

DESCRIPTION

Title of Invention: TANK FACILITY

Technical Field

[0001] The present disclosure relates to a tank facility that stores cryogenic liquefied gas.

Background Art

[0002] Cryogenic liquefied gas, such as liquefied hydrogen or LNG (Liquefied Natural Gas), is transported to a receiving terminal by liquefied gas transporting means, such as a ship, and is temporarily stored in a tank facility of the receiving terminal. PTL 1 discloses this type of tank facility.

[0003] The tank facility disclosed in PTL 1 includes: a tank; a receiving pipe through which liquefied gas is supplied from transporting means to the tank; a delivering pipe through which the liquefied gas is delivered from the tank to an outside; a boil off gas pipe through which boil off gas generated in the tank is discharged to an outside of the tank; a boil off gas compressor located at the boil off gas pipe; and a return gas pipe through which part of the boil off gas returns to the transporting means.

[0004] When receiving the liquefied gas, the receiving pipe needs to be cooled to prevent the vaporization of the liquefied gas. Therefore, PTL 1 describes that: the tank facility further includes a bypass pipe connecting the receiving pipe and the return gas pipe; and when the tank facility is not receiving the liquefied gas, the boil off gas is made to flow from the tank through the receiving pipe, the bypass pipe, the return gas pipe, and the boil off gas pipe in this order to cool the receiving pipe.

Citation List

Patent Literature

[0005] PTL 1: Japanese Laid-Open Patent Application Publication No. 2015-64022

Summary of Invention

Technical Problem

[0006] The boil off gas generated by the vaporization in the tank flows through and cools the receiving pipe to be warmed. For the purpose of compressing the cryogenic boil off gas which has been generated by the vaporization in the tank, selected as the boil off gas compressor is a compressor which can deal with a suction gas temperature corresponding to the temperature of the cryogenic boil off gas. To be specific, since the density of the boil off gas which has

been warmed after having cooled the receiving pipe becomes low, it is difficult to compress the boil off gas by the boil off gas compressor such that the pressure of the boil off gas becomes target pressure.

[0007] The present disclosure was made under these circumstances, and an object of the present disclosure is to be able to compress boil off gas, which has been used to cool a receiving pipe, by a boil off gas compressor located at a boil off gas pipe in a tank facility.

Solution to Problem

[0008] In order to solve the above problems, a tank facility according to one aspect of the present disclosure includes:

- a tank including a liquid inlet, a liquid outlet, and a gas outlet and storing liquefied gas;

- a receiving pipe which is connected to the liquid inlet of the tank and through which the liquefied gas to be received by the tank flows;

- a delivering pipe which is connected to the liquid outlet of the tank and through which the liquefied gas delivered from the tank flows;

- a BOG pipe which is connected to the gas outlet of the tank and into which boil off gas flows, the boil off gas being generated by vaporization of the liquefied gas in the tank;

- a BOG compressor located at the BOG pipe;

- a cooling gas supply pipe which is connected to an upstream portion of the receiving pipe and through which the boil off gas as cooling gas is supplied to the receiving pipe when the liquefied gas is not flowing through the receiving pipe;

- a cooling gas transfer pipe which is connected to a downstream portion of the receiving pipe and a portion, located upstream of the BOG compressor, of the BOG pipe and through which the cooling gas having flowed through the receiving pipe is conveyed to the BOG pipe; and

- a heat exchanger which is located at the cooling gas transfer pipe and performs heat exchange between the cooling gas and the liquefied gas.

Advantageous Effects of Invention

[0009] According to the above aspect of the present disclosure, in the tank facility, the boil off gas which has been used to cool the receiving pipe can be compressed by the boil off gas compressor located at the boil off gas pipe.

Brief Description of Drawings

[0010] FIG. 1 is a schematic diagram showing a schematic configuration of a tank facility according to Embodiment 1 of the present disclosure.

FIG. 2 is a diagram showing the flow of cooling gas at the time of precooling of a receiving pipe.

FIG. 3 is a schematic diagram showing a schematic configuration of the tank facility according to Modified Example 1.

FIG. 4 is a schematic diagram showing a schematic configuration of the tank facility according to Modified Example 2.

Description of Embodiments

[0011] Next, an embodiment of the present disclosure will be described with reference to the drawings. FIG. 1 is a schematic diagram showing a schematic configuration of a tank facility 1 according to one embodiment of the present disclosure. As shown in FIG. 1, the tank facility 1 according to the present disclosure is located at, for example, a liquefied gas receiving terminal 11 in a coastal area. An unloading arm 5, a return gas arm 16, and the tank facility 1 are located at the liquefied gas receiving terminal 11. The unloading arm 5 and the return gas arm 16 are located at a quay at which liquefied gas transporting means 10, such as a liquefied gas transport ship, arrives. The tank facility 1 is a facility which receives and stores liquefied gas 100 transported by the liquefied gas transporting means 10, vaporizes the stored liquefied gas 100, and sends the gas to an outside. The liquefied gas 100 stored in the tank facility 1 according to the present embodiment is liquefied hydrogen. However, the liquefied gas 100 stored in the tank facility 1 according to the present disclosure is not limited to this and may be cryogenic or supercryogenic liquefied gas, such as LNG (Liquefied Natural Gas) or cooled LPG (Liquefied Petroleum Gas). Moreover, a place where the tank facility 1 is located is not limited to the coastal area, and the tank facility 1 may be located on land or the sea in accordance with the liquefied gas transporting means 10.

[0012] The tank facility 1 includes a tank 2, a receiving pipe 3, a delivering pipe 7, a vaporizer 8, a supply gas pipe 9, a return gas pipe 15, a BOG pipe 12, a BOG compressor 14, a bypass pipe 17, and a cooling gas transfer pipe 31.

[0013] The tank 2 is a vessel that stores the liquefied gas 100 in a cryogenic liquid state. Since the liquefied gas 100 in the tank 2 is stored substantially at a boiling point, boil off gas 300 is generated by natural vaporization of the liquefied gas 100 in the tank 2 and accumulates in an upper portion and top portion of the tank 2. The tank 2 includes a liquid inlet 24, a liquid outlet

25, and a gas outlet 26. The gas outlet 26 is open at the upper portion or top portion of the tank 2.

[0014] The receiving pipe 3 connects the unloading arm 5 and the tank 2. An upstream end portion of the receiving pipe 3 is connected to the unloading arm 5, and a downstream end portion of the receiving pipe 3 is connected to the liquid inlet 24 of the tank 2. A receiving valve 4 that opens and closes the receiving pipe 3 is located at a portion of the receiving pipe 3, i.e., at a downstream portion of the receiving pipe 3. When receiving the liquefied gas 100, the receiving valve 4 opens, and the cryogenic liquefied gas 100 which has been transported by the liquefied gas transporting means 10 is supplied to the receiving pipe 3 through the unloading arm 5, flows into the tank 2 through the receiving pipe 3, and is stored in the tank 2.

[0015] The delivering pipe 7 connects the liquid outlet 25 of the tank 2 and an inlet of the vaporizer 8. The supply gas pipe 9 is a pipe through which vaporized gas 200 is sent to an outside of the tank facility 1. A delivering pump 6 is located at the delivering pipe 7.

However, the delivering pump 6 may be located at the tank 2. When delivering the liquefied gas 100 stored in the tank 2, the liquefied gas 100 having flowed out to the delivering pipe 7 is pressurized by the operation of the delivering pump 6 to obtain pressure necessary for the sending and is sent to the vaporizer 8.

[0016] The vaporizer 8 performs heat exchange between, for example, water supplied from an outside and the liquefied gas 100 supplied through the delivering pipe 7 to forcibly vaporize the liquefied gas 100, and as a result, obtain the vaporized gas 200. The supply gas pipe 9 is connected to an outlet of the vaporizer 8, and the vaporized gas 200 is sent to an outside through the supply gas pipe 9.

[0017] The BOG pipe 12 connects the tank 2 and the supply gas pipe 9. An upstream end portion of the BOG pipe 12 is connected to the gas outlet 26 of the tank 2, and the boil off gas 300 accumulating at the upper portion in the tank 2 flows out to the BOG pipe 12. A downstream end portion of the BOG pipe 12 is connected to a connection portion P1 located at the supply gas pipe 9. The boil off gas 300 in the tank 2 is sent to the supply gas pipe 9 through the BOG pipe 12, joins the vaporized gas 200, and is sent to an outside through the supply gas pipe 9.

[0018] A BOG valve 13 that opens and closes the BOG pipe 12 is located at a portion of the BOG pipe 12. The BOG valve 13 may be open except for the time of below-described precooling of the receiving pipe 3. Moreover, the BOG compressor 14 is located downstream of the BOG valve 13 of the BOG pipe 12. For example, the BOG compressor 14 may be of a reciprocating type including: a cylinder that sucks the cryogenic boil off gas 300; and a piston

that compresses the sucked boil off gas 300. The BOG compressor 14 compresses the boil off gas 300 flowing through the BOG pipe 12 such that the pressure of the boil off gas 300 becomes substantially equal to the pressure of the vaporized gas 200 sent out from the vaporizer 8.

[0019] The return gas pipe 15 connects the tank 2 and the return gas arm 16. In the tank facility 1 according to the present embodiment, an upstream portion of a return gas line and an upstream portion of a BOG line are shared, and the return gas pipe 15 is connected to the gas outlet 26 of the tank 2 through an upstream portion of the BOG pipe 12. More specifically, an upstream end portion of the return gas pipe 15 is connected to a connection portion P2 located upstream of the BOG valve 13 of the BOG pipe 12. However, the upstream end portion of the return gas pipe 15 may be directly connected to the gas outlet 26 of the tank 2. A downstream end portion of the return gas pipe 15 is connected to the return gas arm 16. A return gas blower 21 is located at a portion of the return gas pipe 15. For example, the return gas blower 21 operates at the time of the below-described precooling of the receiving pipe 3 and at the time of the receiving of the liquefied gas 100. At the time of the receiving of the liquefied gas 100, part of the boil off gas 300 of the tank 2 is made to return to a cargo tank of the liquefied gas transporting means 10 through the return gas pipe 15 and the return gas arm 16 by the operation of the return gas blower 21, and this compensates for a decrease in pressure of the cargo tank due to loading. When the pressure of the boil off gas 300 is adequately high, the return gas blower 21 may be omitted.

[0020] The bypass pipe 17 connects the return gas pipe 15 and the receiving pipe 3. An upstream end portion of the bypass pipe 17 is connected to a connection portion P3 located at the return gas pipe 15. A downstream end portion of the bypass pipe 17 is connected to a connection portion P4 located at an upstream portion of the receiving pipe 3. It is desirable that the connection portion P4 be located at a position of the receiving pipe 3 which is close to the unloading arm 5. A bypass valve 18 that opens and closes the bypass pipe 17 is located at a portion of the bypass pipe 17. The bypass valve 18 is open at the time of the below-described precooling of the receiving pipe 3 and is closed at any other conditions.

[0021] The cooling gas transfer pipe 31 connects the receiving pipe 3 and the BOG pipe 12. An upstream end portion of the cooling gas transfer pipe 31 is connected to a connection portion P5 located at a downstream portion of the receiving pipe 3, i.e., at a portion located upstream of the receiving valve 4. A downstream end portion of the cooling gas transfer pipe 31 is connected to a connection portion P6 located upstream of the BOG compressor 14 of the BOG pipe 12 and downstream of the BOG valve 13 of the BOG pipe 12. A discharge valve 32 that opens and closes the cooling gas transfer pipe 31 is located at an upstream portion of the cooling

gas transfer pipe 31. The discharge valve 32 is open at the time of the below-described precooling of the receiving pipe 3 and is closed at any other conditions. Moreover, a heat exchanger 33 is located at a portion of the cooling gas transfer pipe 31. The heat exchanger 33 performs heat exchange between a cooling gas 301 flowing through the cooling gas transfer pipe 31 and the liquefied gas 100 flowing through the delivering pipe 7 to cool the cooling gas 301.

[0022] **Precooling of Receiving Pipe 3**

The precooling of the receiving pipe 3 will be described with reference to FIG. 2. In the tank facility 1 configured as above, before receiving the liquefied gas 100 from the liquefied gas transporting means 10, the precooling of the receiving pipe 3 is performed. In FIG. 2, the flow of the cooling gas 301 in the tank facility 1 during the precooling of the receiving pipe 3 is shown by thick lines. During the precooling, the receiving valve 4 and the BOG valve 13 are closed, the bypass valve 18 and the discharge valve 32 are open, and the delivering pump 6, the return gas blower 21, and the BOG compressor 14 are operating. Basically, the delivering pump 6 and the BOG compressor 14 are operating at all times.

[0023] To cool the receiving pipe 3, the cooling gas 301 is made to flow through the receiving pipe 3, and the boil off gas 300 in the tank 2 is utilized as the cooling gas 301. During the precooling, as the cooling gas 301, the boil off gas 300 having flowed out from the tank 2 flows through a portion from the upstream end portion of the BOG pipe 12 to the connection portion P2, a portion from the upstream end portion of the return gas pipe 15 to the connection portion P3, the bypass pipe 17, a portion from the connection portion P4 of the receiving pipe 3 to the connection portion P5, the cooling gas transfer pipe 31, a portion from the connection portion P6 of the BOG pipe 12 to the downstream end portion of the BOG pipe 12, and a portion located downstream of the connection portion P1 of the supply gas pipe 9 in this order. In the present embodiment, the return gas pipe 15 and the bypass pipe 17 serve as a cooling gas supply pipe 30 through which the cryogenic cooling gas 301 is supplied to the receiving pipe 3. The cryogenic cooling gas 301 flows through the receiving pipe 3, and this cools the receiving pipe 3.

[0024] The cooling gas 301 which has been warmed by cooling the receiving pipe 3 flows into the cooling gas transfer pipe 31, is subjected to heat exchange with the liquefied gas 100 by the heat exchanger 33 to be cooled, and reaches an inlet of the BOG compressor 14. Herein, it is desirable that the cooling gas 301 which has reached the inlet of the BOG compressor 14 be cooled to have a low temperature that is substantially equal to the temperature of the boil off gas 300 flowing from the tank 2 through the BOG pipe 12. As above, the cooling gas 301 which has been utilized to cool the receiving pipe 3 becomes such an adequately low temperature as to

be compressible by the BOG compressor 14. Therefore, to compress the cooling gas 301 which has been utilized to cool the receiving pipe 3, the tank facility 1 does not have to include an additional compressor for the compression of high-temperature gas that is higher in temperature than the gas compressed by the BOG compressor 14.

[0025] When the receiving pipe 3 is cooled to a predetermined temperature, the precooling is terminated, and the receiving of the liquefied gas 100 starts. At the time of the termination of the precooling, the bypass valve 18 and the discharge valve 32 are closed, and the receiving valve 4 and the BOG valve 13 are open.

[0026] **Modified Example 1**

Modified Example 1 of the above embodiment will be described. FIG. 3 is a schematic diagram showing a schematic configuration of the tank facility 1 according to Modified Example 1. In FIG. 3, the flow of the cooling gas 301 in the tank facility 1 during the precooling of the receiving pipe 3 is shown by thick lines. In the description of the present modified example and the drawings, the same reference signs are used for the same or similar members as or to the above embodiment, and explanations thereof are omitted.

[0027] As shown in FIG. 3, in the tank facility 1 according to Modified Example 1, a liquid extraction pipe 71 is connected to the delivering pipe 7. The liquid extraction pipe 71 is a pipe which extracts part of the liquefied gas 100 flowing through the delivering pipe 7 and then returns the liquefied gas 100 to the main stream of the delivering pipe 7. An upstream end portion of the liquid extraction pipe 71 is connected to a connection portion P7 located downstream of the delivering pump 6 of the delivering pipe 7. A downstream end portion of the liquid extraction pipe 71 is connected to a connection portion P8 located downstream of the connection portion P7 of the delivering pipe 7. An on-off valve 72 and the heat exchanger 33 are located at the liquid extraction pipe 71. The on-off valve 72 opens and closes the liquid extraction pipe 71, and the heat exchanger 33 is located downstream of the on-off valve 72. The on-off valve 72 is open at the time of the precooling of the receiving pipe 3 and is closed at any other conditions.

[0028] In the tank facility 1 according to Modified Example 1, the cooling gas 301 which has been warmed through the receiving pipe 3 at the time of the precooling of the receiving pipe 3 is cooled by the heat exchange at the heat exchanger 33 with the liquefied gas 100 flowing through the liquid extraction pipe 71. To be specific, part of the liquefied gas 100 flowing through the delivering pipe 7 is utilized to cool the cooling gas 301, and the main stream of the liquefied gas 100 flowing through the delivering pipe 7 is not utilized to cool the cooling gas 301. Therefore, the temperature increase of the liquefied gas 100 flowing through the

delivering pipe 7 can be suppressed.

[0029] **Modified Example 2**

Next, Modified Example 2 of the embodiment will be described. FIG. 4 is a schematic diagram showing a schematic configuration of the tank facility 1 according to Modified Example 2. In FIG. 4, the flow of the cooling gas 301 in the tank facility 1 during the precooling of the receiving pipe 3 is shown by thick lines. In the description of the present modified example and the drawings, the same reference signs are used for the same or similar members as or to the above embodiment, and explanations thereof are omitted.

[0030] As shown in FIG. 4, in the tank facility 1 according to Modified Example 2, a circulation pipe 73 is connected to the delivering pipe 7. The circulation pipe 73 is a pipe which extracts part of the liquefied gas 100 flowing through the delivering pipe 7 and then returns the liquefied gas 100 to the tank 2. An upstream end portion of the circulation pipe 73 is connected to a connection portion P9 located upstream of the delivering pump 6 of the delivering pipe 7. A downstream end portion of the liquid extraction pipe 71 is connected to the tank 2. An on-off valve 74 and the heat exchanger 33 are located at the circulation pipe 73. The on-off valve 74 opens and closes the circulation pipe 73, and the heat exchanger 33 is located downstream of the on-off valve 74. The on-off valve 74 is open at the time of the precooling of the receiving pipe 3 and is closed at any other conditions.

[0031] In the tank facility 1 according to Modified Example 2, the cooling gas 301 which has been warmed through the receiving pipe 3 at the time of the precooling of the receiving pipe 3 is cooled by the heat exchange at the heat exchanger 33 with the liquefied gas 100 flowing through the circulation pipe 73. To be specific, part of the liquefied gas 100 flowing through the delivering pipe 7 is utilized to cool the cooling gas 301, and the main stream of the liquefied gas 100 flowing through the delivering pipe 7 is not utilized to cool the cooling gas 301. Therefore, the temperature increase of the liquefied gas 100 flowing through the delivering pipe 7 can be suppressed.

[0032] **Conclusion**

As described above, the tank facility 1 according to the present disclosure includes:
a tank 2 including a liquid inlet 24, a liquid outlet 25, and a gas outlet 26 and storing liquefied gas 100;

a receiving pipe 3 which is connected to the liquid inlet 24 of the tank 2 and through which the liquefied gas 100 to be received by the tank 2 flows;

a delivering pipe 7 which is connected to the liquid outlet 25 of the tank 2 and through which the liquefied gas 100 delivered from the tank 2 flows;

a BOG pipe 12 which is connected to the gas outlet 26 of the tank 2 and into which boil off gas 300 flows, the boil off gas 300 being generated by vaporization of the liquefied gas 100 in the tank 2;

a BOG compressor 14 located at the BOG pipe 12;

a cooling gas supply pipe 30 which is connected to an upstream portion of the receiving pipe 3 and through which the boil off gas 300 as cooling gas 301 is supplied to the receiving pipe 3 when the liquefied gas 100 is not flowing through the receiving pipe 3;

a cooling gas transfer pipe 31 which is connected to a downstream portion of the receiving pipe 3 and a portion, located upstream of the BOG compressor 14, of the BOG pipe 12 and through which the cooling gas 301 having flowed through the receiving pipe 3 is conveyed to the BOG pipe 12; and

a heat exchanger 33 which is located at the cooling gas transfer pipe 31 and performs heat exchange between the cooling gas 301 and the liquefied gas 100.

[0033] According to the tank facility 1 configured as above, the cooling gas 301 which has been warmed by cooling the receiving pipe 3 is cooled by the heat exchanger 33 and is then sent to an upstream side of the BOG compressor 14 of the BOG pipe 12. Therefore, the BOG compressor 14 can compress the cooling gas 301 as with the cryogenic boil off gas 300 generated in the tank 2, and a special compressor that compresses the cooling gas 301 is not required. Moreover, the cooling gas 301 which has been used to cool the receiving pipe 3 can be used as supply gas as with the boil off gas 300.

[0034] Moreover, in the tank facility 1 configured as above, the heat exchanger 33 may perform the heat exchange between the cooling gas 301 and part or all of the liquefied gas 100 flowing through the delivering pipe 7. Or, a circulation pipe 73 through which part of the liquefied gas 100 flowing through the delivering pipe 7 returns to the tank 2 is connected to the delivering pipe 7, and the heat exchanger 33 performs the heat exchange between the liquefied gas 100 flowing through the circulation pipe 73 and the cooling gas 301.

[0035] As above, the heat exchanger 33 can adequately cool the cooling gas 301 by utilizing the liquefied gas 100 flowing through the delivering pipe 7 as a cold source. Moreover, a special cooling medium that cools the cooling gas 301 is not required.

[0036] Moreover, in the tank facility 1 configured as above, the cooling gas supply pipe 30 may include: a return gas pipe 15 connected to the gas outlet 26 of the tank 2; and a bypass pipe 17 connecting the return gas pipe 15 and the upstream portion of the receiving pipe 3.

[0037] The cooling gas supply pipe 30 is not limited to the above and may be configured to be able to supply the boil off gas 300 as the cooling gas 301 to the receiving pipe 3. For

example, the cooling gas supply pipe 30 may be configured as a pipe connecting the BOG pipe 12 and the receiving pipe 3 or a pipe connecting the gas outlet 26 of the tank 2 and the receiving pipe 3.

[0038] The foregoing discussion of the disclosure has been presented for purposes of illustration and description. The foregoing is not intended to limit the disclosure to the form or forms disclosed herein. In the foregoing Detailed Description for example, various features of the disclosure are grouped together in one embodiment for the purpose of streamlining the disclosure. The features of the disclosure may be combined in alternate embodiments, configurations, or aspects other than those discussed above.

CLAIMS

[Claim 1] A tank facility comprising:

a tank including a liquid inlet, a liquid outlet, and a gas outlet and storing liquefied gas;

a receiving pipe which is connected to the liquid inlet of the tank and through which the liquefied gas to be received by the tank flows;

a delivering pipe which is connected to the liquid outlet of the tank and through which the liquefied gas delivered from the tank flows;

a BOG pipe which is connected to the gas outlet of the tank and into which boil off gas flows, the boil off gas being generated by vaporization of the liquefied gas in the tank;

a BOG compressor located at the BOG pipe;

a cooling gas supply pipe which is connected to an upstream portion of the receiving pipe and through which the boil off gas as cooling gas is supplied to the receiving pipe when the liquefied gas is not flowing through the receiving pipe;

a cooling gas transfer pipe which is connected to a downstream portion of the receiving pipe and a portion, located upstream of the BOG compressor, of the BOG pipe and through which the cooling gas having flowed through the receiving pipe is conveyed to the BOG pipe; and

a heat exchanger which is located at the cooling gas transfer pipe and performs heat exchange between the cooling gas and the liquefied gas.

[Claim 2] The tank facility according to claim 1, wherein the heat exchanger performs the heat exchange between the cooling gas and part or all of the liquefied gas flowing through the delivering pipe.

[Claim 3] The tank facility according to claim 1, wherein:

a circulation pipe through which part of the liquefied gas flowing through the delivering pipe returns to the tank is connected to the delivering pipe; and

the heat exchanger performs the heat exchange between the liquefied gas flowing through the circulation pipe and the cooling gas.

[Claim 4] The tank facility according to any one of claims 1 to 3, wherein the cooling gas supply pipe includes:

a return gas pipe connected to the gas outlet of the tank; and

a bypass pipe connecting the return gas pipe and the upstream portion of the receiving pipe.