

DESCRIPTION

Title of Invention

FLOATING STRUCTURE, METHOD FOR LOADING LIQUEFIED CARBON DIOXIDE, AND METHOD FOR UNLOADING LIQUEFIED CARBON DIOXIDE

Technical Field

[0001]

The present disclosure relates to a floating structure, a method for loading liquefied carbon dioxide, and a method for unloading liquefied carbon dioxide.

Priority is claimed on Japanese Patent Application No. 2020-180559, filed October 28, 2020, the content of which is incorporated herein by reference.

Background Art

[0002]

For example, the fuel tank disclosed in PTL 1 discloses a configuration including a loading pipe (pipeline) for loading a liquefied gas (liquefied natural gas (LNG)) into the fuel tank.

Citation List

Patent Literature

[0003]

[PTL 1] PCT Japanese Translation Patent Publication No. 2018-528119

Summary of Invention

Technical Problem

[0004]

Incidentally, when the liquefied carbon dioxide is accommodated in the tank, there is a possibility that the liquefied carbon dioxide solidifies to form dry ice for the following reasons. That is, the pressure of the liquefied carbon dioxide at the lower end of the loading pipe or the unloading pipe that opens in the tank corresponds to the tank operating pressure. In the configuration as disclosed in PTL 1, the pipe top at the highest position in the loading pipe or the unloading pipe is positioned above the highest liquid level in the tank. The pressure of the liquefied carbon dioxide at the pipe top is lower than the pressure of the liquefied carbon dioxide at the lower end of the pipe by the amount corresponding to the head pressure due to the height difference between the liquid surface of the liquefied carbon dioxide in the tank and the pipe top. That is, in the loading pipe or the unloading pipe, the pressure of the liquefied carbon dioxide at the pipe top is lower than the pressure of the liquefied carbon dioxide in the tank.

[0005]

In the case of liquefied carbon dioxide, the pressure at the triple point where the gas phase, the liquid phase,

and the solid phase coexist (triple point pressure) is higher than the triple point pressure of LNG or LPG, and the difference from the tank operating pressure during operation is small. As a result, depending on the tank operating pressure (tank design pressure), the pressure of the liquefied carbon dioxide may become equal to or less than the triple point pressure at the pipe top where the pressure of the liquefied carbon dioxide is the lowest, and the flash evaporation of the liquefied carbon dioxide may occur. Then, due to the latent heat of evaporation of the flash evaporation of the liquefied carbon dioxide, a decrease in temperature of the liquefied carbon dioxide remaining without evaporation occurs, and the liquefied carbon dioxide solidifies at the pipe top to form dry ice. When dry ice is formed in the loading pipe or the unloading pipe, the flow of the liquefied carbon dioxide in the pipe is obstructed, which may affect the loading and unloading work of the liquefied carbon dioxide.

[0006]

The present disclosure is made in order to solve the above problems, and an object thereof is to provide a floating structure, a method for loading liquefied carbon dioxide, and a method for unloading liquefied carbon dioxide that can suppress the formation of dry ice in a pipe and smoothly perform loading and unloading work of liquefied

carbon dioxide.

Solution to Problem

[0007]

In order to solve the above problems, the floating structure according to the present disclosure includes a floating main structure, a tank, and a loading pipe. The tank is disposed in the floating main structure. The tank is capable of storing liquefied carbon dioxide. The loading pipe discharges liquefied carbon dioxide supplied from an outside into the tank. The loading pipe includes a first loading pipe and a second loading pipe. The first loading pipe is disposed outside the tank. The first loading pipe has a first inner diameter. The second loading pipe has one end connected to the first loading pipe, and the other end open inside the tank. The second loading pipe has a second inner diameter smaller than the first inner diameter.

[0008]

The floating structure according to the present disclosure includes a floating main structure, a plurality of tanks, an unloading pipe, and a transfer pipe. The tank is disposed in the floating main structure. The tank is capable of storing liquefied carbon dioxide. The unloading pipe is provided in each of the plurality of tanks. The unloading pipe delivers liquefied carbon dioxide in the tank to an outside of the floating main structure. The transfer

pipe is disposed to straddle between the first tank and the second tank. The transfer pipe allows an inside of the first tank and an inside of the second tank to communicate with each other. The transfer pipe includes a first transfer pipe and a second transfer pipe. The first transfer pipe is disposed on a first tank side. The transfer pipe has a first inner diameter. The second transfer pipe has one end connected to the first transfer pipe, and the other end open inside the second tank. The second transfer pipe has a second inner diameter smaller than the first inner diameter.

[0009]

A method for loading liquefied carbon dioxide according to the present disclosure is a method for loading liquefied carbon dioxide in the floating structure described above. The method for loading liquefied carbon dioxide includes: a step of loading liquefied carbon dioxide into the tank from the first loading pipe through the second loading pipe; and a step of loading liquefied carbon dioxide into the tank from the first loading pipe through the third loading pipe when a liquid level of liquefied carbon dioxide in the tank reaches a predetermined liquid level.

[0010]

A method for unloading liquefied carbon dioxide according to the present disclosure is a method for

unloading liquefied carbon dioxide in the floating structure described above. The method for unloading liquefied carbon dioxide includes: a step of transferring liquefied carbon dioxide in the first tank from the first transfer pipe into the second tank through the second transfer pipe by pressurizing the inside of the first tank; a step of transferring liquefied carbon dioxide in the first tank from the first transfer pipe into the second tank through the third transfer pipe when a liquid level of liquefied carbon dioxide in the second tank reaches a predetermined liquid level; and a step of delivering the liquefied carbon dioxide in the second tank to an outside of the second tank by the unloading pipe.

Advantageous Effects of Invention

[0011]

According to the floating structure, the method for loading liquefied carbon dioxide, and the method for unloading liquefied carbon dioxide according to the present disclosure, it is possible to suppress the formation of dry ice in the pipe and smoothly perform the loading and unloading work.

Brief Description of Drawings

[0012]

Fig. 1 is a plan view showing a schematic configuration of a ship as a floating structure according to each

embodiment of the present disclosure.

Fig. 2 is a view showing a tank, a loading pipe, and an unloading pipe provided in a ship according to a first embodiment of the present disclosure, and is a sectional view taken along line II-II of Fig. 1.

Fig. 3 is a sectional view showing a tank, a loading pipe, and an unloading pipe provided in a ship according to a second embodiment of the present disclosure.

Fig. 4 is a flowchart showing a procedure of a method for loading liquefied carbon dioxide according to the second embodiment of the present disclosure.

Fig. 5 is a sectional view showing a state where the liquefied carbon dioxide is loaded through a second loading pipe in a method for loading liquefied carbon dioxide according to the second embodiment of the present disclosure.

Fig. 6 is a sectional view showing a state where the liquefied carbon dioxide is loaded through a third loading pipe in a method for loading liquefied carbon dioxide according to the second embodiment of the present disclosure.

Fig. 7 is a sectional view showing a tank, a loading pipe, and an unloading pipe provided in a ship according to a third embodiment of the present disclosure.

Fig. 8 is a sectional view showing a tank, a loading pipe, and an unloading pipe provided in a ship according to a fourth embodiment of the present disclosure.

Fig. 9 is a flowchart showing a procedure of a method for unloading liquefied carbon dioxide according to the fourth embodiment of the present disclosure.

Fig. 10 is a sectional view showing a state where liquefied carbon dioxide is transferred through a second loading pipe in the method for unloading liquefied carbon dioxide according to the fourth embodiment of the present disclosure.

Fig. 11 is a sectional view showing a state where liquefied carbon dioxide is transferred through a third loading pipe in the method for unloading liquefied carbon dioxide according to the fourth embodiment of the present disclosure.

Description of Embodiments

[0013]

Hereinafter, a floating structure, a method for loading liquefied carbon dioxide, and a method for unloading liquefied carbon dioxide according to the embodiments of the present disclosure will be described with reference to Figs. 1 to 11.

<First Embodiment>

(Configuration of Ship)

As shown in Fig. 1, in the embodiment of the present disclosure, a ship 1 which is a floating structure carries liquefied carbon dioxide. The ship 1 includes at least a

hull 2 as a floating main structure and a tank facility 10A.

[0014]

(Configuration of Hull)

The hull 2 has a pair of sides 3A and 3B, a bottom (not shown), and an upper deck 5, which form an outer shell thereof. The sides 3A and 3B each have a pair of side shell platings which form the left and right sides. The bottom (not shown) has a bottom shell plating connecting the sides 3A and 3B to each other. Due to the pair of sides 3A and 3B and the bottom (not shown), the outer shell of the hull 2 has a U-shape in a cross section orthogonal to a stem-stern direction Da. The upper deck 5 shown in this embodiment is a continuous deck exposed to the outside. In the hull 2, a superstructure 7 having an accommodation space is formed on the upper deck 5 on a stern 2b side.

[0015]

Inside the hull 2, a cargo tank storage compartment (hold) 8 is formed on a stem 2a side of the superstructure 7. The cargo tank storage compartment 8 is recessed toward the bottom below the upper deck 5, and is open upward.

[0016]

(Configuration of Tank Facility)

A plurality of tank facilities 10A are disposed in the cargo tank storage compartment 8 along the stem-stern direction Da. In the embodiment of the present disclosure,

two tank facilities 10A are disposed at intervals in the stem-stern direction Da.

[0017]

As shown in Fig. 2, the tank facility 10A includes at least a tank 11, a loading pipe 20A, and an unloading pipe 30.

In this embodiment, the tank 11 is disposed on the hull 2. The tank 11 has, for example, a cylindrical shape extending in the horizontal direction. The tank 11 accommodates a liquefied carbon dioxide L inside thereof. The tank main body includes a tubular portion 12 and an end spherical portion 13. The tubular portion 12 extends in the horizontal direction as a longitudinal direction Dx. In this embodiment, the tubular portion 12 is formed in a cylindrical shape having a circular cross-sectional shape orthogonal to the longitudinal direction Dx. The end spherical portions 13 are respectively disposed at both end portions of the tubular portion 12 in the longitudinal direction Dx. Each of the end spherical portions 13 has a hemispherical shape and blocks the openings at both ends of the tubular portion 12 in the longitudinal direction Dx. The tank 11 is not limited to a cylindrical shape, and the tank 11 may have a spherical shape, a square shape, or the like.

[0018]

The loading pipe 20A loads the liquefied carbon dioxide L supplied from the outside of the ship, such as an on-land liquefied carbon dioxide supply facility, into the tank 11. The loading pipe 20A includes a first loading pipe 21 and a second loading pipe 22.

[0019]

The first loading pipe 21 is detachably connected to a supply pipe (not shown) to which liquefied carbon dioxide is supplied from the liquefied carbon dioxide supply facility or the like on the outside of the ship. The first loading pipe 21 is disposed outside the tank 11. The first loading pipe 21 in this embodiment extends in the horizontal direction above the tank 11 in a vertical direction D_v . The first loading pipe 21 has a first inner diameter D_1 .

[0020]

One end 22a (in other words, the upper end in the vertical direction D_v) of the second loading pipe 22 is connected to the first loading pipe 21. The second loading pipe 22 penetrates the top of the tank 11 and extends from the outside to the inside of the tank 11. The second loading pipe 22 extends in the vertical direction D_v inside the tank 11. The other end 22b (in other words, the lower end in the vertical direction D_v) of the second loading pipe 22 is open downward in the lower portion of the tank 11. The second loading pipe 22 has a second inner diameter D_2 that

is smaller than the first inner diameter D1. In this embodiment, the second loading pipe 22 has the second inner diameter D2 over the entire length thereof. In the second loading pipe 22, only a constant length on the other end 22b side may be formed by the second inner diameter D2, and the one end 22a side may be formed by the same first inner diameter D1 as the first loading pipe 21.

[0021]

The unloading pipe 30 delivers the liquefied carbon dioxide L in the tank 11 to the outside of the ship such as an on-land liquefied carbon dioxide supply facility. The unloading pipe 30 penetrates the top of the tank 11 from the outside of the tank 11 and extends to the inside of the tank 11. The tip portion of the unloading pipe 30 is disposed in the lower portion inside the tank 11. A pump 31 is provided at the tip portion of the unloading pipe 30. The pump 31 sucks in the liquefied carbon dioxide L in the tank 11. The unloading pipe 30 delivers the liquefied carbon dioxide L sucked by the pump 31 to the outside of the tank 11 (the outside of the ship).

[0022]

(Effects)

In the ship 1 as described above, the liquefied carbon dioxide L is loaded into the tank 11 from the first loading pipe 21 through the second loading pipe 22. The second

inner diameter D2 of the second loading pipe 22 is smaller than the first inner diameter D1 of the first loading pipe 21. Therefore, a pressure loss ΔP in the second loading pipe 22 is greater than that in the first loading pipe 21.

[0023]

Here, a pressure P_L of the liquefied carbon dioxide L at the pipe top of the loading pipe 20A is expressed by the following equation (1).

$$P_L = P_T - \rho g (h_2 - h_1)/1000 + \Delta P \dots (1)$$

Here,

P_L : Pressure of the liquefied carbon dioxide L at the pipe top of the loading pipe 20A (kPaG)

P_T : Pressure of the liquefied carbon dioxide L in the upper portion of the tank 11 (kPaG)

ρ : Liquid density of the liquefied carbon dioxide L (kg/m³)

g : Gravitational acceleration (m/s²)

h_2 : Height from the lowermost portion of tank 11 to the pipe top of the loading pipe 20A (m)

h_1 : Height from the lowermost portion of the tank 11 to the liquid level of the liquefied carbon dioxide L (m)

[0024]

According to the above equation (1), the pressure (P_L) of the liquefied carbon dioxide L at the pipe top of the loading pipe 20A is increased by the amount of the pressure

loss ΔP . Since the pressure of the liquefied carbon dioxide L at the pipe top of the loading pipe 20A is increased, it is possible to suppress the approach of the pressure of the liquefied carbon dioxide L to the triple point pressure. As a result, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the loading pipe 20A are suppressed. As a result, in a case where the liquefied carbon dioxide L is accommodated in the tank 11, it is possible to suppress the formation of dry ice in the loading pipe 20A and smoothly perform the loading work.

[0025]

<Second Embodiment>

Next, the second embodiment of the floating structure and the method for loading liquefied carbon dioxide according to the present disclosure will be described. The second embodiment described below is different from the first embodiment only in the configuration including a third loading pipe 23, and thus the same parts as those in the first embodiment will be given the same reference numerals, and the redundant description will be omitted.

[0026]

As shown in Fig. 3, a tank facility 10B includes at least the tank 11, a loading pipe 20B, and the unloading pipe 30.

The loading pipe 20B loads the liquefied carbon

dioxide L supplied from the outside of the ship, such as an on-land liquefied carbon dioxide supply facility, into the tank 11. The loading pipe 20B includes the first loading pipe 21, the second loading pipe 22, and the third loading pipe 23.

[0027]

The first loading pipe 21 is detachably connected to a supply pipe (not shown) to which liquefied carbon dioxide is supplied from the liquefied carbon dioxide supply facility or the like on the outside of the ship. The first loading pipe 21 is disposed outside the tank 11. Similar to the first embodiment, the first loading pipe 21 extends in the horizontal direction above the tank 11 in the vertical direction D_v . The first loading pipe 21 has a first inner diameter D_1 .

[0028]

One end 22a (in other words, the upper end in the vertical direction D_v) of the second loading pipe 22 is connected to the first loading pipe 21. The second loading pipe 22 penetrates the top of the tank 11 and extends from the outside to the inside of the tank 11. The second loading pipe 22 extends in the vertical direction D_v inside the tank 11. The other end 22b (in other words, the upper end in the vertical direction D_v) of the second loading pipe 22 is open downward in the lower portion of the tank 11. The

second loading pipe 22 has a second inner diameter D2 that is smaller than the first inner diameter D1.

[0029]

A base 23a (in other words, the upper end in the vertical direction Dv) of the third loading pipe 23 is connected to the first loading pipe 21. The third loading pipe 23 penetrates the top of the tank 11 and extends from the outside to the inside of the tank 11. The third loading pipe 23 extends in the vertical direction Dv inside the tank 11. A tip 23b (in other words, the lower end in the vertical direction Dv) of the third loading pipe 23 is open downward in the lower portion of the tank 11. The third loading pipe 23 has a third inner diameter D3 that is greater than the second inner diameter D2. The third inner diameter D3 may be the same as the first inner diameter D1 of the first loading pipe 21.

[0030]

An opening-closing valve 24 is provided in the second loading pipe 22. The opening-closing valve 24 opens and closes the second loading pipe 22. Similarly, the opening-closing valve 25 is provided in the third loading pipe 23. The opening-closing valve 25 opens and closes the third loading pipe 23.

[0031]

(Procedure of Method for Loading Liquefied Carbon

Dioxide)

As shown in Fig. 4, a method S1 for loading liquefied carbon dioxide according to the embodiment of the present disclosure includes a step S2 of loading the liquefied carbon dioxide L through the second loading pipe 22; and a step S3 of loading the liquefied carbon dioxide L through the third loading pipe 23.

[0032]

As shown in Fig. 5, in the step S2 of loading the liquefied carbon dioxide L through the second loading pipe 22, the opening-closing valve 24 is opened and the opening-closing valve 25 is closed. As a result, the first loading pipe 21 and the second loading pipe 22 are in a state of being communicated with each other. In this state, the liquefied carbon dioxide L supplied from the outside of the ship is fed from the first loading pipe 21 into the tank 11 through the second loading pipe 22. At this time, the second inner diameter D2 of the second loading pipe 22 is smaller than the first inner diameter D1 of the first loading pipe 21. Therefore, the pressure loss ΔP in the second loading pipe 22 becomes large, and the liquefied carbon dioxide L is loaded while suppressing the formation of dry ice in the loading pipe 20A.

[0033]

As shown in Fig. 6, thereafter, when the liquid level

of the liquefied carbon dioxide L in the tank 11 reaches a predetermined specified liquid level, the process is shifted to the step S3 of loading the liquefied carbon dioxide L through the third loading pipe 23. To this end, the opening-closing valve 24 is closed and the opening-closing valve 25 is opened. As a result, the first loading pipe 21 and the third loading pipe 23 are in a state of being communicated with each other. When the liquid level of the liquefied carbon dioxide L in the tank 11 rises and reaches the specified liquid level as described above, the differential pressure between the liquefied carbon dioxide L in the tank 11 and the pipe top of the loading pipe 20B becomes smaller. As a result, the liquefied carbon dioxide L is unlikely to solidify at the pipe top of the loading pipe 20B.

[0034]

In the step S3 performed in such a state, the liquefied carbon dioxide L supplied from the outside of the ship can be fed from the first loading pipe 21 into the tank 11 through the third loading pipe 23. The third inner diameter D3 of the third loading pipe 23 is greater than the second inner diameter D2 of the second loading pipe 22. Therefore, compared to the step S2, the flow rate of the liquefied carbon dioxide L supplied into the tank 11 through the third loading pipe 23 can be increased.

[0035]

(Effects)

In the ship 1 and the method S1 for loading the liquefied carbon dioxide L according to the second embodiment described above, when the liquid level of the liquefied carbon dioxide L in the tank 11 is low, the liquefied carbon dioxide L is loaded from the first loading pipe 21 into the tank 11 through the second loading pipe 22. Since the second inner diameter D2 of the second loading pipe 22 is smaller than the first inner diameter D1 of the first loading pipe 21, the pressure loss ΔP formed in the second loading pipe 22 increases the pressure of the liquefied carbon dioxide L at the pipe top of the loading pipe 20B. As a result, it is possible to suppress the solidification of the liquefied carbon dioxide L in the loading pipe 20B and the formation of dry ice. As a result, in a case where the liquefied carbon dioxide L is accommodated in the tank 11, it is possible to suppress the formation of dry ice in the loading pipe 20B and smoothly perform the loading work.

Further, after the liquid level of the liquefied carbon dioxide L in the tank 11 rises and reaches the specified liquid level, the liquefied carbon dioxide L is loaded into the tank 11 through the third loading pipe 23. As a result, the liquefied carbon dioxide L can be loaded in a short period of time.

[0036]

<Third Embodiment>

Next, the third embodiment of the floating structure and the method for loading liquefied carbon dioxide according to the present disclosure will be described. In the third embodiment described below, the same reference numerals will be given to the same parts as those of the first and second embodiments described above, and the redundant description thereof will be omitted.

As shown in Fig. 7, the tank facility 10C includes at least a plurality of tanks 11, a loading pipe 20C, the unloading pipe 30, and a transfer pipe 40C.

The loading pipe 20C loads the liquefied carbon dioxide L supplied from the outside of the ship, such as an on-land liquefied carbon dioxide supply facility, into the tank 11. The loading pipes 20C of the third embodiment are provided one by one in each of the plurality of tanks 11.

[0037]

The unloading pipe 30 delivers the liquefied carbon dioxide L in each of the tanks 11 to the outside of the ship such as an on-land liquefied carbon dioxide supply facility. The unloading pipe 30 penetrates the top of the tank 11 from the outside of the tank 11 and extends to the inside of the tank 11. The tip portion of the unloading pipe 30 is disposed in the lower portion inside the tank 11. The pump

31 is provided at the tip portion of the unloading pipe 30. The pump 31 sucks in the liquefied carbon dioxide L in the tank 11. The unloading pipe 30 delivers the liquefied carbon dioxide L sucked by the pump 31 to the outside of the tank 11 (the outside of the ship). Similarly to the loading pipe 20C, the unloading pipes 30 of the third embodiment are provided one by one in each of the plurality of tanks 11. In the following description, a case where two tanks 11, a first tank 11P and a second tank 11Q are provided as the plurality of tanks 11 will be described as an example.

[0038]

The transfer pipe 40C is disposed to straddle between the first tank 11P and the second tank 11Q. The inside of the first tank 11P and the inside of the second tank 11Q communicate with each other through the transfer pipe 40C. The transfer pipe 40C makes it possible to transfer the liquefied carbon dioxide L from the first tank 11P to the second tank 11Q. The transfer pipe 40C includes a first transfer pipe 41 and a second transfer pipe 42.

[0039]

The first transfer pipe 41 is disposed on the first tank 11P side. A first end 41a of the first transfer pipe 41 is inserted into the first tank 11P and is open downward in the lower portion of the first tank 11P. The first

transfer pipe 41 extends upward from the first end 41a and reaches the outside of the first tank 11P. An intermediate portion 41b disposed on the outside of both the first tank 11P and the second tank 11Q in the first transfer pipe 41 extends in the horizontal direction above the first tank 11P and the second tank 11Q. The first transfer pipe 41 has a first inner diameter D11.

[0040]

One end 42a of the second transfer pipe 42 is connected to the first transfer pipe 41. The second transfer pipe 42 penetrates the top of the second tank 11Q and extends from the outside to the inside of the second tank 11Q. The second transfer pipe 42 extends in the vertical direction Dv in the second tank 11Q. The other end 42b of the second transfer pipe 42 is open downward in the lower portion of the second tank 11Q. The second transfer pipe 42 has a second inner diameter D12 that is smaller than the first inner diameter D11. In the third embodiment, the second transfer pipe 42 has the second inner diameter D12 over the entire length thereof. In the second transfer pipe 42, only a constant length on the other end 42b side may be formed by the second inner diameter D12, and the one end 42a side may be formed by the same first inner diameter D11 as the first transfer pipe 41.

[0041]

An opening-closing valve 45 is provided in the transfer pipe 40C. The opening-closing valve 45 opens and closes the transfer pipe 40C. The opening-closing valve 45 is normally closed.

In each tank 11 (first tank 11P, second tank 11Q), when the liquefied carbon dioxide L in the tank 11 is unloaded, the pump 31 provided in the unloading pipe 30 is operated in each tank 11. Then, the liquefied carbon dioxide L in the tank 11 is sucked by the pump 31, and is delivered to the outside of the ship through the unloading pipe 30.

[0042]

When the pump 31 of the first tank 11P is in a state where the required function is not exhibited due to a failure or the like, the opening-closing valve 45 is opened. Then, the inside of the first tank 11P and the inside of the second tank 11Q communicate with each other through the transfer pipe 40C. In this state, a pressurizing gas G_p (for example, boil-off gas) in a tank other than the first tank 11P (for example, the second tank 11Q) is supplied into the first tank 11P through a pressurizing gas pipe (not shown). Then, the pressure of the gas phase in the first tank 11P is increased, and the liquefied carbon dioxide L in the first tank 11P is pressurized. Accordingly, due to the pressure difference between the pressure of the gas

phase in the first tank 11P and the pressure of the gas phase in the second tank 11Q, the liquefied carbon dioxide L in the first tank 11P is fed into the second tank 11Q through the transfer pipe 40C (first transfer pipe 41, second transfer pipe 42). The liquefied carbon dioxide L transferred from the first tank 11P into the second tank 11Q is delivered to the outside of the ship through the unloading pipe 30 by the pump 31 provided in the unloading pipe 30 of the second tank 11Q.

[0043]

(Effects)

In the ship 1 as described above, the liquefied carbon dioxide L is transferred from the first tank 11P to the second tank 11Q through the second transfer pipe 42 from the first transfer pipe 41. The liquefied carbon dioxide L transferred to the second tank 11Q is delivered to the outside through the unloading pipe 30 of the second tank 11Q. In this manner, even when the unloading work cannot be performed in the unloading pipe 30 of the first tank 11P, the liquefied carbon dioxide L in the first tank 11P can be unloaded on the outside through the second tank 11Q.

Since the second inner diameter D12 of the second transfer pipe 42 is smaller than the first inner diameter D11 of the first transfer pipe 41, the pressure loss ΔP of the second transfer pipe 42 is greater than that of the

first transfer pipe 41, and the pressure of the liquefied carbon dioxide L flowing through the transfer pipe 40C can be increased by the amount corresponding to the pressure loss ΔP . Therefore, the pressure of the liquefied carbon dioxide L at the pipe top of the transfer pipe 40C is increased, and it is possible to suppress the approach of the pressure of the liquefied carbon dioxide L to the triple point pressure. As a result, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the transfer pipe 40C are suppressed. As a result, even in a case where the liquefied carbon dioxide L is transferred from the first tank 11P to the second tank 11Q by the transfer pipe 40C, it is possible to suppress the formation of dry ice in the transfer pipe 40C, and smoothly perform the transfer work and unloading work.

[0044]

<Fourth Embodiment>

Next, the fourth embodiment of the floating structure and the method for unloading liquefied carbon dioxide according to the present disclosure will be described. The fourth embodiment described below is different from the third embodiment only in the configuration including a third transfer pipe 43, and thus the same parts as those in the third embodiment will be given the same reference numerals, and the redundant description will be omitted.

[0045]

As shown in Fig. 8, the tank facility 10D includes at least the plurality of tanks 11, the plurality of loading pipes 20C, the plurality of unloading pipes 30, and a transfer pipe 40D. Even in the fourth embodiment, a case where there are two tanks 11 (first tank 11P, second tank 11Q) will be described as an example.

[0046]

The transfer pipe 40D is disposed to straddle between the first tank 11P and the second tank 11Q. The transfer pipe 40D transfers the liquefied carbon dioxide L from the first tank 11P to the second tank 11Q. The transfer pipe 40D includes the first transfer pipe 41, the second transfer pipe 42, and the third transfer pipe 43.

[0047]

The first transfer pipe 41 is disposed on the first tank 11P side. A first end 41a of the first transfer pipe 41 is inserted into the first tank 11P and is open downward in the lower portion of the first tank 11P. The intermediate portion 41b disposed on the outside of both the first tank 11P and the second tank 11Q in the first transfer pipe 41 extends in the horizontal direction above the first tank 11P and the second tank 11Q. The first transfer pipe 41 has a first inner diameter D11.

[0048]

The one end 42a (in other words, the upper end in the vertical direction D_v) of the second transfer pipe 42 is connected to the first transfer pipe 41. The second transfer pipe 42 penetrates the top of the second tank 11Q and extends from the outside to the inside of the second tank 11Q. The second transfer pipe 42 extends in the vertical direction D_v in the second tank 11Q. The other end 42b of the second transfer pipe 42 is open downward in the lower portion of the second tank 11Q. The second transfer pipe 42 has a second inner diameter D_{12} that is smaller than the first inner diameter D_{11} .

[0049]

A base 43a (in other words, the upper end in the vertical direction D_v) of the third transfer pipe 43 is connected to the first transfer pipe 41. The third transfer pipe 43 penetrates the top of the second tank 11Q and extends from the outside to the inside of the second tank 11Q. The third transfer pipe 43 extends in the vertical direction D_v in the second tank 11Q. A tip 43b (in other words, the lower end in the vertical direction D_v) of the third transfer pipe 43 is open downward in the lower portion of the tank 11. The third transfer pipe 43 has a third inner diameter D_{13} that is greater than the second inner diameter D_2 . The third inner diameter D_{13} may be the same as the first inner diameter D_{11} of the first transfer pipe 41.

[0050]

An opening-closing valve 46 is provided in the second transfer pipe 42. The opening-closing valve 46 opens and closes the second transfer pipe 42. An opening-closing valve 47 is provided in the third transfer pipe 43. The opening-closing valve 47 opens and closes the third transfer pipe 43. The opening-closing valves 46 and 47 are normally closed.

In each tank (first tank 11P, second tank 11Q), when the liquefied carbon dioxide L in the tank 11 is unloaded, the pump 31 provided in the unloading pipe 30 is operated in each tank 11. Then, the liquefied carbon dioxide L in the tank 11 is sucked by the pump 31, and is delivered to the outside of the ship through the unloading pipe 30.

[0051]

(Procedure of Method for Unloading Liquefied Carbon Dioxide)

When the pump 31 of the first tank 11P is in a state where the required function cannot be exhibited due to a failure or the like, a method S11 for unloading liquefied carbon dioxide described below is executed.

As shown in Fig. 9, the method S11 for unloading liquefied carbon dioxide according to the embodiment of the present disclosure includes a step S12 of transferring the liquefied carbon dioxide L through the second transfer pipe

42, a step S13 of transferring the liquefied carbon dioxide L through the third transfer pipe 43, and a step S14 of delivering the liquefied carbon dioxide L to the outside.

[0052]

As shown in Fig. 10, in the step S12 of transferring the liquefied carbon dioxide L through the second transfer pipe 42, the opening-closing valve 46 is opened and the opening-closing valve 47 is closed. As a result, the first transfer pipe 41 and the second transfer pipe 42 are in a state of being communicated with each other. In this state, as the pressurizing gas Gp, the boil-off gas in a tank other than the first tank 11P (for example, the second tank 11Q) is introduced into the first tank 11P through a pressurizing gas pipe (not shown). Then, the pressure of the gas phase in the first tank 11P increases, and a pressure difference between the pressure of the gas phase in the first tank 11P and the pressure of the gas phase in the second tank 11Q occurs. As a result, the liquefied carbon dioxide L in the first tank 11P is fed into the second tank 11Q through the first transfer pipe 41 and the second transfer pipe 42. At this time, the second inner diameter D2 of the second transfer pipe 42 is smaller than the first inner diameter D1 of the first transfer pipe 41. Therefore, the pressure loss ΔP in the second transfer pipe 42 becomes large, and the liquefied carbon dioxide L is loaded while suppressing

the formation of dry ice in the transfer pipe 40D.

[0053]

As shown in Fig. 11, when the liquid level of the liquefied carbon dioxide L in the second tank 11Q reaches a predetermined specified liquid level, the process is shifted to the step S13 of transferring the liquefied carbon dioxide L through the third transfer pipe 43. To this end, the opening-closing valve 46 is closed and the opening-closing valve 47 is opened. As a result, the first transfer pipe 41 and the third transfer pipe 43 are in a state of being communicated with each other.

When the liquid level of the liquefied carbon dioxide L in the tank 11 rises and reaches the specified liquid level as described above, the differential pressure between the liquefied carbon dioxide L in the second tank 11Q and the pipe top of the transfer pipe 40D becomes smaller. As a result, the liquefied carbon dioxide L is unlikely to solidify at the pipe top of the transfer pipe 40D.

The step S13 is performed in such a state. In this step S13, the liquefied carbon dioxide L in the first tank 11P is transferred into the second tank 11Q from the first transfer pipe 41 through the third transfer pipe 43 using the pressurizing gas Gp in the same manner as described above. At this time, the third inner diameter D3 of the third transfer pipe 43 is greater than the second inner

diameter D2 of the second transfer pipe 42. Therefore, compared to the step S12, the flow rate of the liquefied carbon dioxide L supplied into the second tank 11Q through the third transfer pipe 43 can be increased.

[0054]

In the step S14 of delivering the liquefied carbon dioxide L to the outside of the second tank 11Q, the liquefied carbon dioxide L in the second tank 11Q is delivered to the outside of the tank 11 by the unloading pipe 30. The step S14 may be performed in parallel with the above steps S12 and S13.

[0055]

(Effects)

In the ship 1 and the method S11 for unloading the liquefied carbon dioxide L as described above, when the liquid level of the liquefied carbon dioxide L in the tank 11 is low, the liquefied carbon dioxide L is transferred from the first tank 11P to the second tank 11Q through the second transfer pipe 42, and accordingly, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the transfer pipe 40D are suppressed. In addition, when the liquid level of the liquefied carbon dioxide L in the second tank 11Q rises, the differential pressure between the liquefied carbon dioxide L in the second tank 11Q and the pipe top of the transfer pipe 40D becomes small, and

the liquefied carbon dioxide L is unlikely to solidify at the pipe top, the liquefied carbon dioxide L is transferred from the first tank 11P to the second tank 11Q through the third transfer pipe 43. Accordingly, the liquefied carbon dioxide L can be transferred in a short period of time. As a result, even in a case where the liquefied carbon dioxide L is transferred from the first tank 11P to the second tank 11Q by the transfer pipe 40D, it is possible to suppress the formation of dry ice in the transfer pipe 40D, and smoothly perform the transfer work and unloading work.

[0056]

(Other Embodiments)

Above, the embodiments of the present disclosure have been described in detail with reference to the drawings, but the specific configuration is not limited to the embodiments, and includes design changes and the like within a scope not departing from the gist of the present disclosure.

In each of the above embodiments, the configuration is provided with two tanks 11, but the number and arrangement of the tanks 11 are not limited thereto. Three or more tanks 11 may be provided. Further, in each of the above embodiments, a case where the plurality of tanks 11 are disposed side by side in the stem-stern direction Da has been shown. However, the tanks 11 may be disposed side by

side in the ship width direction (in other words, the left-right side direction).

[0057]

In addition, in each of the above embodiments, the ship 1 is exemplified as the floating structure, but the present disclosure is not limited thereto. The floating structure may be an offshore floating structure facility that does not include a propulsion mechanism.

[0058]

<Additional Note>

The floating structure 1, the method for loading the liquefied carbon dioxide L, and the method for unloading the liquefied carbon dioxide L described in each embodiment are ascertained as follows, for example.

[0059]

(1) According to a first aspect, the floating structure 1 includes: the floating main structure 2; the tank 11 disposed in the floating main structure 2 and capable of storing the liquefied carbon dioxide L; and the loading pipes 20A and 20B for discharging the liquefied carbon dioxide L supplied from the outside into the tank 11, and the loading pipes 20A and 20B include the first loading pipe 21 disposed outside the tank 11 and having the first inner diameter D1, and the second loading pipe 22 having the one end 22a connected to the first loading pipe 21, the

other end 22b open inside the tank 11, and the second inner diameter D2 smaller than the first inner diameter D1.

Examples of the floating structure 1 include a ship and an offshore floating structure facility. Examples of the floating main structure 2 include the floating main structure 2 of a hull or an offshore floating structure facility.

[0060]

In the floating structure 1, the liquefied carbon dioxide L is loaded into the tank 11 from the first loading pipe 21 through the second loading pipe 22. The second inner diameter D2 of the second loading pipe 22 is smaller than the first inner diameter D1 of the first loading pipe 21. Therefore, a pressure loss ΔP in the second loading pipe 22 is greater than that in the first loading pipe 21. As a result, the pressure of the liquefied carbon dioxide L flowing through the loading pipes 20A and 20B is increased by the amount of the pressure loss ΔP . Since the pressure of the liquefied carbon dioxide L at the pipe tops of the loading pipes 20A and 20B is increased, it is possible to suppress the approach of the pressure of the liquefied carbon dioxide L to the triple point pressure. As a result, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the loading pipes 20A and 20B are suppressed. As a result, in a case where the liquefied

carbon dioxide L is accommodated in the tank 11, it is possible to suppress the formation of dry ice in the loading pipes 20A and 20B and smoothly perform the loading work.

[0061]

(2) In the floating structure 1 according to a second aspect, which is the floating structure 1 of (1), the loading pipe 20B further includes the third loading pipe 23 having the base 23a connected to the first loading pipe 21, the tip 23b open inside the tank 11, and the third inner diameter D3 greater than the second inner diameter D2.

[0062]

As a result, when the liquefied carbon dioxide L is loaded into the tank 11 through the third loading pipe 23 having the third inner diameter D3 greater than the second loading pipe 22, the liquefied carbon dioxide L can be loaded in a short period of time.

[0063]

(3) According to a third aspect, there is provided the floating structure 1 including: the floating main structure 2; the plurality of tanks 11 disposed in the floating main structure 2 and capable of storing the liquefied carbon dioxide L; the unloading pipe 30 provided in each of the plurality of tanks 11 for delivering the liquefied carbon dioxide L in the tank 11 to the outside of the floating main structure 2; and the transfer pipes 40C and 40D disposed to

straddle between the first tank 11P and the second tank 11Q that form the plurality of tanks 11 and allowing the inside of the first tank 11P and the inside of the second tank 11Q to communicate with each other, in which the transfer pipes 40C and 40D include the first transfer pipe 41 disposed on the first tank 11P side and having the first inner diameter D11, and the second transfer pipe 42 having the one end 42a connected to the first transfer pipe 41, the other end 42b open inside the second tank 11Q, and the second inner diameter D12 smaller than the first inner diameter D11.

[0064]

Accordingly, the transfer pipes 40C and 40D make it possible to transfer the liquefied carbon dioxide L from the first tank 11P to the second tank 11Q. The liquefied carbon dioxide L transferred to the second tank 11Q is delivered to the outside through the unloading pipe 30 of the second tank 11Q. In this manner, even when the unloading work cannot be performed in the unloading pipe 30 of the first tank 11P, the liquefied carbon dioxide L in the first tank 11P can be unloaded on the outside through the second tank 11Q.

The second inner diameter D12 of the second transfer pipe 42 is smaller than the first inner diameter D11 of the first transfer pipe 41. Therefore, the pressure loss ΔP in the second transfer pipe 42 is greater than that in the

first transfer pipe 41. As a result, the pressure of the liquefied carbon dioxide L flowing through the transfer pipes 40C and 40D is increased by the amount of the pressure loss ΔP . Since the pressure of the liquefied carbon dioxide L at the pipe tops of the transfer pipes 40C and 40D is increased, it is possible to suppress the approach of the pressure of the liquefied carbon dioxide L to the triple point pressure. As a result, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the transfer pipes 40C and 40D are suppressed. As a result, in a case where the liquefied carbon dioxide L is accommodated in the tank 11, it is possible to suppress the formation of dry ice in the transfer pipes 40C and 40D and smoothly perform the transfer work and the unloading work.

[0065]

(4) In the floating structure 1 according to a fourth aspect, which is the floating structure 1 of (3), the transfer pipe 40D further includes the third transfer pipe 43 having the base 43a connected to the first transfer pipe 41, the tip 43b open inside the second tank 11Q, and the third inner diameter D13 greater than the second inner diameter D12.

[0066]

As a result, when the liquefied carbon dioxide L is transferred through the third transfer pipe 43 having the

third inner diameter D13 greater than the second transfer pipe 42, the liquefied carbon dioxide L can be transferred in a short period of time.

[0067]

(5) According to a fifth aspect, there is provided the method S1 for loading the liquefied carbon dioxide L, which is the method S1 for loading the liquefied carbon dioxide L in the floating structure 1 of (2), the method including: the step S2 of loading the liquefied carbon dioxide L into the tank 11 from the first loading pipe 21 through the second loading pipe 22; and the step S3 of loading the liquefied carbon dioxide L into the tank 11 from the first loading pipe 21 through the third loading pipe 23 when the liquid level of the liquefied carbon dioxide L in the tank 11 reaches the predetermined liquid level.

[0068]

Accordingly, when the liquid level of the liquefied carbon dioxide L in the tank 11 is low, the liquefied carbon dioxide L is loaded into the tank 11 through the first loading pipe 21, and accordingly, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the loading pipe 20B are suppressed. Further, the liquid level of the liquefied carbon dioxide L in the tank 11 rises, the differential pressure between the liquefied carbon dioxide L in the tank 11 and the pipe top of the loading

pipe 20B becomes small, and the liquefied carbon dioxide L is unlikely to solidify at the pipe top, the liquefied carbon dioxide L is loaded into the tank 11 through the third loading pipe 23. Accordingly, the liquefied carbon dioxide L can be loaded in a short period of time.

[0069]

(6) According to a sixth aspect, there is provided the method S11 for unloading the liquefied carbon dioxide L, which is the method S11 for unloading the liquefied carbon dioxide L in the floating structure 1 of (4), the method including: the step S12 of transferring the liquefied carbon dioxide L in the first tank 11P from the first transfer pipe 41 into the second tank 11Q through the second transfer pipe 42 by pressurizing the inside of the first tank 11P; the step S13 of transferring the liquefied carbon dioxide L in the first tank 11P from the first transfer pipe 41 into the second tank 11Q through the third transfer pipe 43 when the liquid level of the liquefied carbon dioxide L in the second tank 11Q reaches a predetermined liquid level; and the step S14 of delivering the liquefied carbon dioxide L in the second tank 11Q to the outside of the second tank 11Q by the unloading pipe 30.

[0070]

Accordingly, when the liquid level of the liquefied carbon dioxide L in the second tank 11Q is low, the liquefied

carbon dioxide L is transferred from the first tank 11P to the second tank 11Q through the second transfer pipe 42, and accordingly, the solidification of the liquefied carbon dioxide L and the formation of dry ice in the transfer pipe 40D are suppressed. In addition, when the liquid level of the liquefied carbon dioxide L in the second tank 11Q rises, the differential pressure between the liquefied carbon dioxide L in the second tank 11Q and the pipe top of the transfer pipe 40D becomes small, and the liquefied carbon dioxide L is unlikely to solidify at the pipe top, the liquefied carbon dioxide L is transferred from the first tank 11P to the second tank 11Q through the third transfer pipe 43. Accordingly, the liquefied carbon dioxide L can be transferred in a short period of time.

Industrial Applicability

[0071]

According to the floating structure, the method for loading liquefied carbon dioxide, and the method for unloading liquefied carbon dioxide according to the present disclosure, it is possible to suppress the formation of dry ice in the pipe and smoothly perform the loading and unloading work.

Reference Signs List

[0072]

1: Ship (floating structure)

2: Hull (floating main structure)

2a: Stem

2b: Stern

3A, 3B: Side

5: Upper deck

7: Superstructure

8: Cargo tank storage compartment

10A to 10D: Tank facility

11: Tank

11P: First tank

11Q: Second tank

12: Tubular portion

13: End spherical portion

20A to 20C: Loading pipe

21: First loading pipe

22: Second loading pipe

22a: One end

22b: Other end

23: Third loading pipe

23a: Base

23b: Tip

24, 25: Opening-closing valve

30: Unloading pipe

31: Pump

40C, 40D: Transfer pipe

41: First transfer pipe
41a: First end
41b: Intermediate portion
42: Second transfer pipe
42a: One end
42b: Other end
43: Third transfer pipe
43a: Base
43b: Tip
45 to 47: Opening-closing valve
Gp: Pressurizing gas
L: Liquefied carbon dioxide

Claims

[Claim 1]

A floating structure comprising:

a floating main structure;

a tank disposed in the floating main structure and capable of storing liquefied carbon dioxide; and

a loading pipe for discharging liquefied carbon dioxide supplied from an outside into the tank, wherein

the loading pipe includes

a first loading pipe disposed outside the tank and having a first inner diameter, and

a second loading pipe having one end connected to the first loading pipe, the other end open inside the tank, and a second inner diameter smaller than the first inner diameter.

[Claim 2]

The floating structure according to Claim 1, wherein

the loading pipe further includes a third loading pipe having a base connected to the first loading pipe, a tip open inside the tank, and a third inner diameter greater than the second inner diameter.

[Claim 3]

A floating structure comprising:

a floating main structure;

a plurality of tanks disposed in the floating main structure and capable of storing liquefied carbon dioxide;

an unloading pipe provided in each of the plurality of tanks for delivering liquefied carbon dioxide in the tank to an outside of the floating main structure; and

a transfer pipe disposed to straddle between a first tank and a second tank that form the plurality of tanks and allowing an inside of the first tank and an inside of the second tank to communicate with each other, wherein

the transfer pipe includes

a first transfer pipe disposed on a first tank side and having a first inner diameter, and

a second transfer pipe having one end connected to the first transfer pipe, the other end open inside the second tank, and a second inner diameter smaller than the first inner diameter.

[Claim 4]

The floating structure according to Claim 3, wherein

the transfer pipe further includes a third transfer pipe having a base connected to the first transfer pipe, a tip open inside the second tank, and a third inner diameter greater than the second inner diameter.

[Claim 5]

A method for loading liquefied carbon dioxide in the floating structure according to Claim 2, the method comprising:

a step of loading liquefied carbon dioxide into the tank from the first loading pipe through the second loading pipe; and

a step of loading liquefied carbon dioxide into the tank from the first loading pipe through the third loading pipe when a liquid level of liquefied carbon dioxide in the tank reaches a predetermined liquid level.

[Claim 6]

A method for unloading liquefied carbon dioxide in the floating structure according to Claim 4, the method comprising:

a step of transferring liquefied carbon dioxide in the first tank from the first transfer pipe into the second tank through the second transfer pipe by pressurizing the inside of the first tank;

a step of transferring liquefied carbon dioxide in the first tank from the first transfer pipe into the second tank through the third transfer pipe when a liquid level of liquefied carbon dioxide in the second tank reaches a

predetermined liquid level; and

a step of delivering the liquefied carbon dioxide in the second tank to an outside of the second tank by the unloading pipe.