D E S C R I P T I O N

WATER-BORNE FLOATING FACILITY

Technical Field

The present invention relates to a water floating facility.

Background Art

Generally, ships to transport liquefied natural gas (LNG) are known (cf. Patent Literature 1 cited below). The LNG transported by the ship is regasified through a floating storage and regasification unit (FSRU) using heat of the sea water, and is sent to land facilities. It is known that power used for the operation of the FSRU is generated by a diesel generator using a fossil fuel, for example.

However, when cold heat of the LNG is heated by the sea water, and the sea water cooled is returned to the ocean without any treatment, the cold sea water may affect the natural environment such as the ecosystem. Furthermore, when the exhaust heat of the diesel generator working for the operation is cooled by the sea water, and the sea water used therein is discharged, it may affect the natural environment.

Citation List

Patent Literature

Patent Literature 1: JP 2019-34665 A

Summary of Invention

An object of an embodiment of the present invention is to provide a water floating facility which functions as an FSRU using water in the natural environment while suppressing its affect to the natural environment.

In accordance with an aspect of the present invention, a water floating facility includes a tank to

store liquefied gas; vaporization means configured to vaporize the gas stored in the tank; gas sending means configured to send the gas vaporized by the vaporization means to a land facility; water intake means configured to take water in a natural environment; and Rankine cycle power generation means configured to generate electricity through Rankine cycle, based on a temperature difference between the gas and the water taken by the water intake means.

Brief Description of Drawings

FIG. 1 is a diagram of the structure of a water floating facility of an embodiment of the present invention.

FIG. 2 is a T-s diagram of a temperature/specific enthalpy of organic Rankine cycle (ORC) of the embodiment.

Mode for Carrying Out the Invention (Embodiment)

FIG. 1 is a diagram illustrating the structure of a water floating facility 1 of an embodiment of the present invention.

The water floating facility 1 is a water floating (ocean floating) LNG base configured to store LNG, to regasify the stored LNG, and to send high pressure gas to land facilities (for example, a gas pipeline). That is, the water floating facility 1 is an FSRU. Furthermore, the water floating facility 1 is a mobile object which can navigate on water (for example, a ship).

Note that the water floating facility 1 may be shaped and structured optionally as long as it can store a liquefied gas (for example, LNG), regasify (gasify) the liquefied gas to send the regasified gas to land facilities while floating on the sea water, river, lake, or the like. For example, the water

floating facility 1 may not be shaped as a ship, or may not include a propelling unit. Here, the water floating facility 1 will be described as being a ship navigating on the ocean.

The water floating facility 1 includes a turbo generator 3, LNG vaporizer 4, organic medium circulating pump 5, first heat exchanger 6, second heat exchanger 7, third heat exchanger 8, fourth heat exchanger 9, fifth heat exchanger 10, diesel generator 11, recondenser (reliquefier) 12, LNG booster pump 13, trim heater (regasification temperature adjustment heat exchanger) 14, LNG tank 15, feed pump 16, boil off gas (BOG) compressor 17, heating sea water pump 18, heating medium circulating pump 19, cooling sea water pump 20, cooling fresh water booster pump 21, organic medium plumbing L1, LNG plumbing L2, BOG plumbing L3, sea water plumbing L4, heating medium plumbing L5, cooling fresh water plumbing L6, and regasification plumbing L7.

The organic medium plumbing L1 is a plumbing through which an organic medium used in a power generation system 2 flows. The organic medium plumbing L1 is structured such that the organic medium circulates between the LNG vaporizer 4 and the turbo generator 3. The organic medium plumbing L1 includes a path which passes through the LNG vaporizer 4 to the turbo generator 3 via the first heat exchanger 6 and the second heat exchanger 7, successively, and the path from the LNG vaporizer 4 to the first heat exchanger 6 is branched to a path passing through the third heat exchanger 8 and a path diverting the third heat exchanger 8 (bypath). While the BOG compressor 17 is being operated, the organic medium flows through the path through the third heat exchanger 8, and while the BOG compressor 17 is being stopped, the organic medium

flows through the path diverting the third heat exchanger 8. Note that, the order of the organic medium passing three heat exchangers 6 to 8 is arbitrary. The organic medium is, for example, propane; however, it may not be an inflammable medium but may be a nonflammable medium with thermal property close to that of propane.

The LNG plumbing L2 is structured such that the LNG is sent from the LNG tank 15 to the recondenser 12. The components of LNG are arbitrary.

The BOG plumbing L3 is structured such that the boil off gas (BOG) is sent from the upper part of the LNG tank 15 to the recondenser 12 through the BOG compressor 17 and the third heat exchanger 8, successively. Furthermore, the BOG plumbing 13 includes a path to send the BOG as a fuel supplier of the diesel generator 11. The BOG is a gaseous natural gas formed of a part of the LNG stored in the LNG tank 15 by heat input.

The sea water plumbing L4 is structured such that the sea water taken in to each of the fourth heat exchanger 9 and the fifth heat exchanger 10 from the outside of the ship is sent, and the sea water used for heating or cooling in each of the fourth heat exchanger 9 and the fifth heat exchanger 10 is released to the outside of the ship.

The heating medium plumbing L5 is a plumbing through which the heating medium flows. The heating medium plumbing L5 is structured to include a path in which the heating medium is circulated between the fourth heat exchanger 9 and the trim heater 14, and a path in which the heating medium is circulated between the fourth heat exchanger 9 and the first heat exchanger 6. The heating medium is used to heat the organic medium by the first heat exchanger 6, and is

used as the heating medium of the trim heater 14 as well.

Note that, if the organic medium is directly heated by the sea water, the sea water may possibly be frozen inside the first heat exchanger 6. Thus, a heating medium which is an antifreeze heating medium as an intermediate medium between the organic medium and the sea water. For example, the heating medium is ethylene glycol aqueous solution (glycol water); however, it may be another medium such as propane.

The cooling fresh water plumbing L6 is a plumbing through which fresh water to cool engine charge by an air cooler or the like of the diesel generator 11. The cooling fresh water plumbing L6 is structured such that the fresh water is circulated through the fifth heat exchanger 10, diesel generator 11, and second heat exchanger 7, successively.

The regasification plumbing L7 is structured such that the natural gas vaporized (regasified) is sent to land facilities from the LNG vaporizer 4 through the trim heater 14.

The power generating system 2 includes the turbo generator 3, LNG vaporizer 4, organic medium circulating pump 5, first heat exchanger 6, second heat exchanger 7, third heat exchanger 8, and organic medium plumbing L1.

The power generating system 2 is an organic Rankine cycle (ORC) power generating system which generates electricity through the Rankine cycle using an organic medium. The electricity is generated in the turbo generator 3 using a temperature difference between cold heat of the LNG and other heat sources.

The outline of the operation of the power generating system 2 is as follows. Each of the heat exchangers 6 to 8 heats (vaporizes) the organic medium

to generate superheated steam. The turbo generator 3 expands the superheated steam generated by the heat exchangers 6 to 8 with a turbine to rotate the turbine. The turbo generator 3 generates the electricity with the rotation power (work). The organic medium worked in the turbine of the turbo generator 3 in a gaseous state or in a gas-liquid mixed state is cooled by the LNG vaporizer 4 to be condensed/liquefied, and is returned to each of the heat exchangers 6 to 8. The power generating system 2 repeats the above series of operations to execute a cycle for generating electricity.

The turbo generator 3 includes a turbine rotor with blades and a power generator connected thereto. The turbo generator 3 is a power generator using a high molecule organic medium instead of steam.

The LNG vaporizer 4 is a heat exchanger to absorb the heat from the organic medium flowing in the organic medium plumbing L1 in order to vaporize (regasify) the LNG. For example, the LNG vaporizer 4 is a shell & tube type; however, the type may be different.

The organic medium circulating pump 5 is a pump to pressurize the condensed/liquefied organic medium which has been cooled by the LNG vaporizer 4, and to circulate the organic medium to the organic medium plumbing L1 of the power generating system 2. Note that, a tank to temporarily store the liquefied organic medium may be disposed in the upper stream side of the organic medium circulating pump 5 (downstream side of the LNG vaporizer 4).

The first heat exchanger 6 performs heat exchange between the organic medium flowing in the organic medium plumbing L1 and the heating medium flowing in the heating medium plumbing L5 to heat the organic medium with the heating medium. Note that, the first

heat exchanger 6 may not be used for a certain period of time, or may not be disposed at all. In that case, the power generating system 2 uses the second heat exchanger 7 and the third heat exchanger 8 to perform the Rankine cycle with the waste heat of the diesel generator 11 and the heat recovery of the BOG compressor 17. Thus, the water floating facility 1 may reduce the amount of the sea water used.

The second heat exchanger 7 performs heat exchange between the organic medium flowing in the organic medium plumbing L1 and the fresh water flowing in the cooling fresh water plumbing L6 to heat the organic medium with the fresh water. Thus, the second heat exchanger 7 heats the organic medium using the waste heat from the diesel generator 11.

The third heat exchanger 8 performs heat exchange between the organic medium flowing in the organic medium plumbing L1 and the BOG flowing in the BOG plumbing L3 to heat the organic medium with the BOG.

The fourth heat exchanger 9 performs heat exchange between the sea water flowing in the sea water plumbing L4 and the heating medium flowing in the heating medium plumbing L5 to heat the heating medium with the sea water.

The fifth heat exchanger 10 performs heat exchange between the sea water flowing in the sea water plumbing L4 and the fresh water flowing in the cooling fresh water plumbing L6 to cool the fresh water with the sea water.

The diesel generator 11 is a power generator to produce the in-ship power required for the regasification process (for example, power supplies for the LNG booster pump 13, BOG compressor 17, and heating sea water pump 18). The diesel generator 11 is a dual-fuel diesel generator which generates electricity by

combusting heavy fuel oil and the BOG supplied from the BOG compressor 17. Note that the diesel generator 11 may be a different generator which does not use a diesel engine.

The recondenser 12 is a pressure vessel to reliquefy (recondense) a part of the BOG supplied from the BOG compressor 17. The recondenser 12 reliquefies (recondenses) a part of the BOG using a latent heat of vaporization generated by spraying the LNG to the BOG in the pressurized state. The reliquefied BOG is mixed with the sprayed LNG to be sent to the LNG vaporizer 4 with the LNG booster pump 13. Note that the reliquefied BOG may be returned to the LNG tank 15.

The LNG booster pump 13 is a pump to pressurize the LNG supplied from the recondenser 12 (including the reliquefied BOG), and to send the pressurized LNG to land facilities through the LNG vaporizer 4. The LNG booster pump 13 determines a designed discharge pressure corresponding to a requested pressure on the land side. The LNG booster pump 13 functions as a suction drum which maintains the liquid surface to a certain extent or more in order to prevent idling.

The trim heater 14 performs heat exchange between the heating medium flowing in the heating medium plumbing L5 and the regasified gas flowing in the regasification plumbing L7 to heat the regasified gas with the heating medium. The heating medium is heated by the sea water in the fourth heat exchanger 9, and thus, the trim heater 14 is a heat exchanger using the sea water as a heating heat source. The trim heater 14 heats the regasified gas sent from the LNG vaporizer 4 to the regasification plumbing L7 to adjust a temperature of the regasified gas. The capacity of the trim heater 14 is determined to correspond to a requested pressure on the land side.

The LNG tank 15 is a tank to store the LNG. BOG from evaporated/vaporized some LNG resides in the upper part of the LNG tank 15.

The feed pump 16 is disposed on the bottom surface of the LNG tank 15, and is connected to the LNG plumbing L2. The feed pump 16 is a pump to feed the LNG amount of which is required for the regasification from the LNG tank 15 to the recondenser 12.

The BOG compressor 17 is a gas compressor which takes in the BOG residing in the upper part of the LNG tank 15, compresses the BOG, and sends the compressed BOG to the recondenser 12. The BOG compressor 17 is used for pressure controlling of the LNG tank 15. When the BOG keeps increasing, the inner pressure of the LNG tank 15 increases, and thus, the BOG compressor 17 compresses the BOG to protect the LNG tank 15. The compressed BOG may be sent to the recondenser 12, or may be incinerated as a fuel for the diesel generator 11.

The heating sea water pump 18 is provided with the sea water plumbing L4. The heating sea water pump 18 is a pump to take in the sea water from the outside of the ship, and to send the sea water to the fourth heat exchanger 9.

The heating medium circulating pump 19 is a pump to pressurize and circulate the heating medium. The heating medium circulating pump 19 is provided with the heating medium plumbing L5.

The cooling sea water pump 20 is provided with the sea water plumbing L4. The cooling sea water pump 20 is a pump to take in the sea water from the outside of the ship, and to send the sea water to the fifth heat exchanger 10.

The cooling fresh water booster pump 21 is provided with the cooling fresh water plumbing L6. The

cooling fresh water booster pump 21 is a pump to pressurize the fresh water used for cooling of the diesel generator 11 to be circulated through the diesel generator 11, and second heat exchanger 7 and the fifth heat exchanger 10 of the power generating system 2, successively.

Now, the power generating system 2 will be explained.

The power generating system 2 is operated by a closed cycle of the organic medium flowing in the organic medium plumbing L1. The organic medium is heated and evaporated by the heat recovered from the downstream gas of the BOG compressor 17, heat obtained from the sea water, and heat obtained from the waste heat of the diesel generator 11. A difference between the heat thereof and the cold heat obtained from the LNG is used to liquefy the organic medium to produce an expansion force. The turbo generator 3 generates electricity by converting the expansion force into rotation energy.

The organic medium is pressurized by the organic medium circulating pump 5, and is circulated in the organic medium plumbing L1. As primary heating of the organic medium, the third heat exchanger 8 recovers the heat excessively supplied to the BOG plumbing L3 by the BOG compressor 17. As secondary heating of the organic medium, the first heat exchanger 6 takes in the heat from the sea water through the heating medium. The heating medium takes in the heat from the sea water through the fourth heat exchanger 9. As third heating (and vaporizing) of the organic medium, the second heat exchanger 7 recovers the waste heat applied to the cooling fresh water of the diesel generator 11. Through the heating/vaporizing process, energy required for electric generation is applied to the organic

medium, and the power generating system 2 obtains power by the organic medium passing the turbo generator 3.

FIG. 2 is a T-s diagram indicating a temperature/specific enthalpy of the organic medium used in the ORC of the power generating system 2 of the present embodiment. Furthermore, a saturation curve Cs of the organic medium is indicated in FIG. 2.

The organic medium output from the LNG vaporizer 4 is pressurized by the organic medium circulating pump 5 to be circulated in the organic medium plumbing L1 in order to perform the ORC (state P5).

The organic medium is heated by the first heat exchanger 6 and the third heat exchanger 8 in a liquefied or gas-liquid two-phase (states P6 and P8). While the BOG compressor 17 is in operation, the organic medium passes the third heat exchanger 8 in order to recover the heat of the downstream of the BOG compressor 17 (state P8). While the BOG compressor 17 is being stopped, the organic medium passes the bypath which diverts the third heat exchanger 8.

The organic medium is heated by the second heat exchanger 7 using the waste heat of the diesel generator 11. Thus, a state where at least a part thereof is liquefied (state P7a) eventually transitions to a state where all thereof is vaporized (state P7b). The vaporized organic medium enters the turbo generator 3 in a high temperature and high pressure state (state P3), works therein (generates electricity), and returns to the LNG vaporizer 4. At that time, the organic medium in the vaporized state (state P4a) returns to the liquefied state (state P4b).

Now, an operation in which the LNG is regasified to be sent to land facilities will be explained.

When the LNG is regasified by the LNG vaporizer 4, the LNG in the LNG tank 15 is sent to the recondenser

12 by the feed pump 16. Furthermore, the BOG residing in the upper part of the LNG tank 15 is sent to the recondenser 12 by the BOG compressor 17 through the third heat exchanger 8. Thus, the temperature of the BOG is decreased by the third heat exchanger 8 before being sent to the recondenser 12.

In the recondenser 12, the LNG sent therein by the feed pump 16 is sprayed, and a part of the BOG sent from the BOG compressor 17 is reliquefied. At that time, the efficiency of reliquefication of the BOG is increased since the temperature of the BOG has already been decreased, and thus, the recondenser 12 can reliquefy more BOG.

The reliquefied BOG and the LNG sent from the LNG tank 15 are pressurized by the LNG booster pump 13 to a certain pressure, and are sent to the LNG vaporizer 4. The LNG vaporizer 4 regasify the LNG sent therein, and send the regasified LNG to the trim heater 14. The trim heater 14 adjusts the temperature of the natural gas sent therein, and send the gas to land facilities.

According to the present embodiment, the following effects can be achieved.

The power generating system 2 is a closed loop type in which LNG is heated using steam as a heat source while it also has an advantage of an open loop type because of an indirect heating system thereof in which an organic medium is regasified using the sea water (water in natural environment) with an intermediate medium to produce a heat source.

Specifically, as compared to a closed loop type system in which regasification is performed without using the sea water as a heat source, the present embodiment can suppress fuel consumption and carbon dioxide emissions. Furthermore, by adopting an indirect heating system, an influence to the natural

environment (for example, ecosystem) caused by decreasing the sea water temperature due to the cold heat of the LNG can be suppressed. Furthermore, a possible risk to each component of the water floating facility 1 (such as LNG vaporizer 4) by the sea water circulating therein (for example, tube damaged by frozen sea water) can be avoided.

Furthermore, the power generating system 2 performs the LNG cold heat electric generation using the LNG coldness, and thus, the LNG cold heat leaking to the ocean can further be suppressed.

Furthermore, with the second heat exchanger 7 to heat the organic medium with the fresh water used for cooling the diesel generator 11, energy efficiency of the power generating system 2 is improved, and the waste heat of the diesel generator 11 to be released in the sea water can be decreased. Thus, an influence to the natural environment caused by increased sea water temperature can be suppressed.

Note that, the BOG compressor 17 must be driven to send excessive BOG to the recondenser 12. Thus, the temperature of the BOG is increased, and the input heat excessive for the reliquefication process is added to the BOG. With the excess input heat, efficiency of the reliquefication decreases, and speed of increase of the internal pressure of the LNG tank 15 increases. When the inner pressure of the LNG tank 15 is increased to a certain extent or more, the BOG must be incinerated to protect the LNG tank 15. Thus, the energy efficiency of the water floating facility 1 as a whole decreases, and the amount of carbon dioxide produced thereby increases.

Therefore, the third heat exchanger 8 to heat the organic medium with the BOG is provided with the water floating facility 1 in order to improve the energy

efficiency of the power generating system 2, and the efficiency of reliquefication performed by the recondenser 12 can be increased. Thus, the inner pressure of the LNG tank 15 can be efficiently decreased, and the amount of BOG to be incinerated can be decreased.

As can be understood from the above, the water floating facility 1 with the power generating system 2 which uses the LNG cold heat for the FSRU can suppress an influence to the natural environment, and the energy used for operation of the FSRU can be reduced.

C L A I M S

1. A water floating facility characterized by comprising:

a tank to store liquefied gas;

vaporization means configured to vaporize the gas stored in the tank;

gas sending means configured to send the gas vaporized by the vaporization means to a land facility;

water intake means configured to take water in a natural environment;

Rankine cycle power generation means configured to generate electricity through Rankine cycle, based on a temperature difference between the gas and the water taken by the water intake means; and

first heating means configured to heat a Rankine cycle medium used in the Rankine cycle, based on the water taken in by the water intake means,

characterized in that the first heating means uses an intermediate medium heated by the water in order to heat the Rankine cycle medium.

2. The water floating facility of claim 1, characterized by further comprising:

another electric generation means which is different from the Rankine cycle power generation means; and

second heating means configured to heat the Rankine cycle medium, based on fresh water used for cooling of the another electric generation means.

3. The water floating facility of claim 2, characterized by further comprising:

cooling means configured to cool the fresh water, based on the water taken in by the water intake means.

4. The water floating facility of claim 1, characterized by further comprising:

another electric generation means which is different from the Rankine cycle power generation means, using the vaporized gas generated in the tank as a fuel.

5. The water floating facility of claim 1, characterized by further comprising:

temperature adjustment means configured to adjust a temperature of the gas vaporized by the vaporization means, based on the water taken in by the water intake means.

6. The water floating facility of claim 1, characterized by further comprising a function to move on the water.