

DESCRIPTION

Title of Invention

SHIP AND METHOD OF LOADING LIQUEFIED CARBON DIOXIDE INTO
SHIP

Technical Field

[0001]

The present disclosure relates to a ship and a method of loading liquefied carbon dioxide into a ship.

This application claims the right of priority based on Japanese Patent Application No. 2019-228784 filed with the Japan Patent Office on December 19, 2019, the content of which is incorporated herein by reference.

Background Art

[0002]

PTL 1 discloses loading a liquefied gas such as LNG (Liquefied Natural Gas) into a tank through a pipe led from the vicinity of a top portion of the tank to the vicinity of a bottom portion of the tank.

Citation List

Patent Literature

[0003]

[PTL 1] Japanese Patent No. 5769445

Summary of Invention

Technical Problem

[0004]

Incidentally, there is a demand for carrying liquefied carbon dioxide by using a tank as in PTL 1. In the liquefied carbon dioxide, the pressure of a triple point (hereinafter referred to as triple point pressure) at which a gas phase, a liquid phase, and a solid phase coexist is higher than the triple point pressure of LNG or LPG. Therefore, the triple point pressure becomes close to the operating pressure of the tank. In a case where the liquefied carbon dioxide is contained in the tank, for the following reasons, there is a possibility that the liquefied carbon dioxide may be solidified to generate dry ice.

[0005]

In the tank of PTL 1, a lower end of a loading pipe, which is open in the tank, is disposed at a lower portion in the tank. With such disposition, the vicinity of the opening of the loading pipe is pressurized with an increase in liquid head. Therefore, flash evaporation of the liquefied gas discharged from the opening of the loading pipe can be suppressed. However, in a pipe top portion disposed at the highest position of the loading pipe, the pressure of the liquefied carbon dioxide inside is reduced by the amount corresponds to the height difference between the liquid level of the liquefied carbon dioxide in the tank

and the pipe top portion with respect to the pressure of the liquefied carbon dioxide at the pipe lower end.

[0006]

As a result, depending on a tank operating pressure, the pressure of the liquefied carbon dioxide becomes equal to or lower than the triple point pressure in the pipe top portion of the loading pipe where the pressure of the liquefied carbon dioxide becomes the lowest, or the liquefied carbon dioxide evaporates, and due to the evaporation latent heat thereof, the temperature of the liquefied carbon dioxide remaining without evaporating is lowered, so that there is a possibility that the liquefied carbon dioxide may be solidified in the pipe top portion of the loading pipe to generate dry ice.

Then, in this manner, if dry ice is generated in the loading pipe, the flow of the liquefied carbon dioxide in the loading pipe is obstructed, so that there is a possibility that the operation of the tank may be affected.

[0007]

The present disclosure has been made in order to solve the above problem, and has an object to provide a ship and a method of loading liquefied carbon dioxide into a ship, in which it is possible to suppress the generation of dry ice in a loading pipe and smoothly perform the operation of a tank.

Solution to Problem

[0008]

In order to solve the above problem, a ship according to the present disclosure includes a hull, a tank, and a loading pipe. The hull has a pair of broadsides. The tank is provided in the hull. The tank is capable of storing liquefied carbon dioxide. The loading pipe loads liquefied carbon dioxide that is supplied from an outside of the ship into the tank. The loading pipe includes a transport pipe, an upper loading pipe, a lower loading pipe, a first on-off valve, and a second on-off valve. The transport pipe has a connection part for connection with the outside of the ship. The upper loading pipe branches off and extends from the transport pipe. The upper loading pipe is open to an upper portion in the tank. The lower loading pipe branches off and extends from the transport pipe. The lower loading pipe is open to a lower portion in the tank. The first on-off valve is provided in the upper loading pipe. The second on-off valve is provided in the lower loading pipe.

[0009]

A method of loading liquefied carbon dioxide into a ship according to the present disclosure is a method of loading liquefied carbon dioxide into the ship described above. The method of loading liquefied carbon dioxide into a ship includes: a step of opening the first on-off valve

to load the liquefied carbon dioxide into the tank through the upper loading pipe; and a step of closing the first on-off valve and opening the second on-off valve to load the liquefied carbon dioxide into the tank through the lower loading pipe, after a liquid level of the liquefied carbon dioxide in the tank has reached a switching level set to be higher than an opening of the lower loading pipe.

Advantageous Effects of Invention

[0010]

According to the ship and the method of loading liquefied carbon dioxide into a ship of the present disclosure, it is possible to suppress the generation of dry ice in a loading pipe and smoothly perform the operation of a tank.

Brief Description of Drawings

[0011]

Fig. 1 is a plan view showing a schematic configuration of a ship according to an embodiment of the present disclosure.

Fig. 2 is a side sectional view showing a tank and a loading pipe provided in the ship according to the embodiment of the present disclosure.

Fig. 3 is a side sectional view showing a state where liquefied carbon dioxide is loaded into a tank from an upper loading pipe, in the ship according to the embodiment of

the present disclosure.

Fig. 4 is a side sectional view showing a state where liquefied carbon dioxide is loaded into a tank from a spray pipe, in the ship according to the embodiment of the present disclosure.

Fig. 5 is a diagram showing a hardware configuration of a control device provided on the ship according to the embodiment of the present disclosure.

Fig. 6 is a functional block diagram of the control device provided on the ship according to the embodiment of the present disclosure.

Fig. 7 is a flowchart showing procedure of a method of loading liquefied carbon dioxide into a ship according to the embodiment of the present disclosure.

Fig. 8 is a flowchart showing procedure of processing that is performed by the control device in order to execute the method of loading liquefied carbon dioxide into a ship according to the embodiment of the present disclosure.

Fig. 9 is a side sectional view showing a tank and a loading pipe provided in a ship according to a modification example the embodiment of the present disclosure.

Description of Embodiments

[0012]

Hereinafter, a ship according to an embodiment of the present disclosure will be described with reference to Figs.

1 and 2.

(Hull Composition of Ship)

A ship 1 of an embodiment of the present disclosure carries liquefied carbon dioxide or various liquefied gases including liquefied carbon dioxide. As shown in Figs. 1 and 2, the ship 1 includes at least a hull 2, a tank 21, and a loading pipe 30. In this embodiment, a case of carrying liquefied carbon dioxide will be described as an example.

[0013]

(Configuration of Hull)

As shown in Fig. 1, the hull 2 has a pair of broadsides 3A and 3B forming an outer shell thereof, a ship bottom (not shown), and an exposure deck 5. The broadsides 3A and 3B are provided with a pair of broadside outer plates forming the left and right broadsides respectively. The ship bottom (not shown) is provided with a ship bottom outer plate connecting the broadsides 3A and 3B. Due to the pair of broadsides 3A and 3B and the ship bottom (not shown), the outer shell of the hull 2 has a U-shape in a cross-section orthogonal to a bow-stern direction Da. The exposure deck 5 is an all-deck that is exposed to the outside. In the hull 2, a superstructure 7 having an accommodation space is formed on the exposure deck 5 on the stern 2b side.

[0014]

In the hull 2, a tank system storage compartment (a hold) 8 is formed on the bow 2a side with respect to the superstructure (the accommodation space) 7. The tank system storage compartment 8 is a closed compartment that is recessed toward the ship bottom (not shown) below the exposure deck 5 and protrudes upward or has the exposure deck 5 as a ceiling.

[0015]

(Configuration of Tank)

A plurality of tanks 21 are provided in the tank system storage compartment 8. In the tank 21 in this embodiment, for example, a total of seven tanks 21 are provided in the tank system storage compartment 8. The layout and the number of tanks 21 installed in the tank system storage compartment 8 are not limited in any way. In this embodiment, each tank 21 has, for example, a cylindrical shape extending in the horizontal direction (specifically, the bow-stern direction). The tank 21 contains liquefied carbon dioxide L inside. The tank 21 is not limited to a cylindrical shape and may have a spherical shape.

[0016]

(Configuration of Loading Pipe)

The loading pipe 30 loads the liquefied carbon dioxide L, which is supplied from the outside of the ship, such as a liquefied carbon dioxide supply facility on land or a

bunker ship, into the tank 21.

As shown in Fig. 2, the loading pipe 30 includes a transport pipe 31, an upper loading pipe 32, a lower loading pipe 33, a first on-off valve 34, a second on-off valve 35, and a spray pipe 38.

[0017]

The loading pipe 30 has a connection part 31j provided at a bunker station or the like and connected to the outside of the ship. The connection part 31j has, for example, a flange or the like, and is provided on at least one (for example, the broadside 3A) of the broadsides 3A and 3B. A supply pipe (not shown) for supplying liquefied carbon dioxide from the outside of the ship, such as a liquefied carbon dioxide supply facility or a bunker ship, can be mounted to or dismounted from the connection part 31j. The loading pipe 30 is mainly provided in the hull 2.

[0018]

The upper loading pipe 32 branches off from the transport pipe 31 and reaches the inside of the tank 21. The upper loading pipe 32 of this embodiment extends downward in a ship height direction (hereinafter referred to as an up-down direction Dv) from the transport pipe 31. An opening 32a formed at a lower end of the upper loading pipe 32 is located at an upper portion in the tank 21. Here, the upper portion in the tank 21 means a region in the tank

21 above the center of the tank 21 in the up-down direction Dv. The opening 32a of the upper loading pipe 32 may be located at a height equal to or higher than a height Ha when a liquid level Lf of the liquefied carbon dioxide L is at a height corresponding to, for example, 90% of the volume of the tank 21 in the up-down direction Dv. As shown in Fig. 3, the upper loading pipe 32 supplies the liquefied carbon dioxide L into the tank 21 from the opening 32a provided at the upper portion in the tank 21.

[0019]

The lower loading pipe 33 branches off from the transport pipe 31 and reaches the inside of the tank 21, similar to the upper loading pipe 32. The lower loading pipe 33 of this embodiment extends downward in the up-down direction Dv from the transport pipe 31. An opening 33a formed at a lower end of the lower loading pipe 33 is located at a lower portion in the tank 21. Here, the lower portion in the tank 21 means a region in the tank 21 below the center of the tank 21 in the up-down direction Dv. The opening 33a of the lower loading pipe 33 may be located at a height equal to or lower than a height Hb when the liquid level Lf of the liquefied carbon dioxide L is at a height corresponding to, for example, 10% of the volume of the tank 21 in the up-down direction Dv. As shown in Fig. 2, the lower loading pipe 33 supplies the liquefied carbon dioxide

L into the tank 21 from the opening 33a provided at the lower portion in the tank 21.

[0020]

The first on-off valve 34 is provided in the upper loading pipe 32. The first on-off valve 34 opens and closes the flow path in the upper loading pipe 32.

The second on-off valve 35 is provided in the lower loading pipe 33. The second on-off valve 35 opens and closes the flow path in the lower loading pipe 33.

Each of the first on-off valve 34 and the second on-off valve 35 can be switched between an opened state and a closed state, based on a control signal that is output from a control device 60 (described later).

[0021]

The spray pipe 38 branches off from the transport pipe 31 and reaches the inside of the tank 21. The spray pipe 38 has a plurality of injection holes (not shown). The injection holes of the spray pipe 38 exemplified in this embodiment are disposed on the lower side with respect to the opening 32a of the upper loading pipe 32 and the lower side with respect to the opening 33a of the lower loading pipe 33 in the up-down direction Dv. As shown in Fig. 4, the spray pipe 38 injects the liquefied carbon dioxide L that is supplied through the transport pipe 31 into the tank 21 from the plurality of injection holes. The spray pipe

38 is provided with an on-off valve 39 for opening and closing the flow path from the transport pipe 31 to the spray pipe 38 on the side close to the transport pipe 31. The on-off valve 39 can be switched between an opened state and a closed state, based on a control signal that is output from the control device 60 (described later).

[0022]

The ship 1 further includes a liquid level detection unit 51, a pressure detection unit 52, and the control device 60.

[0023]

(Configurations of Liquid Level Detection Unit and Pressure Detection Unit)

The liquid level detection unit 51 detects the liquid level L_f of the liquefied carbon dioxide L that is stored in the tank 21. The liquid level detection unit 51 outputs a detection signal of the detected liquid level L_f to the control device 60.

[0024]

The pressure detection unit 52 detects a pressure P of the liquefied carbon dioxide L in the loading pipe 30. The pressure detection unit 52 is provided, for example, at a top portion 30t, which is the highest position of the loading pipe 30. The pressure detection unit 52 detects the pressure P of the liquefied carbon dioxide L in the

loading pipe 30 at the top portion 30t. The pressure detection unit 52 outputs a detection signal of the detected pressure P to the control device 60.

[0025]

(Configuration of Control Device)

The control device 60 controls the opening/closing operations of the first on-off valve 34 and the second on-off valve 35, based on the liquid level Lf of the liquefied carbon dioxide L in the tank 21, which is detected by the liquid level detection unit 51, when the liquefied carbon dioxide L is loaded into the tank 21.

[0026]

(Hardware Configuration Diagram)

As shown in Fig. 5, the control device 60 is a computer that includes a CPU 61 (Central Processing Unit), a ROM 62 (Read Only Memory), a RAM 63 (Random Access Memory), an HDD 64 (Hard Disk Drive), and a signal receiving module 65. The detection signal from the liquid level detection unit 51 and the detection signal from the pressure detection unit 52 are input to the signal receiving module 65.

[0027]

(Functional Block Diagram)

As shown in Fig. 6, the control device 60 realizes a functional configuration of each of a signal input unit 70, an on-off valve control unit 71, a liquid level

determination unit 72, a pressure determination unit 73, and an output unit 74 by executing, for example, a program stored in the own device in advance by the CPU 61.

The signal input unit 70 receives the detection signal from the liquid level detection unit 51 and the detection signal from the pressure detection unit 52 by using the signal receiving module 65.

[0028]

The liquid level determination unit 72 determines whether or not the liquid level L_f of the liquefied carbon dioxide L in the tank 21 detected by the liquid level detection unit 51 has reached a switching level L_s (refer to Figs. 2 and 3) set in advance to be higher than the opening 33a of the lower loading pipe 33. As the switching level L_s , for example, the liquid level L_f in the range where the pressure P of the liquefied carbon dioxide L in the loading pipe 30 at the top portion 30t becomes higher than the triple point pressure of the liquefied carbon dioxide L when only the second on-off valve 35 of the lower loading pipe 33 is made be in an opened state is set. Further, as the switching level L_s , a lower limit or the liquid level L_f slightly higher than the lower limit, of the liquid level L_f in the range where the pressure P of the liquefied carbon dioxide L in the loading pipe 30 at the top portion 30t becomes higher than the triple point

pressure of the liquefied carbon dioxide L, may be set. The switching level L_s can be obtained by, for example, an experiment, simulation, calculation, or the like.

[0029]

The pressure determination unit 73 determines whether or not the pressure P of the liquefied carbon dioxide L detected by the pressure detection unit 52 has been lowered to a pressure equal to or lower than a reference pressure P_s determined in advance. Here, the reference pressure P_s is the triple point pressure of the liquefied carbon dioxide L, or a pressure higher than the triple point pressure.

[0030]

The on-off valve control unit 71 controls the opening/closing operations of the first on-off valve 34, the second on-off valve 35, and the on-off valve 39.

The on-off valve control unit 71 makes the on-off valve 39 be in an opened state and the first on-off valve 34 and the second on-off valve 35 be in a closed state, prior to the loading of the liquefied carbon dioxide L into the tank 21. At the time of the start of the loading of the liquefied carbon dioxide L into the tank 21, the on-off valve control unit 71 makes the on-off valve 39 be in a closed state and the first on-off valve 34 be in an opened state. Further, after the start of the loading of the liquefied carbon dioxide L, the on-off valve control unit 71 makes the first

on-off valve 34 be in a closed state and the second on-off valve 35 be in an opened state, in a case where the liquid level determination unit 72 determines that the liquid level L_f of the liquefied carbon dioxide L detected by the liquid level detection unit 51 has reached the switching level L_s . The on-off valve control unit 71 outputs a control signal for opening and closing the first on-off valve 34 and the second on-off valve 35 to the first on-off valve 34 and the second on-off valve 35 through the output unit 74. Further, the on-off valve control unit 71 makes the first on-off valve 34 be in an opened state, in a case where the pressure of the liquefied carbon dioxide L detected by the pressure detection unit 52 becomes equal to or lower than the reference pressure P_s determined in advance, when the second on-off valve 35 is made be in an opened state.

[0031]

(Procedure of Method of Loading Liquefied Carbon Dioxide into Ship)

As shown in Fig. 7, a method S10 of loading the liquefied carbon dioxide L into the ship 1 according to this embodiment includes a step S11 of loading the liquefied carbon dioxide through the upper loading pipe, and a step S12 of loading the liquefied carbon dioxide through the lower loading pipe.

[0032]

In the step S11 of loading the liquefied carbon dioxide through the upper loading pipe, first, only the on-off valve 39 among the first on-off valve 34, the second on-off valve 35, and the on-off valve 39 is made be in an opened state. Then, as shown in Fig. 4, the liquefied carbon dioxide L is injected from the spray pipe 38 into the tank. In this way, the inside of the tank 21 is cooled, the pressure in the tank 21 is lowered, and more liquefied carbon dioxide L can be loaded.

[0033]

Thereafter, the on-off valve 39 is made be in a closed state and the first on-off valve 34 is made be in an opened state. In this way, as shown in Fig. 3, the liquefied carbon dioxide L is loaded into the tank 21 through the upper loading pipe 32. In this state, the upper loading pipe 32 is open to the upper portion in the tank 21. Therefore, the liquefied carbon dioxide L is discharged to a gas phase in the tank 21 from the opening 32a of the upper loading pipe 32. Further, a height difference Δh_1 from the top portion 30t, which is located at the highest position of the loading pipe 30, is smaller than a height difference Δh_2 between the opening 33a of the lower loading pipe 33, which is open to the lower portion in the tank 21, and the top portion 30t. Therefore, it is possible to suppress a decrease in the pressure of the liquefied carbon dioxide L

in the top portion 30t of the loading pipe 30 regardless of the position of the liquid level Lf of the liquefied carbon dioxide L.

[0034]

After the liquefied carbon dioxide L is loaded into the tank 21 through the upper loading pipe 32 and the liquid level Lf of the liquefied carbon dioxide L has reached the switching level Ls set to be higher than the opening 33a of the lower loading pipe 33, the processing transitions to the step S12 of loading the liquefied carbon dioxide through the lower loading pipe. In the step S12 of loading the liquefied carbon dioxide through the lower loading pipe, the first on-off valve 34 is made be in a closed state and the second on-off valve 35 is made be in an opened state. In this way, as shown in Fig. 2, the liquefied carbon dioxide L is loaded into the tank 21 through the lower loading pipe 33. In this state, the liquefied carbon dioxide L is stored to a level higher than the opening 33a of the lower loading pipe 33 (specifically, a level higher than the switching level Ls). Therefore, a pressure according to the height of the liquid level Lf (specifically, the switching level Ls or higher) of the liquefied carbon dioxide L stored in the tank 21 is applied to the liquefied carbon dioxide L in the lower loading pipe 33. In this way, the pressure of the liquefied carbon dioxide L in the top portion 30t of

the loading pipe 30 is increased.

[0035]

(Processing Procedure)

Next, procedure of processing for automatically executing the method of loading the liquefied carbon dioxide into the ship under the control of the control device 60 will be described.

As shown in Fig. 8, when the loading of the liquefied carbon dioxide L into the tank 21 is started, first, the control device 60 causes the on-off valve control unit 71 to make the on-off valve 39 of the spray pipe 38 be in an opened state (step S21). Then, the liquefied carbon dioxide L that is supplied from the outside of the ship is injected into the tank 21 from the spray pipe 38, and the pressure in the tank 21 is lowered.

[0036]

Subsequently, the control device 60 causes the on-off valve control unit 71 to make the on-off valve 39 be in a closed state and the first on-off valve 34 be in an opened state (step S22). Then, the liquefied carbon dioxide L, which is supplied from the outside of the ship, is supplied from the upper portion in the tank 21 through the transport pipe 31 and the upper loading pipe 32. In this way, the "step S11 of loading the liquefied carbon dioxide through the upper loading pipe" is executed.

[0037]

After the start of the loading of the liquefied carbon dioxide L, the liquid level determination unit 72 determines whether or not the liquid level Lf of the liquefied carbon dioxide L detected by the liquid level detection unit 51 has reached the switching level Ls set to be higher than the opening 33a of the lower loading pipe 33 (step S23). As a result of this determination, in a case where it is determined that the liquid level Lf has not reached the switching level Ls, the processing of step S23 is repeated at time intervals determined in advance. On the other hand, in a case where it is determined that the liquid level Lf has reached the switching level Ls, the processing proceeds to step S24.

[0038]

In step S24, the on-off valve control unit 71 makes the first on-off valve 34 be in a closed state and the second on-off valve 35 be in an opened state. In this way, the supply of the liquefied carbon dioxide L to the tank 21 through the upper loading pipe 32 is stopped. Further, the supply of the liquefied carbon dioxide L to the tank 21 through the lower loading pipe 33 is started. In this way, the "step S12 of loading the liquefied carbon dioxide through the lower loading pipe" is executed.

[0039]

After the start of the loading of the liquefied carbon dioxide L through the lower loading pipe 33, the pressure determination unit 73 determines whether or not the pressure P detected by the pressure detection unit 52, that is, the pressure P of the liquefied carbon dioxide L in the top portion 30t of the loading pipe 30 has been lowered to a pressure equal to or lower than the reference pressure P_s determined in advance (step S25). As a result, in a case where it is determined that the pressure of the liquefied carbon dioxide L has reached the reference pressure P_s , the processing proceeds to step S26.

[0040]

In step S26, the on-off valve control unit 71 operates the second on-off valve 35 toward a closed state and the first on-off valve 34 toward an opened state. At this time, the second on-off valve 35 may be operated to a fully-closed state in a short time or may be gradually closed, such as being stepwise closed for each the opening degree set in advance, for example. Similarly, the first on-off valve 34 may be operated to a fully-opened state in a short time or may be gradually opened, such as being stepwise opened for each opening degree determined in advance, for example.

[0041]

In this way, for example, in a case where the pressure P of the liquefied carbon dioxide L is lowered to a pressure

equal to or lower than the reference pressure P_s while the liquefied carbon dioxide L is being loaded through the lower loading pipe 33, the first on-off valve 34 is operated in an open direction. Then, as shown in Fig. 3, the liquefied carbon dioxide L is supplied into the tank 21 from the upper loading pipe 32. At this time, the opening 32a of the upper loading pipe 32 is disposed in the gas phase above the liquid level L_f of the liquefied carbon dioxide L loaded in the tank 21. The pressure of the gas phase (the operating pressure of the tank 21) is set to be higher than the reference pressure P_s . Therefore, the pressure of the liquefied carbon dioxide L in the top portion 30t of the loading pipe 30 increases.

[0042]

Thereafter, the pressure determination unit 73 determines whether or not the pressure of the liquefied carbon dioxide L in the top portion 30t of the loading pipe 30, which is detected by the pressure detection unit 52, has been returned to a return pressure P_t determined in advance ($P_t > P_s$) (Step S27). As a result of this determination, in a case where it is determined that the pressure of the liquefied carbon dioxide L has not reached the return pressure P_t , the loading of the liquefied carbon dioxide L from the upper loading pipe 32 is continued. On the other hand, in a case where in step S27, it is determined

that the pressure of the liquefied carbon dioxide L has reached the return pressure P_t , the on-off valve control unit 71 makes the first on-off valve 34 be in a closed state and the second on-off valve 35 be in an opened state (step S28). In this way, the liquefied carbon dioxide L returns to a state of being supplied into the tank 21 from the lower loading pipe 33.

[0043]

In this way, the liquefied carbon dioxide L is loaded into the tank 21, and when loading of a predetermined amount is completed, the on-off valve control unit 71 closes both the first on-off valve 34 and the second on-off valve 35 and ends the loading of the liquefied carbon dioxide L.

[0044]

(Operation and Effects)

The ship 1 of the above embodiment includes the upper loading pipe 32 that is open to the upper portion in the tank 21, the lower loading pipe 33 that is open to the lower portion in the tank 21, the first on-off valve 34 provided in the upper loading pipe 32, and the second on-off valve 35 provided in the lower loading pipe 33.

In the ship 1, when the first on-off valve 34 is made be in an opened state, the liquefied carbon dioxide L that is supplied from the outside of the ship 1 is supplied from the upper portion of the tank 21 through the transport pipe

31 and the upper loading pipe 32. Further, when the second on-off valve 35 is made be in an opened state, the liquefied carbon dioxide L that is supplied from the outside of the ship is supplied from the lower portion of the tank 21 through the transport pipe 31 and the lower loading pipe 33. Since the opening 32a of the upper loading pipe 32 is located at the upper portion in the tank 21, the height difference from the top portion 30t that is at the highest position in the loading pipe 30 is smaller than that in the opening 33a of the lower loading pipe 33 that is located at the lower portion in the tank 21, Therefore, when the liquefied carbon dioxide L is loaded by the upper loading pipe 32, it is possible to suppress a decrease in the pressure P of the liquefied carbon dioxide L at the highest position in the loading pipe 30 regardless of the liquid level Lf.

[0045]

Further, since the opening 33a of the lower loading pipe 33 is located at the lower portion in the tank 21, if the liquefied carbon dioxide L is stored to a level higher than the opening 33a of the lower loading pipe 33, a pressure according to the height of the liquid level Lf of the liquefied carbon dioxide L stored in the tank 21 is applied to the liquefied carbon dioxide L in the lower loading pipe 33. Then, if the liquid level Lf reaches a position where due to a rise of the liquid level Lf, an ambient pressure

of the opening 33a becomes higher than the gas phase in the tank 21, it is possible to make the liquefied carbon dioxide L flowing into the tank 21 from the opening 33a be in a pressurized state (in other words, a sub-cool state). Therefore, it is possible to suppress the occurrence of flash evaporation of the liquefied carbon dioxide L flowing into the tank 21.

[0046]

In this manner, by appropriately adjusting the open/closed states of the first on-off valve 34 and the second on-off valve 35 according to the storage state or the like of the liquefied carbon dioxide L in the tank 21, it is possible to suppress a decrease in the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30. Therefore, it is possible to restrain the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 from approaching the triple point pressure. In this way, it becomes possible to suppress the generation of dry ice due to the solidification of the liquefied carbon dioxide L in the loading pipe 30 and smoothly perform the operation of the tank 21.

[0047]

The ship 1 of the above embodiment further includes the control device 60 for controlling the opening/closing

operations of the first on-off valve 34 and the second on-off valve 35, based on the liquid level L_f of the liquefied carbon dioxide L in the tank 21, in a case where the liquefied carbon dioxide L is loaded into the tank 21.

By controlling the opening/closing operations of the first on-off valve 34 and the second on-off valve 35 by the control device 60, based on the liquid level L_f of the liquefied carbon dioxide L in the tank 21, it is possible to automatically suppress a decrease in the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30.

[0048]

Further, in the ship 1 of the above embodiment, a configuration is made such that the control device 60 makes the second on-off valve 35 be in an opened state in a case where the liquid level L_f of the liquefied carbon dioxide L that is detected by the liquid level detection unit 51 reaches the switching level L_s set to be higher than the opening 33a of the lower loading pipe 33.

By such control of the control device 60, it is possible to load the liquefied carbon dioxide L into the tank 21 through the upper loading pipe 32 by making the first on-off valve 34 be in an opened state until the liquid level L_f of the liquefied carbon dioxide L in the tank 21 reaches the set switching level L_s . Since the upper loading

pipe 32 is open to the upper portion in the tank 21, it is possible to perform the loading of the liquefied carbon dioxide L in a state of suppressing a decrease in the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30.

[0049]

Further, by such control of the control device 60, it is possible to load the liquefied carbon dioxide L into the tank 21 through the lower loading pipe 33 by making the second on-off valve 35 be in an opened state in a case where the liquid level L_f of the liquefied carbon dioxide L in the tank 21 reaches the switching level L_s . At this time, since the liquefied carbon dioxide L is stored to a level higher than the switching level L_s , a pressure according to the height of the liquid level L_f of the liquefied carbon dioxide L stored in the tank 21, that is, the liquid level L_f equal to or higher than the switching level L_s , is applied to the liquefied carbon dioxide L in the lower loading pipe 33. In this way, it is possible to perform the loading of the liquefied carbon dioxide L in a state where the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 is increased.

[0050]

Further, in the ship 1 of the above embodiment, a configuration is made such that the control device 60 makes

the first on-off valve 34 be in an opened state in a case where the pressure P of the liquefied carbon dioxide L that is detected by the pressure detection unit 52 is equal to or lower than the reference pressure P_s determined in advance, when the second on-off valve 35 is in an opened state.

In this way, it is possible to make the first on-off valve 34 be in an opened state in a case where the pressure P of the liquefied carbon dioxide L in the loading pipe 30 is lowered to a pressure equal to or lower than the reference pressure P_s in a state where the second on-off valve 35 is made be in an opened state and the liquefied carbon dioxide L is loaded into the tank 21 through the lower loading pipe 33. Since the upper loading pipe 32 is open to the upper portion in the tank 21, it is possible to make the height difference from the highest position of the loading pipe 30 small as compared with when the liquefied carbon dioxide L is loaded through the lower loading pipe 33. In this way, it becomes possible to increase the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30.

[0051]

In the method of loading the liquefied carbon dioxide L into the ship 1 of the above embodiment, when loading the liquefied carbon dioxide L into the tank 21, first, the

first on-off valve 34 is made be in an opened state and the liquefied carbon dioxide L is loaded into the tank 21 through the upper loading pipe 32. Since the upper loading pipe 32 is open to the upper portion in the tank 21, it is possible to perform the loading of the liquefied carbon dioxide L in a state of suppressing a decrease in the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30. Therefore, by restraining the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 from approaching the triple point pressure, it is possible to suppress the generation of dry ice due to the solidification of the liquefied carbon dioxide L in the loading pipe 30. Therefore, it becomes possible to smoothly perform the operation of the tank 21.

[0052]

In the method of loading the liquefied carbon dioxide L, thereafter, the second on-off valve 35 is made be in an opened state and the liquefied carbon dioxide L is loaded into the tank 21 through the lower loading pipe 33. In a state where the liquefied carbon dioxide L is loaded through the lower loading pipe 33, the liquefied carbon dioxide L is stored to a level higher than the opening of the lower loading pipe 33. Therefore, a pressure according to the height of the liquid level L_f of the liquefied carbon

dioxide L stored in the tank 21 can be applied to the liquefied carbon dioxide L in the lower loading pipe 33. In this way, flash evaporation of the liquefied carbon dioxide L that has flowed into the tank 21 can be suppressed.

[0053]

<Other Embodiments>

The embodiments of the present disclosure have been described in detail above with reference to the drawings. However, the specific configurations are not limited to the embodiments, and also include design changes or the like within a scope which does not deviate from the gist of the present disclosure.

In the above embodiment, the lower loading pipe 33 is provided so as to extend downward from the top portion of the tank 21 into the tank 21. However, there is no limitation thereto.

For example, as shown in Fig. 9, a lower loading pipe 33B may be provided so as to wrap around from the upper side to the lower side of the tank 21, and an end portion of the lower loading pipe 33B may be connected to a lower end 21b of the tank 21. Even with such a configuration, the opening 33a of the lower loading pipe 33B can be located at the lower portion in the tank 21.

[0054]

Further, in the above embodiment, the processing

procedure in the method S10 of loading the liquefied carbon dioxide L into the ship 1 and the control device 60 for executing the method S10 of loading the liquefied carbon dioxide L into the ship 1 are shown. However, the procedure can be appropriately changed in order.

[0055]

Further, in the above embodiment, the liquefied carbon dioxide L is injected from the spray pipe 38 into the tank 21. However, the injection of the liquefied carbon dioxide L may be omitted.

[0056]

<Additional Remark>

The ships 1 and the method of loading liquefied carbon dioxide into the ship 1 described in the embodiment are grasped as follows, for example.

[0057]

(1) The ship 1 according to a first aspect includes the hull 2 having a pair of broadsides 3A and 3B, the tank 21 that is provided in the hull 2 and is capable of storing the liquefied carbon dioxide L, and the loading pipe 30 that loads the liquefied carbon dioxide L that is supplied from the outside of the ship into the tank 21, in which the loading pipe 30 includes the transport pipe 31 having the connection part 31j for connection with the outside of the ship and extending into the hull 2, the upper loading pipe

32 that branches off and extends from the transport pipe 31 and is open to the upper portion in the tank 21, the lower loading pipe 33 that branches off and extends from the transport pipe 31 and is open to the lower portion in the tank 21, the first on-off valve 34 provided in the upper loading pipe 32, and the second on-off valve 35 provided in the lower loading pipe 33.

[0058]

In the ship 1, when the first on-off valve 34 is opened, the liquefied carbon dioxide L that is supplied from the outside of the ship is supplied from the upper portion in the tank 21 through the transport pipe 31 and the upper loading pipe 32. Further, when the second on-off valve 35 is opened, the liquefied carbon dioxide L that is supplied from the outside of the ship is supplied from the lower portion in the tank 21 through the transport pipe 31 and the lower loading pipe 33.

Since the upper loading pipe 32 is open to the upper portion in the tank 21, the height difference from the highest position in the loading pipe 30 is small as compared with that in the lower loading pipe 33 that is open to the lower portion in the tank 21. In this way, it is possible to suppress a decrease in the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 regardless of the liquid level L_f in the tank 21.

Further, since the lower loading pipe 33 is open to the lower portion in the tank 21, when the liquefied carbon dioxide L is stored to a level higher than the opening of the lower loading pipe 33, a pressure according to the height of the liquid level L_f of the liquefied carbon dioxide L stored in the tank 21 is applied to the liquefied carbon dioxide L in the lower loading pipe 33. In this way, the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 can be increased.

In this manner, by appropriately adjusting the opening and closing of the first on-off valve 34 and the second on-off valve 35 according to the storage situation or the like of the liquefied carbon dioxide L in the tank 21, it is possible to suppress a decrease in the pressure of the liquefied carbon dioxide L at the highest position in the loading pipe 30. Therefore, the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 can be restrained from approaching the triple point pressure. In this way, it is possible to suppress the generation of dry ice due to the solidification of the liquefied carbon dioxide L in the loading pipe 30. As a result, in a case where the liquefied carbon dioxide L is contained in the tank 21, it is possible to suppress the generation of dry ice in the loading pipe 30 and smoothly perform the operation of the tank 21.

[0059]

(2) In the ship 1 according to a second aspect, the ship according to the above (1) further includes the control device 60 that controls the opening/closing operations of the first on-off valve 34 and the second on-off valve 35, based on the liquid level Lf of the liquefied carbon dioxide L in the tank 21, in a case where the liquefied carbon dioxide L is loaded into the tank 21.

[0060]

In this way, the control device 60 controls the opening/closing operations of the first on-off valve 34 and the second on-off valve 35, based on the liquid level Lf of the liquefied carbon dioxide L in the tank 21, so that it is possible to automatically suppress a decrease in the pressure of the liquefied carbon dioxide L at the highest position in the loading pipe 30.

[0061]

(3) In the ship 1 according to the above (3), the ship 1 of the above (2) further includes the liquid level detection unit 51 that detects the liquid level Lf of the liquefied carbon dioxide L that is stored in the tank 21, in which the control device 60 opens the first on-off valve 34 to load the liquefied carbon dioxide L into the tank 21 through the upper loading pipe 32, and opens the second on-off valve 35 to load the liquefied carbon dioxide L into

the tank 21 through the lower loading pipe 33 in a case where the liquid level L_f of the liquefied carbon dioxide L that is detected by the liquid level detection unit 51 reaches the switching level L_s set to be higher than the opening 33a of the lower loading pipe 33.

[0062]

In this way, by the control of the control device 60, the first on-off valve 34 is opened and the liquefied carbon dioxide L is loaded into the tank 21 through the upper loading pipe 32 until the liquid level L_f of the liquefied carbon dioxide L in the tank 21 reaches the set switching level L_s . Since the upper loading pipe 32 is open to the upper portion in the tank 21, the loading of the liquefied carbon dioxide L can be performed in a state of suppressing a decrease in the pressure of the liquefied carbon dioxide L at the highest position in the loading pipe 30.

Further, by the control of the control device 60, when the liquid level L_f of the liquefied carbon dioxide L in the tank 21 has reached the switching level L_s set to be higher than the opening 33a of the lower loading pipe 33, the second on-off valve 35 is opened and the liquefied carbon dioxide L is loaded into the tank 21 through the lower loading pipe 33. In this state, the liquefied carbon dioxide L is stored to a level higher than the opening of the lower loading pipe 33, and therefore, a pressure

according to the height of the liquid level L_f of the liquefied carbon dioxide L stored in the tank 21 is applied to the liquefied carbon dioxide L in the lower loading pipe 33. In this way, it is possible to perform the loading of the liquefied carbon dioxide L in a state where the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 is increased.

[0063]

(4) In the ship 1 according to a fourth aspect, the ship 1 of the above (2) or (3) further includes the pressure detection unit 52 that detects the pressure of the liquefied carbon dioxide L in the loading pipe 30, in which the control device 60 opens the first on-off valve 34 in a case where the pressure P of the liquefied carbon dioxide L that is detected by the pressure detection unit 52 is equal to or lower than the reference pressure P_s determined in advance, in a state where the second on-off valve 35 is opened.

[0064]

In this way, the first on-off valve 34 is opened in a case where the pressure P of the liquefied carbon dioxide L in the loading pipe 30 has been lowered to a pressure equal to or lower than the reference pressure P_s in a state where the second on-off valve 35 is opened and the liquefied carbon dioxide L is loaded into the tank 21 through the lower loading pipe 33. Since the upper loading pipe 32 is

open to the upper portion in the tank 21, it is possible to make the height difference from the highest position in the loading pipe 30 small as compared with when the liquefied carbon dioxide L is loaded through the lower loading pipe 33. In this way, it is possible to perform the loading of the liquefied carbon dioxide L in a state of suppressing a decrease in the pressure of the liquefied carbon dioxide L at the highest position in the loading pipe 30.

[0065]

(5) The method of loading the liquefied carbon dioxide L into the ship 1 according to a fifth aspect is a method of loading the liquefied carbon dioxide L into the ship 1 of any one of the above (1) to (4) including: a step S11 of opening the first on-off valve 34 to load the liquefied carbon dioxide L into the tank 21 through the upper loading pipe 32, and a step S12 of closing the first on-off valve 34 and opening the second on-off valve 35 to load the liquefied carbon dioxide L into the tank 21 through the lower loading pipe 33, after the liquid level L_f of the liquefied carbon dioxide L in the tank 21 has reached the switching level L_s set to be higher than the opening 33a of the lower loading pipe 33.

[0066]

In this way, when the liquefied carbon dioxide L is loaded into the tank 21, first, the first on-off valve 34

is opened and the liquefied carbon dioxide L is loaded into the tank 21 through the upper loading pipe 32. Since the upper loading pipe 32 is open to the upper portion in the tank 21, the loading of the liquefied carbon dioxide L can be performed in a state of suppressing a decrease in the pressure of the liquefied carbon dioxide L at the highest position in the loading pipe 30.

Thereafter, the second on-off valve 35 is opened and the liquefied carbon dioxide L is loaded into the tank 21 through the lower loading pipe 33. In this state, the liquefied carbon dioxide L is stored to a level higher than the opening of the lower loading pipe 33, and therefore, a pressure according to the height of the liquid level L_f of the liquefied carbon dioxide L stored in the tank 21 is applied to the liquefied carbon dioxide L in the lower loading pipe 33. In this way, it is possible to perform the loading of the liquefied carbon dioxide L in a state where the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 is increased.

In this way, the pressure of the liquefied carbon dioxide L at the highest position of the loading pipe 30 is restrained from approaching the triple point pressure. In this way, it is possible to suppress the generation of dry ice due to the solidification of the liquefied carbon dioxide L in the loading pipe 30. As a result, in a case

where the liquefied carbon dioxide L is contained in the tank 21, it is possible to suppress the generation of dry ice in the loading pipe 30 and smoothly perform the operation of the tank 21.

Industrial Applicability

[0067]

According to the ship and the method of loading liquefied carbon dioxide into a ship of the present disclosure, it is possible to suppress the generation of dry ice in a loading pipe and smoothly perform the operation of a tank.

Reference Signs List

[0068]

1: ship

2: hull

2a: bow

2b: stern

3A, 3B: broadside

5: exposure deck

7: superstructure

8: tank system storage compartment

21: tank

21b: lower end

30: loading pipe

30t: top portion

31: transport pipe
31j: connection part
32: upper loading pipe
32a: opening
33, 33B: lower loading pipe
33a: opening
34: first on-off valve
35: second on-off valve
38: spray pipe
39: on-off valve
51: liquid level detection unit
52: pressure detection unit
60: control device
61: CPU
62: ROM
63: RAM
64: HDD
65: signal receiving module
70: signal input unit
71: on-off valve control unit
72: liquid level determination unit
73: pressure determination unit
74: output unit
L: liquefied carbon dioxide
Lf: liquid level

Ls: switching level

Claims

[Claim 1]

A ship comprising:

a hull having a pair of broadsides;

a tank that is provided in the hull and is capable of storing liquefied carbon dioxide; and

a loading pipe that loads liquefied carbon dioxide that is supplied from an outside of the ship into the tank,

wherein the loading pipe includes

a transport pipe having a connection part for connection with the outside of the ship,

an upper loading pipe that branches off and extends from the transport pipe and is open in the tank and at a height equal to or higher than a height of a liquid level of the liquefied carbon dioxide corresponding to 90% of a volume of the tank in an up-down direction,

a lower loading pipe that branches off and extends from the transport pipe and is open in the tank and at a height equal to or lower than a height of the liquid level of the liquefied carbon dioxide corresponding to 10% of the volume of the tank in the up-down direction,

a first on-off valve provided in the upper loading pipe, and

a second on-off valve provided in the lower loading pipe.

[Claim 2]

The ship according to claim 1, further comprising:

a control device that controls opening/closing operations of the first on-off valve and the second on-off valve, based on a liquid level of the liquefied carbon dioxide in the tank, when the liquefied carbon dioxide is loaded into the tank.

[Claim 3]

The ship according to claim 2, further comprising:

a liquid level detection unit that detects the liquid level of the liquefied carbon dioxide that is stored in the tank,

wherein the control device opens the first on-off valve to load the liquefied carbon dioxide into the tank through the upper loading pipe, and the control device closes the first on-off valve and opens the second on-off valve to load the liquefied carbon dioxide into the tank through the lower loading pipe in a case where the liquid level of the liquefied carbon dioxide that is detected by the liquid level detection unit reaches a switching level L_s set to be higher than an opening of the lower loading pipe.

[Claim 4]

The ship according to claim 2 or 3, further comprising:

a pressure detection unit that detects a pressure of the liquefied carbon dioxide in the loading pipe,

wherein the control device closes the second on-off valve and opens the first on-off valve in a case where the pressure of the liquefied carbon dioxide that is detected by the pressure detection unit becomes equal to or lower than a reference pressure determined in advance, in a state where the second on-off valve is opened.

[Claim 5]

A method of loading liquefied carbon dioxide into the ship according to any one of claims 1 to 4, the method comprising:

a step of opening the first on-off valve to load the liquefied carbon dioxide into the tank through the upper loading pipe; and

a step of closing the first on-off valve and opening the second on-off valve to load the liquefied carbon dioxide into the tank through the lower loading pipe, after a liquid level of the liquefied carbon dioxide in the tank has reached a switching level L_s set to be higher than an opening of the lower loading pipe.