed to produce LNG, an LNG tank for storing the LNG produced by the liquefaction system, and a BOG compressor for compressing BOG generated in the LNG tank, the method comprising:

a first step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to the LNG tank to vaporize the LNG remaining in the LNG tank;

a second step of supplying inert gas to the LNG tank to replace hydrocarbon gas remaining in the LNG tank with the inert gas following the first step; and

a third step of supplying the air to the LNG tank to replace the inert gas with the air following the second step.

[Claim 10] The method according to claim 9, wherein the first step includes supplying the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are not in operation, and supplying at least one of the natural gas dehydrated in the dehydration system and the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are in operation.

[Claim 11] The method according to claim 10, wherein the first step includes removing heavy hydrocarbons from the dehydrated natural gas, and supplying the natural gas from which the heavy hydrocarbons are removed to the LNG tank to vaporize the LNG remaining in the LNG tank.

[Claim 12] A method for refilling LNG to an LNG tank initially filled with the air in a floating structure including a dehydration system for removing moisture from natural gas, a liquefaction system for liquefying the natural gas from which moisture has been removed to produce LNG, an LNG tank for storing the LNG produced by the liquefaction system, and a BOG compressor for compressing BOG generated in the LNG tank, the method comprising:

a first step of supplying inert gas to the LNG tank to replace the air in the LNG tank with the inert gas;

a second step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to replace the inert gas with hydrocarbon gas following the first step,

and

a third step of supplying the LNG produced in the liquefaction system or stored in other LNG tanks to the LNG tank following the second step.

[Claim 13]

The method according to claim 12, wherein the second step includes supplying the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are not in operation, and supplying at least one of the natural gas dehydrated in the dehydration system and the BOG compressed by the BOG compressor to the LNG tank when the dehydration system and the liquefaction system are in operation.

[Claim 14]

The method according to claim 13, wherein the first step includes removing heavy hydrocarbons from the dehydrated natural gas, and supplying the natural gas from which the heavy hydrocarbons are removed to the LNG tank to replace the inert gas in the LNG tank with the dehydrated natural gas from which the heavy hydrocarbons are removed.

[Claim 15]

A method for replacing and refilling LNG in an LNG tank in a floating structure including a dehydration system for removing moisture from natural gas, a liquefaction system for liquefying the natural gas from which moisture has been removed to produce LNG, an LNG tank for storing the LNG produced by the liquefaction system, and a BOG compressor for compressing BOG generated in the LNG tank, the method comprising:

a first step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to the LNG tank to vaporize the LNG remaining in the LNG tank;

a second step of supplying inert gas to the LNG tank to replace hydrocarbon gas remaining in the LNG tank with the inert gas following the first step; and

a third step of supplying the air to the LNG tank to replace the inert gas with the air following the second step;

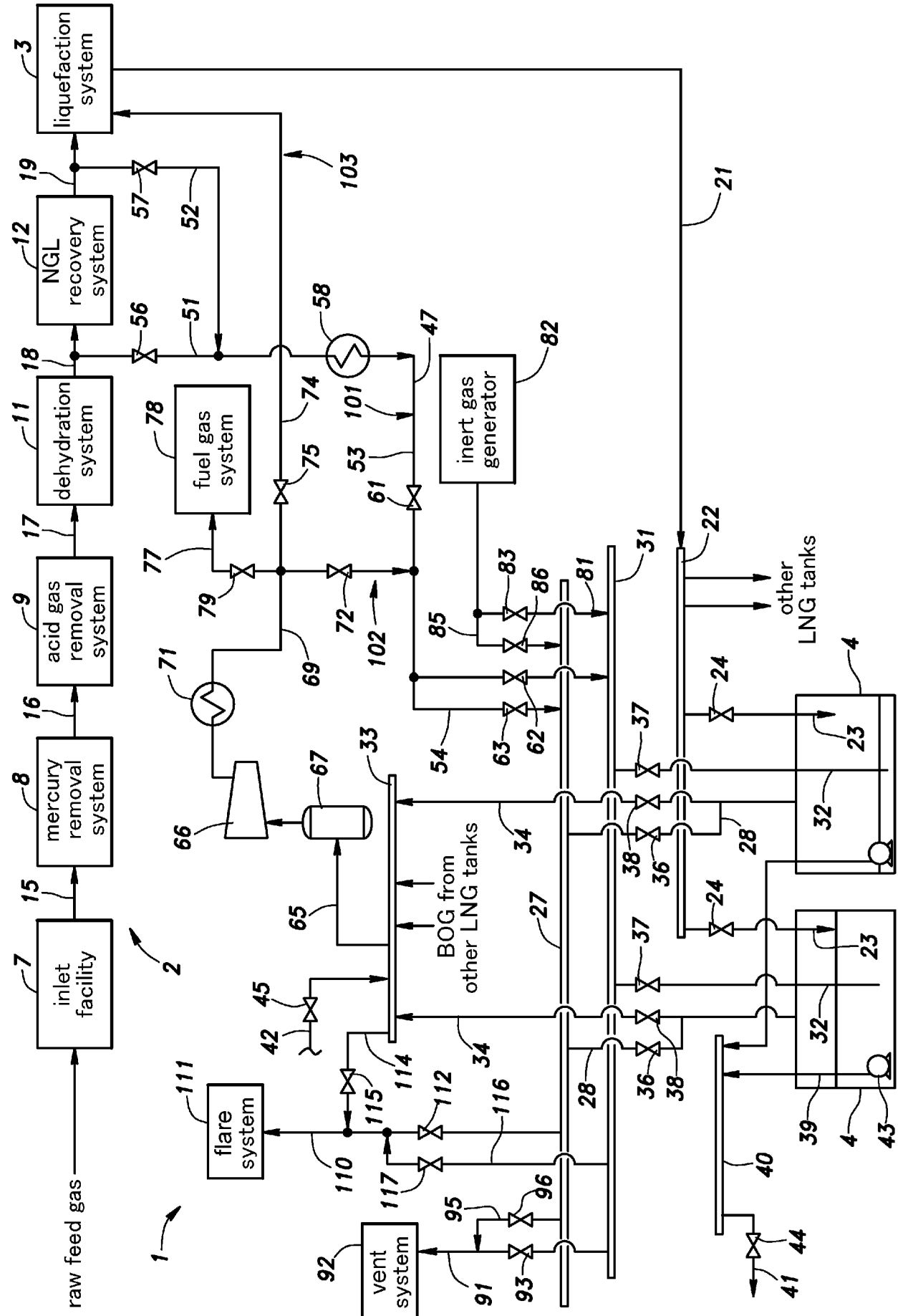
a fourth step of performing maintenance work inside the LNG tank following the third step;

a fifth step of supplying inert gas to the LNG tank to replace the air in the LNG tank with the inert gas following the fourth step;

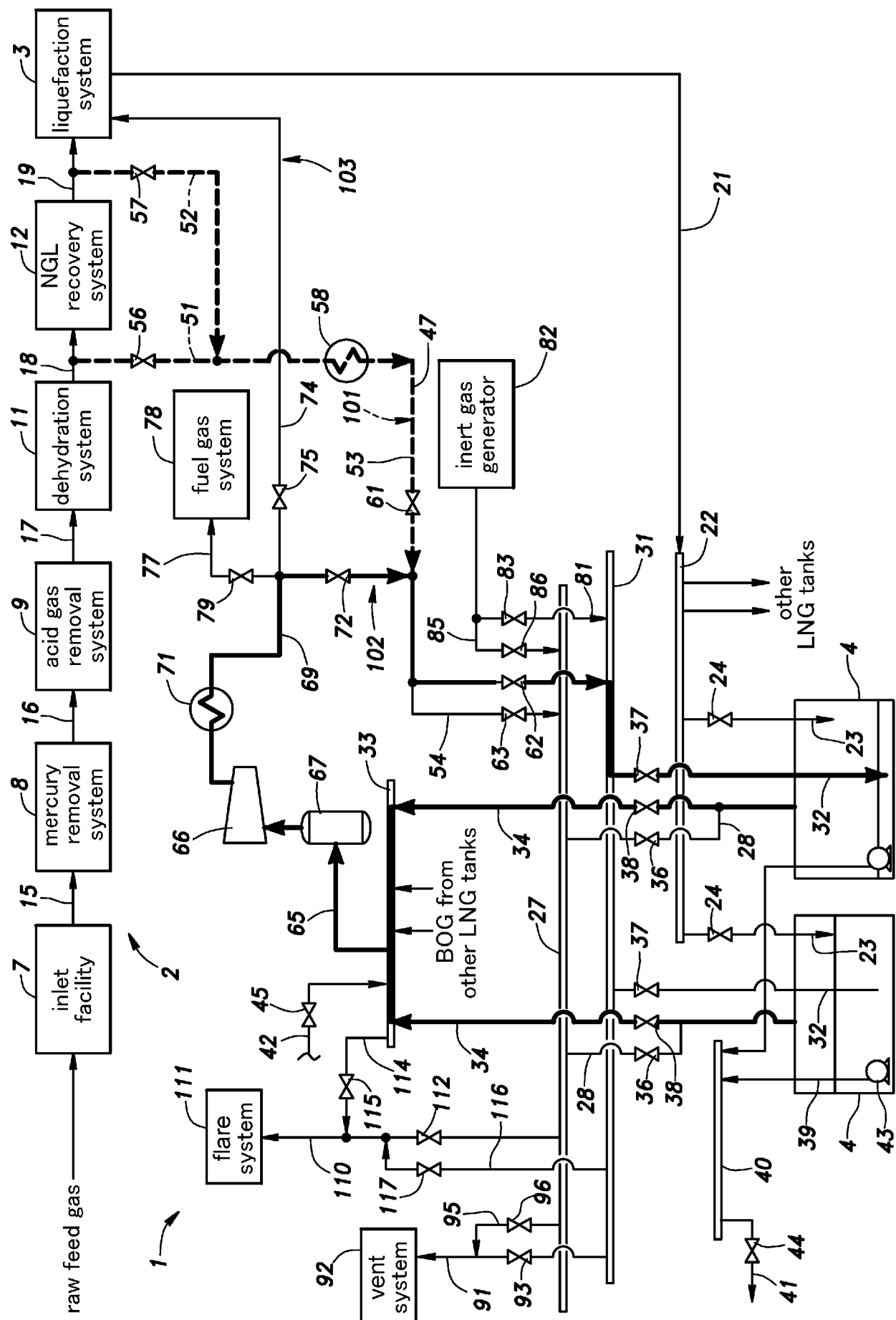
a sixth step of supplying the natural gas dehydrated in the dehydration system and/or the BOG compressed in the BOG compressor to replace

the inert gas with hydrocarbon gas following the fifth step, and a seventh step of supplying the LNG produced in the liquefaction system or stored in other LNG tanks to the LNG tank following the sixth step.

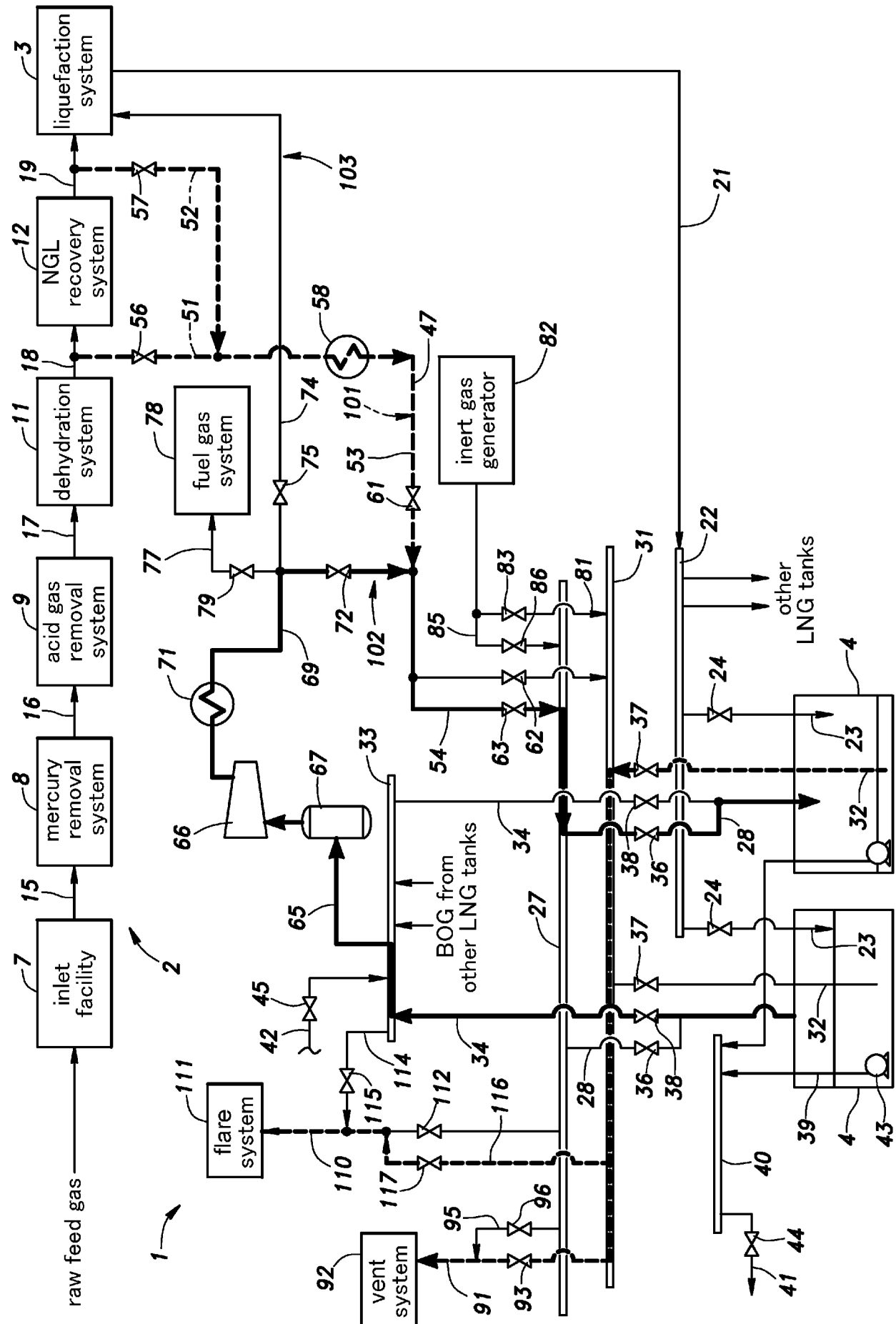
[Fig. 1]



[Fig. 2]



[Fig. 3]



INTERNATIONAL SEARCH REPORT

International application No

PCT/JP2017/034766

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F25J1/00 F25J1/02
 ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 F25J

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/366561 A1 (DAVIES PAUL RAYMOND [US] ET AL) 18 December 2014 (2014-12-18)	1-5,7-11
Y	figures 1, 2A, 2B paragraph [0009] paragraph [0020] paragraph [0024] - paragraph [0038] paragraph [0041] - paragraph [0045] -----	6,12-15
Y	US 3 374 638 A (BASILE NORMAN K ET AL) 26 March 1968 (1968-03-26)	6
A	column 1, line 30 - line 49 column 2, line 16 - line 17 -----	1-5,7-15
Y	KR 2016 0129403 A (DAEWOO SHIPBUILDING & MARINE [KR]) 9 November 2016 (2016-11-09)	12-15
A	figure 1 column 0005 - column 0017 column 0022 - column 0026 -----	1-11



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

15 June 2018

Date of mailing of the international search report

25/06/2018

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Karspeck, Sabine

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/JP2017/034766

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014366561 A1	18-12-2014	AU 2014281090 A1	21-01-2016
		CN 105452752 A	30-03-2016
		EP 3011226 A1	27-04-2016
		JP 2016522378 A	28-07-2016
		RU 2016101068 A	24-07-2017
		US 2014366561 A1	18-12-2014
		WO 2014204601 A1	24-12-2014

US 3374638 A	26-03-1968	DE 1551599 A1	08-10-1970
		JP S4823565 B1	14-07-1973
		SE 329099 B	28-09-1970
		US 3374638 A	26-03-1968

KR 20160129403 A	09-11-2016	NONE	
