

{DESCRIPTION}

{Title of Invention}

LIQUEFIED GAS VAPORIZATION DEVICE AND FLOATING UNIT
HAVING THE SAME

{Technical Field}

{0001}

The present disclosure relates to a liquefied gas vaporization device that gasifies a liquefied gas and to a floating unit having the same.

{Background Art}

{0002}

As disclosed in PTL 1, it is known that LNG is re-gasified when the LNG is supplied to the outside.

{Citation List}

{Patent Literature}

{0003}

{PTL 1}

Japanese Unexamined Patent Application Publication
(Translation of PCT Application) No. 2002-506960

{Summary of Invention}

{Technical Problem}

{0004}

During re-gasification, LNG in an LNG tank is consumed, and there is no risk of excessive increase in the pressure in the LNG tank. On the other hand, when re-gasification is

stopped, a boil-off gas (BOG) may occur in the LNG tank due to inevitable intrusive heat or the like, and there is a risk of excessive increase in the pressure in the LNG tank. In such a case, the BOG is taken out of the LNG tank, and is subjected to an incineration process in a gas combustion unit (GCU).

{0005}

To provide a GCU as a unit in order to perform an incineration process on the BOG, an installation space is required, and an initial investment is increased. To solve these problems, it is considered that, in a case of a unit having a regas boiler as a heat source used in re-gasification of LNG, the regas boiler may be used also as a GCU.

{0006}

However, when a regas boiler is used as a GCU, it is necessary to have a condenser with a large capacity to condense steam generated by the regas boiler, and this increases an initial investment.

{0007}

The present disclosure has been made in view of such circumstances and intends to provide a liquefied gas vaporization device that can condense steam generated during a boil-off gas incineration process without involving an increase in the initial investment and provide a floating unit having the liquefied gas vaporization device.

{Solution to Problem}

{0008}

A liquefied gas vaporization device according to one aspect of the present disclosure includes: a vaporizer configured to heat and gasify a liquefied gas; an anti-freezing solution circulation path which is connected to the vaporizer and in which an anti-freezing solution circulates; a boiler configured to combust a boil-off gas generated in a liquefied gas tank to generate steam; a steam heat exchanger configured to exchange heat between the steam generated by the boiler and the anti-freezing solution circulating in the anti-freezing circulation path; and a controller configured to perform control in a boil-off gas incineration process mode in which the boil-off gas generated in the liquefied gas tank is subjected to an incineration process in the boiler without a liquefied gas being heated in the vaporizer, and the controller delivers the steam generated in the boiler to the steam heat exchanger in the boil-off gas incineration process mode.

{0009}

In the boil-off gas incineration process mode, steam generated by the boiler is delivered to the steam heat exchanger. Heat is exchanged between the steam and an anti-freezing solution in the steam heat exchanger, and heat is dissipated via the anti-freezing solution circulating in the anti-freezing solution circulation path. This eliminates the

need for providing a large condenser that would otherwise be required in the boil-off gas incineration process mode, and the initial investment can be reduced.

As the anti-freezing solution, glycol such as ethylene glycol is used, for example.

{0010}

Furthermore, the liquefied gas vaporization device according to one aspect of the present disclosure includes a seawater heat exchanger provided in the anti-freezing solution circulation path and configured to exchange heat between an anti-freezing solution and seawater, and the controller performs control so that heat is dissipated from the anti-freezing solution to the seawater in the seawater heat exchanger in the boil-off gas incineration process mode.

{0011}

The seawater heat exchanger is provided in the anti-freezing solution circulation path, and heat is dissipated from the anti-freezing solution to seawater via the seawater heat exchanger. This allows condensing heat of steam to be effectively dissipated to the outside.

Note that, when a liquefied gas is gasified in a vaporizer, the seawater heat exchanger is used for heating, with seawater, the anti-freezing solution that has passed through the vaporizer.

{0012}

Furthermore, the liquefied gas vaporization device according to one aspect of the present disclosure includes: a steam turbine; and a steam condenser configured to condense steam discharged from the steam turbine, and the controller delivers the steam generated by the boiler to the steam condenser in the boil-off gas incineration process mode.

{0013}

Steam is delivered also to the steam condenser, and heat can be dissipated also in the steam condenser. Since it is not required to condense the whole steam in the steam condenser, it is not required to increase the size of the steam condenser. For example, the controller may perform control such that steam is firstly condensed in the steam condenser and, when the condensing amount exceeds a predetermined value, steam is condensed in the steam heat exchanger.

{0014}

Further, a floating unit according to one aspect of the present disclosure includes: the liquefied gas vaporization device described any of the above; and the liquefied gas tank that stores a liquefied gas, and the vaporizer gasifies a liquefied gas guided from the liquefied gas tank.

{0015}

By including the liquefied gas vaporization device described above, it is possible to provide a compact floating

unit. The floating unit may be, for example, a Floating Storage and Regasification Unit (FSRU).

Note that the invention of the present aspect can be combined with the invention of each of the aspects described above.

{Advantageous Effects of Invention}

{0016}

Since heat is dissipated by the anti-freezing solution circulation path, it is possible to condense steam generated during the boil-off gas incineration process without involving an increase in the initial investment.

{Brief Description of Drawings}

{0017}

{Fig. 1}

Fig. 1 is a schematic diagram of a configuration of an LNG vaporization unit applied to an FSRU according to one embodiment of the present disclosure, which illustrates an open-loop state.

{Fig. 2}

Fig. 2 is a schematic diagram of a configuration of the LNG vaporization unit of Fig. 1, which illustrates a combined loop state.

{Fig. 3}

Fig. 3 is a schematic diagram of a configuration of the LNG vaporization unit of Fig. 1, which illustrates a GCU mode

state.

{Description of Embodiments}

{0018}

Embodiments according to the present disclosure will be described below with reference to the drawings.

[First Embodiment]

A first embodiment of the present disclosure will be described below.

Fig. 1 illustrates a general configuration of an LNG vaporization device (liquefied gas vaporization device) 1 that gasifies an LNG (liquefied gas), which is a liquefied natural gas, and supplies the gasified LNG to the outside. The LNG vaporization device 1 is provided in a Floating Storage and Regasification Unit (FSRU), which is a floating unit.

{0019}

In addition to the LNG vaporization device 1, the FSRU has an LNG tank 3 and a diesel engine (power generating engine) 5. As the diesel engine 5, a Dual Fuel Diesel Engine (DFDE), for which both oil fuel and gas fuel are available, can be used.

{0020}

An LNG is stored in the LNG tank 3. A boil-off gas (BOG) generated inevitably due to invasive heat or the like is retained above the LNG tank 3. The BOG is guided to the diesel engine 5 via a BOG supply pipe 7. The BOG supply pipe

7 is provided with a BOG compressor 9 and a BOG cooling heat exchanger 10. After the BOG is pressurized by the BOG compressor 9 up to a pressure required by the diesel engine 5, the BOG is cooled by the BOG cooling heat exchanger 10. The BOG cooled by the BOG cooling heat exchanger 10 is guided to the diesel engine 5.

{0021}

The diesel engine 5 drives a generator (not illustrated). The generator driven by the diesel engine 5 generates power required inside the FSRU.

{0022}

The diesel engine 5 is provided with a turbocharger 12. The turbocharger 12 is provided with a discharge turbine and an air compressor (not illustrated). The discharge turbine and the air compressor are coupled by a common shaft and configured to rotate together.

{0023}

An exhaust gas that has passed through the discharge turbine of the turbocharger 12 is guided to an exhaust gas economizer 14. An exhaust gas bypass pipe 15 is provided so as to bypass the exhaust gas economizer 14. When the exhaust gas economizer 14 is used, a bypass valve 15a is closed. Note that, in the present embodiments, a valve in black represents a closed valve, and a valve in white represents an opened valve. Therefore, when the exhaust gas economizer 14 is used,

an exhaust gas economizer valve 14a provided upstream of the exhaust gas economizer 14 is opened.

{0024}

An air compressed by the air compressor of the turbocharger 12 is cooled in an air cooler 16 and then guided to the diesel engine 5.

{0025}

The LNG in the LNG tank 3 is guided to a gas-liquid separator 20 provided outside the LNG tank 3 by an LNG pump 18 provided in the LNG tank 3. An LNG separated from the gas-phase LNG by the gas-liquid separator 20 is guided to a vaporizer 25 through an LNG pipe 23 by a liquid delivery pump (liquefied gas pump) 22. The LNG pump 18 and the liquid delivery pump 22 are electric pumps. The LNG gasified by the vaporizer 25 is supplied to the outside via a gas delivery pipe 26. Start and stop or the rotational speeds of the LNG pump 18 and the liquid delivery pump 22 are controlled by a controller (not illustrated).

{0026}

The LNG vaporization device 1 has a regas boiler 30, a steam turbine 32, a steam turbine generator 34, a steam condenser 36, and a glycol circulation path (anti-freezing solution circulation path) 38, in addition to the vaporizer 25.

{0027}

The regas boiler (boiler) 30 is connected to a boiler BOG supply pipe 40 branched from the BOG supply pipe 7 in the downstream of the BOG compressor 9. The regas boiler 30 is operated by the BOG as fuel guided by the boiler BOG supply pipe 40. Note that the regas boiler 30 may be operated by a fuel oil.

{0028}

A water drum 30a of the regas boiler 30 is connected to an evaporator 44 in the exhaust gas economizer 14 via a drum water pump 42. Water heated by the evaporator 44 is guided to a steam drum 30b of the regas boiler 30. The steam drum 30b is supplied with water by a water supply pump 48 via a water supply pipe 47 from a water supply tank 46.

{0029}

Steam is supplied from the steam drum 30b of the regas boiler 30 to a steam demanding part 50 in the FSRU (onboard) via an onboard steam supply valve 51.

{0030}

A steam turbine steam pipe 52 is provided between the steam drum 30b of the regas boiler 30 and the steam turbine 32. A superheater 53 is provided in the middle of the steam turbine steam pipe 52. The superheater 53 is provided in the exhaust gas economizer 14. In the steam turbine steam pipe 52, a steam stop valve 54 and a steam control valve 55 are provided between the superheater 53 and the steam turbine 32.

The steam stop valve 54 and the steam control valve 55 are controlled by a controller (not illustrated).

{0031}

A branch point P is provided in the steam turbine steam pipe 52 upstream of the superheater 53. A steam dump pipe 57 used for exhausting steam in the steam drum 30b to the steam condenser 36 by bypassing the steam turbine 32 is provided between the branch point P and the steam condenser 36. The steam dump pipe 57 is provided with a steam dump valve 58. The steam dump valve 58 is controlled by a controller (not illustrated) and closed during a normal operation.

{0032}

A steam supply pipe 62 is provided between the steam drum 30b of the regas boiler 30 and a steam heat exchanger 60 provided in the glycol circulation path 38. The steam supply pipe 62 is provided with a steam supply valve 63. The steam supply valve 63 is controlled by a controller (not illustrated). Steam generated after glycol is heated by the steam heat exchanger 60 becomes drain water, and the drain water is guided to the water supply tank 46 via a drain water pipe 65. Note that, as the glycol, ethylene glycol is used, for example.

{0033}

The steam turbine 32 is rotated by steam and rotates a rotary shaft 33. The rotary shaft 33 is connected to the

steam turbine generator 34 and drives the steam turbine generator 34. Power generated by the steam turbine generator 34 is used as power required in a ship, for example, used in the liquid delivery pump 22 for delivering LNG or a circulation pump 67 for circulating glycol.

{0034}

Steam that has been used for work in the steam turbine 32 is guided to the steam condenser 36. The condensed water condensed in the steam condenser 36 is guided to the water supply tank 46 via a condensate pump 69. Seawater is guided into the steam condenser 36 as a heat medium that cools steam.

{0035}

The glycol circulation path 38 is provided with a seawater heat exchanger 72. In the seawater heat exchanger 72, heat is exchanged between the seawater guided via a seawater intake pipe 71 by a seawater pump 70 and the glycol. The seawater that has exchanged heat in the seawater heat exchanger 72 is released to ocean via a drain pipe 73. The seawater pump 70 is controlled by a controller (not illustrated).

{0036}

The glycol circulation path 38 has a circulation pump 67 upstream of the seawater heat exchanger 72. The glycol is circulated by the circulation pump 67 through the seawater heat exchanger 72, the steam heat exchanger 60, and the

vaporizer 25 in this order. The circulation pump 67 is an electric pump and is controlled by a controller (not illustrated).

{0037}

The controller is formed of, for example, a central processing unit (CPU), a random access memory (RAM), a read only memory (ROM), a computer readable storage medium, and the like. Further, as an example, a series of processes to implement various functions is stored in a storage medium or the like in a form of a program. The CPU reads such a program into the RAM or the like and executes a process of edition and operation of information, so that various functions are implemented. Note that a program may be installed in advance in a ROM or other storage mediums, a program may be provided in a state of being stored in a computer readable storage medium, or a program may be delivered via a wired or wireless communication unit. The computer readable storage medium is a magnetic disk, a magneto-optical disk, a CD-ROM, a DVD-ROM, a semiconductor memory, or the like.

[Open Loop]

{0038}

Next, the operation of the LNG vaporization device 1 of the configuration described above will be described. First, an open loop using the seawater heat exchanger 72 without using the steam heat exchanger 60 will be described. In the

case of the open loop, seawater is used as a heat source used for gasifying the LNG. The seawater heat exchanger 72 is used to heat glycol by the seawater, and thereby required heat is obtained. Thus, the open loop is used in a sea area with a high water temperature or in a summer season.

{0039}

In the open loop, the regas boiler 30 does not operate as a heat source for LNG gasification. The steam drum 30b of the regas boiler 30 is used as a gas-liquid separator. The controller starts the drum water pump 42 to guide water in the water drum 30a to the evaporator 44, and causes heat exchange with the exhaust gas flowing in the exhaust gas economizer 14. The water guided to the evaporator 44 is heated and then guided to the steam drum 30b for gas-liquid separation. The steam separated by the steam drum 30b is guided to the steam demanding part 50 and the steam turbine 32. The steam guided to the steam turbine 32 is superheated by the superheater 53 of the exhaust gas economizer 14. An exhaust gas generated by the diesel engine 5 is guided to the exhaust gas economizer 14. Note that, when the amount of steam required by the steam demanding part 50 exceeds the amount of steam generated by heat recovery from the exhaust gas economizer 14, the steam guided to the steam turbine 32 is blocked. When the amount of steam is still insufficient, the regas boiler 30 is operated.

{0040}

The controller closes the steam supply valve 63 so as not to cause the steam to flow to the steam heat exchanger 60. Further, the controller controls the operation of the liquid delivery pump 22, the circulation pump 67, the seawater pump 70, or the like.

{0041}

The LNG guided from the LNG tank 3 is supplied to the vaporizer 25 by the liquid delivery pump 22 via the LNG pipe 23. In the vaporizer 25, the LNG is heated by glycol flowing in the glycol circulation path 38 and gasified. The gasified LNG is guided to an external consumer via the gas delivery pipe 26.

{0042}

The glycol cooled by LNG gasification in the vaporizer 25 is heated by seawater in the seawater heat exchanger 72. The glycol heated by seawater is guided to the steam heat exchanger 60. Since no steam is guided to the steam heat exchanger 60 from the regas boiler 30, the glycol is guided to the vaporizer 25 without being heated by the steam heat exchanger 60.

[Combined (Closed) Loop]

{0043}

Next, a combined loop or a closed loop using the steam heat exchanger 60 will be described with reference to Fig. 2. The combined loop and the closed loop are common to each other

in that both of the loops use the steam heat exchanger 60. However, the seawater heat exchanger 72 is not used in the closed loop, and the seawater heat exchanger 72 is partially used in the combined loop.

{0044}

The BOG is guided from the LNG tank 3 to the regas boiler 30 via the boiler BOG supply pipe 40. In the regas boiler 30, flame is formed by a burner (not illustrated) with the BOG as fuel, thereby, the supply water supplied via the water supply pipe 47 is heated, and steam is generated. The generated steam is guided from the steam drum 30b to the steam demanding part 50. The steam generated by the exhaust gas economizer 14 is also added to the regas boiler 30. The exhaust gas generated by the diesel engine 5 is guided to the exhaust gas economizer 14.

{0045}

The controller opens the steam supply valve 63 and stops the seawater pump 70. This causes the glycol flowing in the glycol circulation path 38 to be heated by the steam heat exchanger 60.

{0046}

As described above, in the closed loop, the seawater heat exchanger 72 is not used, and no cooled seawater is released to ocean. Therefore, the environmental burdens can be reduced.

Note that only a required amount of seawater may be supplied to the seawater heat exchanger 72, and glycol may be supplementally heated, as the combined loop, if necessary.

When it is in the combined loop, it is more advantageous to close the steam control valve 55 to transfer the heat obtained by exhaust heat recovery to the FSRU side and reduce the fuel supplied to the regas boiler 30.

[In GCU Mode]

{0047}

Next, the operation in a GCU mode (during a boil-off gas incineration process mode) will be described with reference to Fig. 3. In the GCU mode, no LNG is heated for gasification in the vaporizer 25. This is a state where no LNG gasification is externally required. Therefore, no heat exchange with LNG is performed in the vaporizer 25.

{0048}

Since no LNG is delivered to the outside, a BOG occurs due to inevitable invasive heat or the like in the LNG tank 3, and the pressure in the LNG tank 3 increases. When the pressure in the LNG tank 3 increases above a predetermined pressure, the controller selects the GCU mode for performing an incineration process on the BOG.

{0049}

Once the GCU mode is selected, the controller supplies the BOG to the regas boiler 30. Accordingly, the BOG is

subjected to an incineration process in the regas boiler 30. Steam generated at this time is delivered from the steam drum 30b to the steam heat exchanger 60, which means that the steam supply valve 63 is opened. At this time, the steam control valve 55 is closed, no steam is supplied to the steam turbine 32, and the steam turbine 32 is stopped.

{0050}

In the glycol circulation path 38, the circulation pump 67 is started, and the glycol is circulated. Further, the seawater pump 70 is started, and seawater is supplied to the seawater heat exchanger 72. Accordingly, the steam supplied to the steam heat exchanger 60 is cooled by the glycol, and the drain water is delivered to the water supply tank 46. The glycol heated due to the use of cooling the steam passes through the vaporizer 25 and is then guided to the seawater heat exchanger 72. Since no LNG has been supplied to the vaporizer 25, the heat of glycol is not exchanged in the vaporizer 25. However, the glycol is cooled by the seawater in the seawater heat exchanger 72. Accordingly, the condensing heat of the steam recovered in the steam heat exchanger 60 is discharged to the outside by the seawater heat exchanger 72.

[Effects and Advantages of the Present Embodiment]

{0051}

According to the present embodiment, the following

effects and advantages are achieved.

In the GCU mode (see Fig. 3), the steam generated by the regas boiler 30 is delivered to the steam heat exchanger 60. Heat is exchanged between the steam and the glycol in the steam heat exchanger 60, and the heat is dissipated via the glycol circulating in the glycol circulation path 38. Thus, steam is dumped by the glycol circulation path 38, and it is not required to provide a large condenser that would otherwise be required in the GCU mode. This can reduce the initial investment.

{0052}

The seawater heat exchanger 72 is provided in the glycol circulation path 38, and heat is dissipated from glycol to seawater via the seawater heat exchanger 72. This allows condensing heat of the steam generated by BOG incineration to be effectively dissipated to the outside.

{0053}

Note that the steam dump valve 58 may be opened to use the steam heat exchanger 60 as an aid of the steam condenser 36. Accordingly, the existing steam condenser 36 can be effectively used. For example, the controller opens the steam dump valve 58 while keeping the steam supply valve 63 closed in the GCU mode, so as to firstly condense the steam dumped by the steam condenser 36. Further, the controller calculates in advance the load of the regas boiler 30 in the GCU mode. When

the heat amount recovered by the steam condenser 36 exceeds a predetermined value, the steam dump valve 58 is caused to maintain the valve aperture thereof, and the steam supply valve 63 is opened to use the steam heat exchanger 60.

Accordingly, the condensing heat of the steam generated by the BOG combustion can be distributed between the steam heat exchanger 60 and the steam condenser 36, and each device capacity can be reduced to its appropriate level.

{Reference Signs List}

{0054}

- 1 LNG gasifier device (liquefied gas vaporization device)
- 3 LNG tank (liquefied gas tank)
- 5 diesel engine (power generating engine)
- 7 BOG supply pipe
- 9 BOG compressor
- 10 BOG cooling heat exchanger
- 12 turbocharger
- 14 exhaust gas economizer
- 14a exhaust gas economizer valve
- 15 exhaust gas bypass pipe
- 15a bypass valve
- 16 air cooler
- 18 LNG pump
- 20 gas-liquid separator
- 22 liquid delivery pump (liquefied gas pump)

- 23 LNG pipe
- 25 vaporizer
- 26 gas delivery pipe
- 30 regas boiler (boiler)
- 30a water drum
- 30b steam drum
- 32 steam turbine
- 33 rotary shaft
- 34 steam turbine generator
- 36 steam condenser
- 38 glycol circulation path (anti-freezing solution
circulation path)
- 40 boiler BOG supply pipe
- 42 drum water pump
- 44 evaporator
- 46 water supply tank
- 47 water supply pipe
- 48 water supply pump
- 50 steam demanding part
- 51 onboard steam supply valve
- 52 steam turbine steam pipe
- 53 superheater
- 54 steam stop valve
- 55 steam control valve
- 57 steam dump pipe

- 58 steam dump valve
- 60 steam heat exchanger
- 62 steam supply pipe
- 63 steam supply valve
- 65 drain water pipe
- 67 circulation pump
- 69 condensate pump
- 70 seawater pump
- 71 seawater intake pipe
- 72 seawater heat exchanger
- 73 drain pipe

{CLAIMS}

{Claim 1}

A liquefied gas vaporization device comprising:

a vaporizer configured to heat and gasify a liquefied gas;

an anti-freezing solution circulation path which is connected to the vaporizer and in which an anti-freezing solution circulates;

a boiler configured to combust a boil-off gas generated in a liquefied gas tank to generate steam;

a steam heat exchanger configured to exchange heat between the steam generated by the boiler and the anti-freezing solution circulating in the anti-freezing solution circulation path; and

a controller configured to perform control in a boil-off gas incineration process mode in which the boil-off gas generated in the liquefied gas tank is subjected to an incineration process in the boiler without a liquefied gas being heated in the vaporizer,

wherein the controller delivers the steam generated in the boiler to the steam heat exchanger in the boil-off gas incineration process mode.

{Claim 2}

The liquefied gas vaporization device according to claim 1 further comprising a seawater heat exchanger provided in the

anti-freezing solution circulation path and configured to exchange heat between an anti-freezing solution and seawater, wherein the controller performs control so that heat is dissipated from the anti-freezing solution to the seawater in the seawater heat exchanger in the boil-off gas incineration process mode.

{Claim 3}

The liquefied gas vaporization device according to claim 1 or 2 further comprising:
a steam turbine; and
a steam condenser configured to condense steam discharged from the steam turbine,
wherein the controller delivers the steam generated by the boiler to the steam condenser in the boil-off gas incineration process mode.

{Claim 4}

A floating unit comprising:
the liquefied gas vaporization device according to claim 1; and
the liquefied gas tank that stores a liquefied gas,
wherein the vaporizer gasifies a liquefied gas guided from the liquefied gas tank.