

DESCRIPTION

Title of Invention: VAPORIZED GAS LIQUEFACTION FACILITY, GAS FUEL SUPPLY SYSTEM, AND METHOD OF LIQUEFYING VAPORIZED GAS

Technical Field

[0001] The present disclosure relates to a vaporized gas liquefaction facility, a gas fuel supply system, and a method of liquefying a vaporized gas.

Background Art

[0002] PTL 1 below discloses a device that cools residual hydrogen vapor, ejected from an ejector, by a heat exchanger and releases it into liquid hydrogen in a receiving tank.

Citation List

Patent Literature

[0003] PTL 1: Japanese Examined Patent Application Publication No. 63-5322

Summary of Invention

Technical Problem

[0004] When a vaporized gas is released into a liquefied gas stored in a liquefied gas tank, the vaporized gas is partially liquefied by being cooled by the liquefied gas. It is preferable that when the vaporized gas can be efficiently liquefied in the liquefied gas tank, the internal pressure of the liquefied gas tank be prevented from increasing.

[0005] An object of the present disclosure is to provide a vaporized gas liquefaction facility that can efficiently liquefy a vaporized gas in a liquefied gas tank.

Solution to Problem

[0006] A vaporized gas liquefaction facility according to one aspect of the present disclosure includes: a liquefied gas tank storing a liquefied gas; and an atomizing nozzle that atomizes a vaporized gas and releases the vaporized gas as bubbles into the liquefied gas stored in the liquefied gas tank.

Advantageous Effects of Invention

[0007] According to the vaporized gas liquefaction facility of one aspect of the present disclosure, the vaporized gas can be efficiently liquefied in the liquefied gas tank.

Brief Description of Drawings

[0008] FIG. 1 is a block diagram of a gas fuel supply system.

Description of Embodiments

[0009] Hereinafter, an embodiment will be described. FIG. 1 is a block diagram of a gas fuel supply system 100. As shown in FIG. 1, the gas fuel supply system 100 includes a liquefied gas tank 11, a supply line 12, a pressure pump 13, a heater 14, a return line 15, an ejector 16, a gas-liquid separator 17, and an atomizing nozzle 18. Among these components, a vaporized gas liquefaction facility 10 according to the present embodiment includes the liquefied gas tank 11, the ejector 16, the gas-liquid separator 17, and the atomizing nozzle 18.

Hereinafter, the components will be described in order.

[0010] The liquefied gas tank 11 is a tank that stores a liquefied gas. Examples of the liquefied gas include liquefied hydrogen, a liquefied natural gas (LNG), and a liquefied petroleum gas (LPG). The liquefied gas tank 11 includes: a liquid phase portion 21 filled with the liquefied gas; and a gas phase portion 22 filled with a vaporized gas generated from the liquefied gas. When the internal pressure of the liquefied gas tank 11 increases and exceeds an allowable value, part of the vaporized gas is discharged from the gas phase portion 22. Normally, the vaporized gas discharged from the liquefied gas tank 11 is disposed of by being released to the atmosphere, incinerated, or the like. Therefore, to prevent gas fuel from being wastefully consumed, it is desirable that the internal pressure of the liquefied gas tank 11 be suppressed.

[0011] The supply line 12 is a line that connects the liquefied gas tank 11 and a gas fuel engine 101 to each other. The gas fuel engine 101 is a facility that uses the vaporized gas as fuel. Examples of the gas fuel engine 101 include a gas engine and a boiler. The supply line 12 acquires the liquefied gas from the liquid phase portion 21 of the liquefied gas tank 11, changes the liquefied gas into the vaporized gas, and supplies the vaporized gas as the gas fuel to the gas fuel engine 101.

[0012] The pressure pump 13 is a pump that is located on the supply line 12 and pressurizes the liquefied gas acquired from the liquefied gas tank 11. The pressure pump 13 may include pumps or may be a single pump. For example, the pressure pump 13 may include a low pressure pump and a high pressure pump that further pressurizes the liquefied gas which has been pressurized by the low pressure pump.

[0013] The heater 14 is a device that is located on the supply line 12 and heats the liquefied gas. The heater 14 of the present embodiment is located at a portion of the supply line 12

which is located downstream of the pressure pump 13. Therefore, the heater 14 heats the liquefied gas which has been pressurized by the pressure pump 13. The liquefied gas which has been heated by the heater 14 changes into the vaporized gas, and the vaporized gas is supplied to the gas fuel engine 101.

[0014] The return line 15 is a line connected to the supply line 12. The return line 15 of the present embodiment is connected to a portion of the supply line 12 which is located downstream of the pressure pump 13 and upstream of the heater 14. A remaining liquefied gas that is the liquefied gas pressurized by the pressure pump 13 and not supplied to the gas fuel engine 101 flows into the return line 15. A relief valve 23 is located on the return line 15. The liquefied gas which has flowed into the return line 15 changes into the vaporized gas by flowing through the relief valve 23. When most of the vaporized gas generated in the return line 15 can be liquefied and return to the liquefied gas tank 11, the internal pressure of the liquefied gas tank 11 can be suppressed, and therefore, the gas fuel can be prevented from being wastefully consumed.

[0015] The ejector 16 is a device that mixes vaporized gases which have been taken in from two different lines. The ejector 16 of the present embodiment takes in the vaporized gas (hereinafter referred to as a “return vaporized gas”) generated in the return line 15, takes in the vaporized gas (hereinafter referred to as a “tank vaporized gas”) in the liquefied gas tank 11, and mix these gases with each other. A pressure-reduced region is formed inside the ejector 16 by utilizing Venturi effect generated by discharging the return vaporized gas from an internal nozzle. A tank line 24 extending from the liquefied gas tank 11 is connected to the pressure-reduced region of the ejector 16, and the tank vaporized gas is drawn into the ejector 16 through the tank line 24. Thus, the return vaporized gas and the tank vaporized gas are taken in the ejector 16 and mixed with each other.

[0016] The return vaporized gas and the tank vaporized gas which have been mixed with each other in the ejector 16 expand by flowing through an internal diffuser in the ejector 16, and as a result, are partially liquefied. Therefore, the ejector 16 discharges a fluid containing the vaporized gas and the liquefied gas, that is, a gas-liquid two-phase fluid. The vaporized gas and the liquefied gas which have been discharged from the ejector 16 are supplied to the gas-liquid separator 17 through a gas-liquid line 25 that connects the ejector 16 and the gas-liquid separator 17 to each other. Instead of the ejector 16, the gas fuel supply system 100 may include a pressure-reducing expansion valve that liquefies the vaporized gas, generated in the return line 15, by reducing the pressure of the vaporized gas. In this case, the return vaporized gas and the tank vaporized gas are not mixed with each other.

[0017] The gas-liquid separator 17 is a device that separates the vaporized gas and the liquefied gas from each other. The gas-liquid separator 17 of the present embodiment separates the vaporized gas and the liquefied gas, which have been discharged from the ejector 16, from each other by utilizing the difference in their specific gravities. However, the gas-liquid separator 17 does not have to have the above structure, and the type of the gas-liquid separator 17 is not limited. The vaporized gas which has been separated from the liquefied gas is supplied to the atomizing nozzle through a gas line 26. On the other hand, the liquefied gas which has been separated from the vaporized gas is supplied to the liquefied gas tank 11 through a liquid line 27. The liquefied gas which has been separated from the vaporized gas may be supplied to the liquid phase portion 21 of the liquefied gas tank 11 or may be supplied to the gas phase portion 22 of the liquefied gas tank 11.

[0018] The atomizing nozzle 18 is a nozzle that is located at the liquid phase portion 21 of the liquefied gas tank 11 and releases the vaporized gas into the liquefied gas stored in the liquefied gas tank 11. When the vaporized gas is released into the liquefied gas, the vaporized gas is liquefied by being cooled by the surrounding liquefied gas. In this case, when the vaporized gas can be efficiently liquefied in the liquefied gas tank 11, the internal pressure of the liquefied gas tank 11 can be suppressed, and the gas fuel can be prevented from being wastefully consumed.

[0019] Therefore, the atomizing nozzle 18 of the present embodiment atomizes the vaporized gas and releases the vaporized gas as bubbles into the liquefied gas. Since the vaporized gas is released as fine bubbles, the surface area of the vaporized gas which contacts the liquefied gas increases, and therefore, the vaporized gas is easily liquefied. Moreover, in the present embodiment, the bubbles released into the liquefied gas include bubbles whose diameters are less than 100 μm . The diameters of the bubbles released into the liquefied gas may be less than 100 μm in terms of Sauter mean diameter. The bubble whose diameter is less than 100 μm has a characteristic of being less likely to rise in the liquid. Therefore, the vaporized gas which has been released into the liquefied gas as the bubbles whose diameters are less than 100 μm stays in the liquefied gas for a long period of time, and as a result, is easily liquefied. The bubbles released into the liquefied gas may include microbubbles whose diameters are 1 μm or more and less than 100 μm or may include ultrafine bubbles whose diameters are less than 1 μm .

[0020] Moreover, the atomizing nozzle 18 of the present embodiment includes a porous material 28 located on a passage for the vaporized gas. The vaporized gas is atomized by

flowing through the porous material 28. Examples of the porous material 28 include: a material including therein a large number of pores; a material made by layering fibers; and a material made by sintering and integrating fine metal particles. The atomizing nozzle 18 may atomize the vaporized gas by introducing the vaporized gas into the liquefied gas that is being sprayed at high speed. Since the atomizing nozzle 18 of the present embodiment atomizes the liquefied gas by utilizing the porous material 28, the speed of the vaporized gas released from the atomizing nozzle 18 can be reduced. As a result, the liquefied gas in the liquefied gas tank 11 is hardly stirred, and this can more efficiently liquefy the vaporized gas.

[0021] Moreover, as described above, the vaporized gas supplied to the atomizing nozzle 18 of the present embodiment is the vaporized gas which has been separated from the liquefied gas by the gas-liquid separator 17. Therefore, the liquefied gas can be prevented from flowing into the porous material 28 of the atomizing nozzle 18, and the porous material 28 can be prevented from being clogged by the liquefied gas. Furthermore, since the vaporized gas is supplied through the gas-liquid separator 17 to the atomizing nozzle 18, the speed of the vaporized gas supplied to the atomizing nozzle 18 can be reduced, and this can prevent the liquefied gas in the liquefied gas tank 11 from being stirred.

[0022] **Conclusion**

A first aspect disclosed in the present description is a vaporized gas liquefaction facility including: a liquefied gas tank storing a liquefied gas; and an atomizing nozzle that atomizes a vaporized gas and releases the vaporized gas as bubbles into the liquefied gas stored in the liquefied gas tank.

[0023] According to this configuration, since the surface area of the vaporized gas which contacts the liquefied gas increases, the vaporized gas can be efficiently liquefied in the cooling liquefied gas tank.

[0024] A second aspect disclosed in the present description is the vaporized gas liquefaction facility according to the first aspect, wherein the bubbles include bubbles whose diameters are less than 100 μm .

[0025] According to this configuration, since the vaporized gas stays in the liquefied gas for a long period of time, the vaporized gas can be more efficiently liquefied in the liquefied gas tank.

[0026] A third aspect disclosed in the present description is the vaporized gas liquefaction facility according to the first or second aspect, wherein the atomizing nozzle includes a porous material that atomizes the vaporized gas by allowing the vaporized gas to flow through the

porous material.

[0027] According to this configuration, since the liquefied gas in the liquefied gas tank is hardly stirred, the vaporized gas can be more efficiently liquefied.

[0028] A fourth aspect disclosed in the present description is the vaporized gas liquefaction facility according to the third aspect, further including a gas-liquid separator that separates the vaporized gas and the liquefied gas from each other, wherein the atomizing nozzle atomizes the vaporized gas which has been separated from the liquefied gas by the gas-liquid separator.

[0029] According to this configuration, the clogging of the porous material can be prevented.

[0030] A fifth aspect disclosed in the present description is the vaporized gas liquefaction facility according to the fourth aspect, further including an ejector that liquefies the vaporized gas by expanding the vaporized gas, wherein the gas-liquid separator separates the vaporized gas and the liquefied gas, which have been discharged from the ejector, from each other.

[0031] According to this configuration, in addition to the liquefaction of the vaporized gas in the liquefied gas tank, the liquefaction of the vaporized gas by the ejector can also be performed.

[0032] A sixth aspect disclosed in the present description is a gas fuel supply system including: a liquefied gas tank storing a liquefied gas; a supply line that connects the liquefied gas tank and a gas fuel engine to each other; a pressure pump that is located on the supply line and pressurizes the liquefied gas; a return line connected to a portion of the supply line which is located downstream of the pressure pump; an ejector that partially liquefies a vaporized gas, generated in the return line, by expanding the vaporized gas; a gas-liquid separator that separates the vaporized gas and the liquefied gas which have been discharged from the ejector; and an atomizing nozzle that atomizes the vaporized gas which has been separated from the liquefied gas by the gas-liquid separator, and releases the vaporized gas as bubbles into the liquefied gas stored in the liquefied gas tank.

[0033] According to this configuration, since the surface area of the vaporized gas which contacts the liquefied gas in the liquefied gas tank increases, the vaporized gas can be efficiently liquefied.

[0034] A seventh aspect disclosed in the present description is a method of liquefying a vaporized gas, including: atomizing a vaporized gas; and releasing the vaporized gas as bubbles into a liquefied gas stored in a liquefied gas tank.

[0035] According to this method, since the surface area of the vaporized gas which contacts the liquefied gas increases, the vaporized gas can be efficiently liquefied in the liquefied gas

tank.

Reference Signs List

[0036]	10	vaporized gas liquefaction facility
	11	liquefied gas tank
	12	supply line
	13	pressure pump
	14	heater
	15	return line
	16	ejector
	17	gas-liquid separator
	18	atomizing nozzle
	28	porous material
	100	gas fuel supply system
	101	gas fuel engine

CLAIMS

- [Claim 1] A vaporized gas liquefaction facility comprising:
a liquefied gas tank storing a liquefied gas; and
an atomizing nozzle that atomizes a vaporized gas and releases the vaporized gas as bubbles into the liquefied gas stored in the liquefied gas tank.
- [Claim 2] The vaporized gas liquefaction facility according to claim 1, wherein the bubbles include bubbles whose diameters are less than 100 μm .
- [Claim 3] The vaporized gas liquefaction facility according to claim 1 or 2, wherein the atomizing nozzle includes a porous material that atomizes the vaporized gas by allowing the vaporized gas to flow through the porous material.
- [Claim 4] The vaporized gas liquefaction facility according to claim 3, further comprising a gas-liquid separator that separates the vaporized gas and the liquefied gas from each other, wherein
the atomizing nozzle atomizes the vaporized gas which has been separated from the liquefied gas by the gas-liquid separator.
- [Claim 5] The vaporized gas liquefaction facility according to claim 4, further comprising an ejector that liquefies the vaporized gas by expanding the vaporized gas, wherein
the gas-liquid separator separates the vaporized gas and the liquefied gas, which have been discharged from the ejector, from each other.
- [Claim 6] A gas fuel supply system comprising:
a liquefied gas tank storing a liquefied gas;
a supply line that connects the liquefied gas tank and a gas fuel engine to each other;
a pressure pump that is located on the supply line and pressurizes the liquefied gas;
a return line connected to a portion of the supply line which is located downstream of the pressure pump;
an ejector that partially liquefies a vaporized gas, generated in the return line, by expanding the vaporized gas;
a gas-liquid separator that separates the vaporized gas and the liquefied gas which

have been discharged from the ejector; and

an atomizing nozzle that atomizes the vaporized gas which has been separated from the liquefied gas by the gas-liquid separator, and releases the vaporized gas as bubbles into the liquefied gas stored in the liquefied gas tank.

[Claim 7] A method of liquefying a vaporized gas, comprising:

atomizing a vaporized gas; and

releasing the vaporized gas as bubbles into a liquefied gas stored in a liquefied gas tank.