DESCRIPTION

TITLE OF INVENTION: TANK SYSTEM, FLOATING BODY, AND METHOD FOR TRANSFERRING LIQUEFIED CARBON DIOXIDE

TECHNICAL FIELD

[0001]

The present disclosure relates to a tank system, a floating body, and a method for transferring liquefied carbon dioxide.

Priority is claimed on Japanese Patent Application No. 2024-094365, filed June 11, 2024, the content of which is incorporated herein by reference

BACKGROUND ART

[0002]

For example, Patent Document 1 discloses a configuration in which a transfer device (natural gas transfer device) for transferring liquefied gas (liquefied natural gas (LNG)) from a vessel (import vessel) including a tank for storing the liquefied gas to an onshore facility (import terminal) is provided. In such a configuration, the vessel transfers the liquefied gas in the tank to a tank of the onshore facility.

Citation List

Patent Document

[0003]

Patent Document 1: Published Japanese Translation No. 2010-503132, of the PCT International Publication

SUMMARY OF INVENTION

Technical Problem

[0004]

Meanwhile, in a case where a plurality of tanks are provided in the vessel, in order to transfer the liquefied gas in the tanks to the onshore facility, a discharge pipe for discharging the liquefied gas in the tanks to the outside and a pump for discharging the liquefied gas in the tanks through the discharge pipe are provided in each of the plurality of tanks.

In such a configuration, for example, even in a case where the pump fails and becomes unusable due to some cause, an alternative measure is required so that the liquefied gas in the tank in which the pump cannot be used can be transferred to the onshore facility. As one of such alternative measures, there is a method for generating a pressure difference between the tanks, transferring the liquefied gas in the tank in which the pump cannot be used to another tank in which the pump can be used, and transferring the liquefied gas to the onshore facility through the other tank.

[0005]

Meanwhile, in a case where the liquefied carbon dioxide is stored in the tank, when the liquefied carbon dioxide is transferred to the other tank by generating the pressure difference between the tanks, the pressure in the other tank gradually decreases and approaches a triple point due to a density difference between the liquefied carbon dioxide and the carbon dioxide gas. Then, when the pressure in the other tank becomes equal to or lower than the triple point, dry ice may be generated. Accordingly, as described above, in a case where the liquefied carbon dioxide is transferred between the plurality of tanks, there is a problem in that it is necessary to temporarily stop the transfer of the liquefied carbon dioxide between the tanks to recover the pressure in the other tank, and it takes time to transfer the liquefied carbon dioxide to a location outside of the tank.

[0006]

The present disclosure has been made to solve the above-described problems, and an object of the present disclosure is to provide a tank system, a floating body, and a method for transferring liquefied carbon dioxide that can rapidly transfer liquefied carbon dioxide in a tank to an outside while suppressing generation of dry ice.

Solution to Problem

[0007]

In order to achieve the above object, the present disclosure relates to a tank system including: a first tank; a second tank; a first discharge line; a connection line; a first transfer line; a first return line; and a switching unit. The first tank and the second tank are configured to store liquefied carbon dioxide. The first discharge line is configured to discharge the liquefied carbon dioxide in the first tank to a location outside of the first tank. The connection line connects an interior of the first tank and an interior of the second tank. The first transfer line is configured to transfer carbon dioxide gas in the first tank into the second tank. The first return line is configured to take out carbon dioxide gas in the second tank, heat the carbon dioxide gas, and return the carbon dioxide gas to the second tank. The switching unit is configured to switch between transfer of the carbon dioxide gas by the first transfer line and return of the carbon dioxide gas by the first return line.

[0008]

The present disclosure relates to a floating body including: a floating body main body; and the tank system as described above provided in the floating body main body.

[0009]

The present disclosure relates to a method for transferring liquefied carbon dioxide in the tank system as described above. The method for transferring liquefied carbon dioxide includes a step of transferring the liquefied carbon dioxide and a step of

switching from transfer of the carbon dioxide gas by the first transfer line to return of the carbon dioxide gas by the first return line. In the step of transferring the liquefied carbon dioxide, the carbon dioxide gas in the first tank is transferred into the second tank through the first transfer line to increase a pressure in the second tank. In the step of transferring the liquefied carbon dioxide, the liquefied carbon dioxide in the second tank is transferred into the first tank through the connection line by a pressure difference between the pressure in the second tank and a pressure in the first tank. In the step of switching from the transfer of the carbon dioxide gas by the first transfer line to the return of the carbon dioxide gas by the first return line, when the pressure in the first tank becomes lower than a preset first threshold value in a state in which the carbon dioxide gas in the first tank is transferred into the second tank, the transfer of the carbon dioxide gas by the first transfer line is switched to the return of the carbon dioxide gas by the first return line.

Advantageous Effects of Invention

[0010]

With the tank system, the floating body, and the method for transferring liquefied carbon dioxide according to the present disclosure, it is possible to rapidly transfer the liquefied carbon dioxide in the tank to the outside while suppressing the generation of dry ice.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

[FIG. 1] A plan view of a floating body including a tank system according to an embodiment of the present disclosure.

[FIG. 2] A diagram showing a tank system according to a first embodiment of the present disclosure, which is a cross-sectional view taken along line II-II of FIG. 1.

[FIG. 3] A diagram showing a state in which carbon dioxide gas flows through a first transfer line in the tank system according to the first embodiment of the present disclosure.

[FIG. 4] A diagram showing a state in which the carbon dioxide gas flows through a first return line in the tank system according to the first embodiment of the present disclosure.

[FIG. 5] A diagram showing a state in which the carbon dioxide gas flows through a second transfer line in the tank system according to the first embodiment of the present disclosure.

[FIG. 6] A diagram showing a state in which the carbon dioxide gas flows through a second return line in the tank system according to the first embodiment of the present disclosure.

[FIG. 7] A flowchart showing a flow of a method for transferring liquefied carbon dioxide according to the first embodiment of the present disclosure.

[FIG. 8] A diagram showing a tank system according to a second embodiment of the present disclosure.

[FIG. 9] A diagram showing a hardware configuration of a control device according to the second embodiment of the present disclosure.

[FIG. 10] A functional block diagram of the control device according to the second embodiment of the present disclosure.

[FIG. 11] A diagram showing a state in which carbon dioxide gas flows through a first transfer line in the tank system according to the second embodiment of the present disclosure.

[FIG. 12] A diagram showing a state in which the carbon dioxide gas flows through a first return line in the tank system according to the second embodiment of the

present disclosure.

[FIG. 13] A diagram showing a state in which the carbon dioxide gas flows through a second transfer line in the tank system according to the second embodiment of the present disclosure.

[FIG. 14] A diagram showing a state in which the carbon dioxide gas flows through a second return line in the tank system according to the second embodiment of the present disclosure.

[FIG. 15] A diagram showing a tank system according to a modification example of the embodiment of the present disclosure.

[FIG. 16] A diagram showing a tank system according to a modification example of the embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0012]

<First Embodiment>

Hereinafter, a tank system, a floating body, and a method for transferring liquefied carbon dioxide according to embodiments of the present disclosure will be described with reference to FIGS. 1 to 16.

(Configuration of Vessel)

As shown in FIG. 1, in the present embodiment, a vessel 1, which is a floating body, transports liquefied carbon dioxide. The vessel 1 includes at least a hull 2 as a floating body main body and a tank system 10A.

[0013]

(Configuration of Hull)

The hull 2 has a pair of side shells 3A and 3B, a bottom (not shown), and an upper deck 5, which form an outer shell of the hull 2. The side shells 3A and 3B

include a pair of side shell plates that respectively form left and right side shells. The bottom has a bottom shell plate that connects the side shells 3A and 3B. The upper deck 5 described in the present embodiment is a continuous deck exposed to the outside. A superstructure 7 having living quarters is formed on the hull 2. The position of the superstructure 7 is merely an example, and, for example, the superstructure 7 may be disposed on a bow 2a side of the hull 2. A cargo loading section (hold) 8 is formed in the hull 2.

[0014]

(Configuration of Tank System)

FIG. 2 is a diagram showing a configuration of the tank system according to the first embodiment of the present disclosure, which is a cross-sectional view taken along line II-II of FIG. 1.

As shown in FIG. 2, the tank system 10A includes a first tank 11A, a second tank 11B, a first pressure detection unit 111A, a second pressure detection unit 111B, a first discharge line 13A, a second discharge line 13B, and a transfer pipe unit 20A. In the tank system 10A according to the first embodiment, a case where one set of the tank systems 10A is provided will be described as an example in the first embodiment. Two or more sets of tank systems 10A may be provided for one hull.

[0015]

(First Tank and Second Tank)

Each of the first tank 11A and the second tank 11B can store liquefied carbon dioxide L. As shown in FIG. 1, the first tank 11A and the second tank 11B are provided in the cargo loading section 8. The first tank 11A and the second tank 11B may be provided above the upper deck 5. In the first embodiment, the first tank 11A and the second tank 11B are disposed, for example, at intervals in a fore and aft direction Da.

The first tank 11A and the second tank 11B may be disposed, for example, side by side in a ship width direction Dw. For example, a case is shown in which each of the first tank 11A and the second tank 11B has a cylindrical shape extending in a horizontal direction. However, the shape of each of the first tank 11A and the second tank 11B is not limited to the cylindrical shape, and may be, for example, a spherical shape, a rectangular shape, or the like.

[0016]

(First Pressure Detection Unit and Second Pressure Detection Unit)

As shown in FIG. 2, the first pressure detection unit 111A is attached to the first tank 11A, and detects a pressure in the first tank 11A. The second pressure detection unit 111B is attached to the second tank 11B, and detects a pressure in the second tank 11B.

[0017]

(First Discharge Line)

The first discharge line 13A discharges the liquefied carbon dioxide L in the first tank 11A to a location outside of the first tank 11A. The first discharge line 13A sends the liquefied carbon dioxide L in the first tank 11A to, for example, an onshore facility, an offshore floating facility, another vessel, and the like. The first discharge line 13A includes an unloading pipe 131A and a pump 132A.

[0018]

The unloading pipe 131A penetrates a top portion of the first tank 11A from the outside of the first tank 11A and extends to the inside of the first tank 11A. One end of the unloading pipe 131A is disposed in a lower portion in the first tank 11A. The pump 132A is connected to one end of the unloading pipe 131A. The pump 132A sucks the liquefied carbon dioxide L in the first tank 11A. The unloading pipe 131A sends the

liquefied carbon dioxide L sucked by the pump 132A to a location outside of the first tank 11A. The other end (not shown) of the unloading pipe 131A is disposed outside the first tank 11A. The other end of the unloading pipe 131A is connected to, for example, a bunkering station (not shown) or the like, is disposed toward one of the side shells 3A and 3B (for example, the side shell 3A), and is detachably connected to a connection pipe (not shown) for connection to the onshore facility, the offshore floating facility, another vessel, and the like.

[0019]

(Second Discharge Line)

The second discharge line 13B discharges the liquefied carbon dioxide L in the second tank 11B to a location outside of the second tank 11B. The second discharge line 13B sends the liquefied carbon dioxide L in the second tank 11B to, for example, an onshore facility, an offshore floating facility, another vessel, and the like. The second discharge line 13B includes an unloading pipe 131B and a pump 132B.

[0020]

The unloading pipe 131B penetrates a top portion of the second tank 11B from the outside of the second tank 11B and extends to the inside of the second tank 11B. One end of the unloading pipe 131B is disposed in a lower portion in the second tank 11B. The pump 132B is connected to one end of the unloading pipe 131B. The pump 132B sucks the liquefied carbon dioxide L in the second tank 11B. The unloading pipe 131B sends the liquefied carbon dioxide L sucked by the pump 132B to a location outside of the second tank 11B. The other end (not shown) of the unloading pipe 131B is disposed outside the second tank 11B. The other end of the unloading pipe 131B is connected to, for example, a bunkering station (not shown) or the like, is disposed toward one of the side shells 3A and 3B (for example, the side shell 3A), and, similarly to the

unloading pipe 131A, is detachably connected to a connection pipe (not shown) for connection to the onshore facility, the offshore floating facility, another vessel, and the like.

[0021]

(Transfer Pipe Unit)

The transfer pipe unit 20A is configured to transfer the liquefied carbon dioxide L in the second tank 11B into the first tank 11A, for example, in a case where the pump 132B of the second discharge line 13B cannot be used due to a failure or the like. In addition, the transfer pipe unit 20A is configured to transfer the liquefied carbon dioxide L in the first tank 11A into the second tank 11B, for example, in a case where the pump 132A of the first discharge line 13A cannot be used due to a failure or the like.

[0022]

The transfer pipe unit 20A includes a liquid transfer pipe 21, a gas transfer pipe 22, a first connection pipe (return pipe) 23, a second connection pipe (first gas discharge pipe) 24, a compressor 31, a heater 32, and a switching unit 120.

[0023]

The liquid transfer pipe 21 communicates a liquid phase in the first tank 11A with a liquid phase in the second tank 11B. One end 21a of the liquid transfer pipe 21 is open to the lower portion in the first tank 11A. The other end 21b of the liquid transfer pipe 21 is open to the lower portion in the second tank 11B. An opening/closing valve 121 is provided partway along the liquid transfer pipe 21. The opening/closing valve 121 can open and close a flow path in the liquid transfer pipe 21. Further, the liquid transfer pipe 21 is provided with a pressure sensor 112 that detects a pressure in the liquid transfer pipe 21. Here, the lower portion of the first tank 11A and the lower portion of the second tank 11B can be described by the same vertical position as the

vertical position at which the pump 132A and the pump 132B are installed inside the first tank 11A and the second tank 11B.

[0024]

The gas transfer pipe 22 communicates a gas phase in the first tank 11A with a gas phase in the second tank 11B. One end 22a of the gas transfer pipe 22 is open to an upper portion in the first tank 11A. The other end 22b of the gas transfer pipe 22 is open to an upper portion in the second tank 11B. The first pressure-feed unit 30 is provided partway along the gas transfer pipe 22. The first pressure-feed unit 30 according to the first embodiment includes a compressor 31 and a heater 32. The compressor 31 compresses the carbon dioxide gas flowing in the gas transfer pipe 22 and sends the carbon dioxide from one of the first tank 11A and the second tank 11B toward the other thereof. The heater 32 heats the carbon dioxide gas flowing in the gas transfer pipe 22. The first pressure-feed unit 30 according to the first embodiment is disposed in the order of the compressor 31 and the heater 32 from one end 22a toward the other end 22b of the gas transfer pipe 22. The disposition order of the compressor 31 and the heater 32 may be reversed from the disposition order described above.

[0025]

The gas transfer pipe 22 is provided with pressure sensors 113 and 114 that detect an inlet pressure and an outlet pressure of the compressor 31.

[0026]

One end 23a of the first connection pipe 23 is connected to the upper portion of the first tank 11A, and the other end 23b of the first connection pipe 23 is connected to the gas transfer pipe 22 between the heater 32 and a second opening/closing valve 122B described later.

[0027]

One end 24a of the second connection pipe 24 is connected to the upper portion of the second tank 11B. The other end 24b of the second connection pipe 24 is connected to the gas transfer pipe 22 between a first opening/closing valve 122A described later and the compressor 31.

[0028]

(Switching Unit)

The switching unit 120 switches a flow mode (flow path) of the carbon dioxide gas in the transfer pipe unit 20A. The switching unit 120 is capable of switching between the transfer of the carbon dioxide gas G by the first transfer line 16A and the return of the carbon dioxide gas G by the first return line 17A. Further, the switching unit 120 is capable of switching between the transfer of the carbon dioxide gas G by the second transfer line 18A and the return of the carbon dioxide gas G by the second return line 19A.

The switching unit 120 described in the first embodiment includes a first opening/closing valve 122A, a second opening/closing valve 122B, a third opening/closing valve 123, and a fourth opening/closing valve 124.

[0029]

The first opening/closing valve 122A is provided between one end 22a of the gas transfer pipe 22 and the compressor 31. The second opening/closing valve 122B is provided between the heater 32 and the other end 22b of the gas transfer pipe 22. Each of the first opening/closing valve 122A and the second opening/closing valve 122B can open and close the flow path in the gas transfer pipe 22.

[0030]

The third opening/closing valve 123 is provided partway along the first connection pipe 23. The third opening/closing valve 123 can open and close the flow

path in the first connection pipe 23. The fourth opening/closing valve 124 is provided partway along the second connection pipe 24. The fourth opening/closing valve 124 can open and close the flow path in the second connection pipe 24.

[0031]

Such a transfer pipe unit 20A is configured to switch a flow mode of the carbon dioxide gas by switching open/closed states of the first opening/closing valve 122A, the second opening/closing valve 122B, the third opening/closing valve 123, and the fourth opening/closing valve 124. The transfer pipe unit 20A includes a connection line 15, a first transfer line 16A, a first return line 17A, a second transfer line 18A, and a second return line 19A.

[0032]

The connection line 15 connects the liquid phase inside the first tank 11A and the liquid phase inside the second tank 11B. The connection line 15 includes a liquid transfer pipe 21. In order to allow the liquefied carbon dioxide L to flow through the connection line 15, the opening/closing valve 121 is set to an open state. The connection line 15 can transfer the liquefied carbon dioxide L between the first tank 11A and the second tank 11B by a pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B. For example, when the pressure in the first tank 11A is higher than the pressure in the second tank 11B, the liquefied carbon dioxide L in the first tank 11A is transferred into the second tank 11B through the connection line 15. On the other hand, when the pressure in the second tank 11B is higher than the pressure in the first tank 11A, the liquefied carbon dioxide L in the second tank 11B is transferred to the first tank 11A through the connection line 15.

[0033]

FIG. 3 is a diagram showing a state in which the carbon dioxide gas flows

through the first transfer line in the tank system according to the first embodiment of the present disclosure.

As shown in FIG. 3, the first transfer line 16A can transfer the carbon dioxide gas G in the first tank 11A into the second tank 11B. The first transfer line 16A includes the gas transfer pipe 22 and the first pressure-feed unit 30.

[0034]

In order to cause the carbon dioxide gas to flow through the first transfer line 16A, the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to a closed state, the first opening/closing valve 122A and the second opening/closing valve 122B are set to an open state, and the compressor 31 is operated. The first transfer line 16A sucks the carbon dioxide gas G in the first tank 11A by using the compressor 31 and pressurizes the carbon dioxide gas G into the second tank 11B. The first transfer line 16A pressurizes (compresses) the carbon dioxide gas G by using the compressor 31 and heats the carbon dioxide gas G by using the heater 32, so that the carbon dioxide gas G in the first tank 11A expands and is transferred into the second tank 11B. By transferring the carbon dioxide gas G expanded in this manner into the second tank 11B, a pressure in the second tank 11B increases.

[0035]

FIG. 4 is a diagram showing a state in which the carbon dioxide gas is caused to flow through the first return line in the tank system according to the first embodiment of the present disclosure.

As shown in FIG. 4, the first return line 17A can take out the carbon dioxide gas G in the second tank 11B, heat the carbon dioxide gas G, and return the carbon dioxide gas G to the second tank 11B. The first return line 17A includes the second connection pipe 24, a portion of the gas transfer pipe 22, and the first pressure-feed unit 30. A

portion of the first transfer line 16A on a side closer to the second tank 11B than a position, in the first transfer line 16A, to which the second connection pipe 24 is connected also serves as the first return line 17A.

[0036]

In order to cause the carbon dioxide gas to flow through the first return line 17A, the first opening/closing valve 122A and the third opening/closing valve 123 are set to a closed state, the second opening/closing valve 122B and the fourth opening/closing valve 124 are set to an open state, and the compressor 31 is operated. The first return line 17A sucks the carbon dioxide gas G in the second tank 11B by using the compressor 31 and supplies the carbon dioxide gas G to a portion of the first transfer line 16A on a side closer to the first tank 11A than the first pressure-feed unit 30. The carbon dioxide gas G supplied to the first transfer line 16A is pressurized by the compressor 31, heated by the heater 32, and then returned to the second tank 11B. In this manner, by expanding the carbon dioxide gas G sucked from the second tank 11B and returning the carbon dioxide gas G into the second tank 11B, the pressure in the second tank 11B increases.

[0037]

FIG. 5 is a diagram showing a state in which the carbon dioxide gas is caused to flow through the second transfer line in the tank system according to the first embodiment of the present disclosure.

As shown in FIG. 5, the second transfer line 18A can transfer the carbon dioxide gas G in the second tank 11B into the first tank 11A. The second transfer line 18A is configured by the second connection pipe 24 of the first return line 17A, the first connection pipe 23 of the second return line 19A, and the first transfer line 16A including the first pressure-feed unit 30 between a position, in the first transfer line 16A, to which the second connection pipe 24 is connected and a position, in the first transfer line 16A,

to which the first connection pipe 23 is connected. The second transfer line 18A includes the second connection pipe 24, a portion of the gas transfer pipe 22, and the first pressure-feed unit 30.

[0038]

In order to cause the carbon dioxide gas to flow through the second transfer line 18A, the first opening/closing valve 122A and the second opening/closing valve 122B are set to a closed state, the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to an open state, and the compressor 31 is operated. The second transfer line 18A sucks the carbon dioxide gas G in the second tank 11B by using the compressor 31 and pressurizes the carbon dioxide gas G into the first tank 11A. The second transfer line 18A pressurizes (compresses) the carbon dioxide gas G by using the compressor 31 and heats the carbon dioxide gas G by using the heater 32 to expand the carbon dioxide gas G in the second tank 11B and transfer the carbon dioxide gas G into the first tank 11A. By transferring the carbon dioxide gas G expanded in this manner into the first tank 11A, the pressure in the first tank 11A is increased.

[0039]

FIG. 6 is a diagram showing a state in which the carbon dioxide gas is caused to flow through the second return line in the tank system according to the first embodiment of the present disclosure.

As shown in FIG. 6, the second return line 19A can take out the carbon dioxide gas G in the first tank 11A, heat the carbon dioxide gas G, and return the carbon dioxide gas G to the first tank 11A. The second return line 19A includes a portion of the gas transfer pipe 22 on a side closer to the first tank 11A than a position, in the gas transfer pipe 22, to which the first connection pipe 23 is connected, and the first connection pipe 23. A portion of the first transfer line 16A on a side closer to the first tank 11A than a

position, in the first transfer line 16A, to which the first connection pipe 23 is connected also serves as the second return line 19A.

[0040]

In order to cause the carbon dioxide gas to flow through the second return line 19A, the second opening/closing valve 122B and the fourth opening/closing valve 124 are set to a closed state, the first opening/closing valve 122A and the third opening/closing valve 123 are set to an open state, and the compressor 31 is operated. The second return line 19A sucks the carbon dioxide gas G in the first tank 11A by using the compressor 31 and supplies the carbon dioxide gas G to a portion of the gas transfer pipe 22 on a side closer to the first tank 11A than a position at which the first connection pipe 23 is connected. The carbon dioxide gas G supplied to the gas transfer pipe 22 is pressurized by the compressor 31, heated by the heater 32, and then returned to the first tank 11A through the first connection pipe 23. In this manner, the carbon dioxide gas G is expanded and returned to the first tank 11A, so that the pressure in the first tank 11A is increased.

[0041]

(Procedure of Method for Transferring Liquefied Carbon Dioxide)

In the tank system 10A, the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside through the first discharge line 13A and the second discharge line 13B. In the first tank 11A, the liquefied carbon dioxide L in the first tank 11A is discharged to a location outside of the first tank 11A through the unloading pipe 131A by the pump 132A of the first discharge line 13A. In the second tank 11B, the liquefied carbon dioxide L in the second tank 11B is discharged to a location outside of the second tank 11B through the unloading pipe 131B by the pump 132B of the second discharge line 13B. The discharge of the liquefied carbon dioxide L

from the first tank 11A and the discharge of the liquefied carbon dioxide L from the second tank 11B may be performed in parallel or sequentially.

[0042]

In a case where any one of the pump 132A of the first tank 11A or the pump 132B of the second tank 11B fails when the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside, the transfer of the liquefied carbon dioxide between the first tank 11A and the second tank 11B is performed in the following procedure.

[0043]

FIG. 7 is a flowchart showing a flow of a method for transferring the liquefied carbon dioxide according to the first embodiment of the present disclosure.

As shown in FIG. 7, the method S10 for transferring the liquefied carbon dioxide L in the tank system 10A as described above includes a step S11 of transferring the liquefied carbon dioxide L, a step S12 of determining whether a pressure in a tank has become lower than a first threshold value, a step S13 of switching from transfer of the carbon dioxide gas G to return of the carbon dioxide gas G, a step S14 of determining whether the pressure in the tank has become higher than a second threshold value, a step S15 of returning the process from return of the carbon dioxide gas G to transfer of the carbon dioxide gas G, and a step S16 of determining whether transfer of the liquefied carbon dioxide L has ended.

The method S10 for transferring the liquefied carbon dioxide L according to the present embodiment is performed by, for example, an operator.

[0044]

Hereinafter, for example, a case will be described in which the pump 132B of the second tank 11B fails when the liquefied carbon dioxide L in the first tank 11A and

the second tank 11B is discharged to the outside.

(Case Where Pump of Second Tank Fails)

In the step S11 of transferring the liquefied carbon dioxide L (hereinafter, simply referred to as step S11), in a case where the pump 132B of the second tank 11B fails, the liquefied carbon dioxide L in the second tank 11B is transferred into the first tank 11A. In such a case, as shown in FIG. 3, the carbon dioxide gas G in the first tank 11A is transferred into the second tank 11B through the first transfer line 16A to pressurize the inside of the second tank 11B. Therefore, in the step S11, the opening/closing valve 121 is opened, the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to a closed state, the first opening/closing valve 122A and the second opening/closing valve 122B are set to an open state, and the compressor 31 is operated.

[0045]

Then, the first transfer line 16A sucks the carbon dioxide gas G in the first tank 11A and pressurizes the carbon dioxide gas G into the second tank 11B. In this case, the first transfer line 16A pressurizes (compresses) the carbon dioxide gas G by using the compressor 31 and heats the carbon dioxide gas G by using the heater 32 to expand the carbon dioxide gas G in the first tank 11A. Therefore, the pressure in the second tank 11B is increased, and the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B is increased. Due to the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B, the liquefied carbon dioxide L in the second tank 11B is pushed out through the liquid transfer pipe 21 of the connection line 15 and is transferred into the first tank 11A.

[0046]

In the step S12 of determining whether or not the pressure in the tank has become lower than the first threshold value (hereinafter, simply referred to as step S12),

the detection value of the first pressure detection unit 111A is monitored while the carbon dioxide gas G in the second tank 11B is being transferred into the first tank 11A in the step S11. In the step S12, it is determined whether or not the pressure in the first tank 11A has become lower than the first threshold value set in advance, based on the detection value of the first pressure detection unit 111A. It is preferable that the first threshold value is set to a triple point or higher of the carbon dioxide gas.

When the detection value of the first pressure detection unit 111A has not become lower than the first threshold value (No in the step S12), the step S11 is continued, and the step S12 is repeatedly performed at predetermined time intervals.

When the detection value of the first pressure detection unit 111A has become lower than the first threshold value (Yes in the step S12), the process proceeds to the step S13 of switching the transfer of the carbon dioxide gas G to the return of the carbon dioxide gas G.

[0047]

In the step S13 of switching the transfer of the carbon dioxide gas G to the return of the carbon dioxide gas G (hereinafter, simply referred to as step S13), the transfer of the carbon dioxide gas G by the first transfer line 16A is switched to the return of the carbon dioxide gas G by the first return line 17A. Specifically, as shown in FIG. 4, the first opening/closing valve 122A and the third opening/closing valve 123 are set to a closed state, and the second opening/closing valve 122B and the fourth opening/closing valve 124 are set to an open state from the state as shown in FIG. 3. Therefore, the carbon dioxide gas G in the second tank 11B is sucked by using the compressor 31 through the second connection pipe 24 of the first return line 17A and is supplied to a portion of the first transfer line 16A on a side closer to the first tank 11A than the first pressure-feed unit 30. The carbon dioxide gas G supplied to the first transfer line 16A is

pressurized by the compressor 31, heated by the heater 32, and then returned to the second tank 11B. In this manner, the carbon dioxide gas G sucked from the second tank 11B is expanded and returned to the second tank 11B, so that the pressure in the second tank 11B can be increased. By increasing the pressure in the second tank 11B, the pressure difference between the pressure in the second tank 11B and the pressure in the first tank 11A is secured, and the transfer of the liquefied carbon dioxide L in the second tank 11B into the first tank 11A through the connection line 15 is continued. As a result, the amount of the liquefied carbon dioxide L in the first tank 11A is increased, so that the pressure in the first tank 11A is increased and is prevented from approaching the triple point.

[0048]

In the step S14 of determining whether or not the pressure in the tank has become higher than the second threshold value (hereinafter, simply referred to as step S14), the pressure in the second tank 11B is confirmed based on the detection value of the second pressure detection unit 111B, and it is determined whether or not the pressure has become higher than the second threshold value determined in advance. Here, the second threshold value may be different from the first threshold value.

When the pressure in the second tank 11B has not become higher than the second threshold value set in advance (No in the step S14), the step S13 is continued.

When the pressure in the second tank 11B has become higher than the second threshold value set in advance (Yes in the step S14), the process proceeds to the step S15 of returning the process from the return of the carbon dioxide gas G to the transfer of the carbon dioxide gas G.

[0049]

In the step S15 of returning the process from the return of the carbon dioxide gas

G to the transfer of the carbon dioxide gas G (hereinafter, simply referred to as step S15), the state shown in FIG. 4 is returned to the state shown in FIG. 3, and the liquefied carbon dioxide L in the second tank 11B is transferred into the first tank 11A. In this case, as shown in FIG. 3, the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to a closed state, and the first opening/closing valve 122A and the second opening/closing valve 122B are set to an open state. Therefore, the carbon dioxide gas G in the first tank 11A can be pressurized by the compressor 31, heated by the heater 32, and then returned to a state of being transferred into the second tank 11B through the first transfer line 16A. As a result, the inside of the second tank 11B is pressurized, and the liquefied carbon dioxide L in the second tank 11B is continuously transferred into the first tank 11A through the connection line 15.

[0050]

In the step S16 of determining whether or not the transfer of the liquefied carbon dioxide L has ended (hereinafter, simply referred to as step S16), it is determined whether or not the transfer of the liquefied carbon dioxide L in the second tank 11B into the first tank 11A has ended, for example, based on the detection value of the pressure sensor 112. For example, in a case where the detection value of the pressure sensor 112 is equal to or lower than a threshold value set in advance, it can be determined that the transfer of the liquefied carbon dioxide L in the second tank 11B into the first tank 11A through the connection line 15 has ended. The determination of whether or not the transfer of the liquefied carbon dioxide L has ended may be performed, for example, based on a liquid level gauge or the like that detects the liquid level in the second tank 11B.

In this manner, after the transfer of the liquefied carbon dioxide L has ended, the liquefied carbon dioxide L transferred from the inside of the second tank 11B to the inside of the first tank 11A is discharged through the first discharge line 13A.

[0051]

Next, for example, a case will be described in which the pump 132A of the first tank 11A fails when the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside.

(Case Where Pump of First Tank Fails)

For example, in a case where the pump 132A of the first tank 11A fails when the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside, in the step S11, the liquefied carbon dioxide L in the first tank 11A is transferred into the second tank 11B. In this case, as shown in FIG. 5, the carbon dioxide gas G in the second tank 11B is transferred into the first tank 11A through the second transfer line 18A to pressurize the inside of the first tank 11A. Therefore, in the step S11, the opening/closing valve 121 is opened, the first opening/closing valve 122A and the second opening/closing valve 122B are set to a closed state, the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to an open state, and the compressor 31 is operated.

[0052]

Then, the second transfer line 18A sucks the carbon dioxide gas G in the second tank 11B through the second connection pipe 24. In this case, the second transfer line 18A pressurizes (compresses) the carbon dioxide gas G by using the compressor 31 and heats the carbon dioxide gas G by using the heater 32 to expand the carbon dioxide gas G in the second tank 11B. Therefore, the pressure in the first tank 11A is increased, and the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B is increased. Due to the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B, the liquefied carbon dioxide L in the first tank 11A is transferred into the second tank 11B through the liquid transfer pipe 21

of the connection line 15.

[0053]

In the step S12, the detection value of the second pressure detection unit 111B is monitored while the carbon dioxide gas G in the first tank 11A is being transferred into the second tank 11B in the step S11. In the step S12, it is determined whether or not the pressure in the second tank 11B has become lower than the first threshold value set in advance, based on the detection value of the second pressure detection unit 111B.

When the detection value of the second pressure detection unit 111B has not become lower than the first threshold value (No in the step S12), the step S11 is continued, and the step S12 is repeatedly performed at predetermined time intervals.

When the detection value of the second pressure detection unit 111B has become lower than the first threshold value (Yes in the step S12), the step S13 is performed.

[0054]

In the step S13, the transfer of the carbon dioxide gas G by the second transfer line 18A is switched to the return of the carbon dioxide gas G by the second return line 19A as shown in FIG. 6. Specifically, the second opening/closing valve 122B and the fourth opening/closing valve 124 are set to a closed state, and the first opening/closing valve 122A and the third opening/closing valve 123 are set to an open state. As a result, the carbon dioxide gas G in the first tank 11A is sucked by using the compressor 31 through the second return line 19A, pressurized by the compressor 31, heated by the heater 32, and then returned to the first tank 11A. In this manner, the carbon dioxide gas G is expanded and returned to the first tank 11A, so that the pressure in the first tank 11A can be increased. By increasing the pressure in the first tank 11A, the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B is secured, and the transfer of the liquefied carbon dioxide L in the first tank 11A to

the second tank 11B through the connection line 15 is continued. As a result, the amount of the liquefied carbon dioxide L in the second tank 11B is increased, so that the pressure in the second tank 11B is increased and is suppressed from approaching the triple point.

[0055]

In the step S14, it is determined whether or not the pressure in the first tank 11A has become lower than the second threshold value determined in advance, based on the detection value of the first pressure detection unit 111A.

When the pressure in the first tank 11A has not become higher than the second threshold value set in advance (No in the step S14), the step S13 is continued.

When the pressure in the first tank 11A has become higher than the second threshold value set in advance (Yes in the step S14), the process proceeds to the step S15.

[0056]

In the step S15, the state shown in FIG. 6 is returned to the state shown in FIG. 5, and the liquefied carbon dioxide L in the first tank 11A is transferred into the second tank 11B. In this case, as shown in FIG. 5, the first opening/closing valve 122A and the second opening/closing valve 122B are set to a closed state, and the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to an open state. Therefore, the carbon dioxide gas G in the second tank 11B can be pressurized by the compressor 31 through the second transfer line 18A, heated by the heater 32, and then returned to a state of being transferred into the first tank 11A. As a result, the inside of the first tank 11A is pressurized, and the liquefied carbon dioxide L in the first tank 11A is continuously transferred into the second tank 11B through the connection line 15.

[0057]

In the step S16, it is determined whether or not the transfer of the liquefied

carbon dioxide L in the first tank 11A into the second tank 11B has ended, for example, based on the detection value of the pressure sensor 112. When the detection value of the pressure sensor 112 is equal to or lower than a threshold value set in advance, the transfer of the liquefied carbon dioxide L in the first tank 11A into the second tank 11B through the connection line 15 ends. The determination of whether or not the transfer of the liquefied carbon dioxide L has ended may be performed, for example, based on a liquid level gauge or the like that detects the liquid level in the first tank 11A.

In this manner, after the transfer of the liquefied carbon dioxide L is completed, the liquefied carbon dioxide L transferred from the inside of the first tank 11A to the inside of the second tank 11B is discharged through the second discharge line 13B.

[0058]

(Operations and Effects)

In the tank system 10A, the vessel 1, and the method S10 for transferring the liquefied carbon dioxide according to the first embodiment, the switching unit 120 is capable of switching the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A. Then, in the first return line 17A, the carbon dioxide gas G in the second tank 11B is taken out and heated, and can be returned to the second tank 11B. Therefore, in a case where the pressure in the first tank 11A, which is the transfer destination of the liquefied carbon dioxide L, approaches the triple point, the transfer of the liquefied carbon dioxide L from the second tank 11B to the first tank 11A can be continued without taking out the carbon dioxide gas G from the first tank 11A, which is the transfer destination. Accordingly, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice in the first tank 11A.

[0059]

In addition, in the first embodiment, the first transfer line 16A on a side closer to the second tank 11B than a position, in the first transfer line 16A, to which the second connection pipe 24 is connected also serves as the first return line 17A. Therefore, it is possible to suppress an increase in the number of components.

[0060]

In the first embodiment, the carbon dioxide gas G passing through the first pressure-feed unit 30 is compressed by the compressor 31 and is heated by the heater 32. Accordingly, the temperature of the carbon dioxide gas G can be further increased by the heater 32 in addition to the temperature rise of the carbon dioxide gas G when being compressed by the compressor 31. Therefore, the pressure in the second tank 11B can be increased, and the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B can be increased. As a result, the liquefied carbon dioxide L in the second tank 11B can be satisfactorily transferred into the first tank 11A through the connection line 15.

[0061]

In the first embodiment, the switching unit 120 is capable of switching the transfer of the carbon dioxide gas G by the second transfer line 18A to the return of the carbon dioxide gas G by the second return line 19A. Then, in the second return line 19A, the carbon dioxide gas G in the first tank 11A can be taken out and heated, and can be returned to the first tank 11A. Therefore, in a case where the pressure in the second tank 11B, which is the transfer destination of the liquefied carbon dioxide L, approaches the triple point, the transfer of the liquefied carbon dioxide L from the first tank 11A to the second tank 11B can be continued without taking out the carbon dioxide gas G from the second tank 11B, which is the transfer destination. Accordingly, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while

suppressing the generation of dry ice in the second tank 11B.

[0062]

In addition, in the first embodiment, the first transfer line 16A including the first pressure-feed unit 30 between the position, in the first transfer line 16A, to which the second connection pipe 24 is connected and the position, in the first transfer line 16A, to which the first connection pipe 23 is connected also serves as the second transfer line 18A. Therefore, it is possible to suppress an increase in the number of components.

[0063]

<Second Embodiment>

Hereinafter, a second embodiment of the tank system, the floating body, and the method for transferring liquefied carbon dioxide according to the present disclosure will be described. In the second embodiment described below, only a configuration including a control device differs from the first embodiment. Therefore, the same portions as those in the first embodiment are denoted by the same reference signs and described, and duplicate description is omitted.

FIG. 8 is a diagram showing the tank system according to the second embodiment of the present disclosure.

As shown in FIG. 8, a tank system 10B of the vessel 1 according to the present embodiment includes the first tank 11A, the second tank 11B, the first discharge line 13A, the second discharge line 13B, the transfer pipe unit 20A, and a control device 60.

Each of the first pressure detection unit 111A, the second pressure detection unit 111B, and the pressure sensors 112 to 114 provided in the transfer pipe unit 20A outputs detection signals thereof to the control device 60.

[0064]

(Hardware Configuration Diagram)

FIG. 9 is a diagram showing a hardware configuration of the control device according to the second embodiment of the present disclosure.

As shown in FIG. 9, the control device 60 has a computer including a processor 61 such as a central processing unit (CPU), a read-only memory (ROM) 62, a random-access memory (RAM) 63, a storage 64 such as a hard disk drive (HDD), and a signal transmission/reception module 65. The signal transmission/reception module 65 receives the detection signals from the first pressure detection unit 111A, the second pressure detection unit 111B, and the pressure sensors 112 to 114.

[0065]

(Functional Block Diagram)

FIG. 10 is a functional block diagram of the control unit according to the second embodiment of the present disclosure.

As shown in FIG. 10, the processor 61 of the control device 60 implements each functional configuration of a signal reception unit 70, a switching control unit 71, and a signal output unit 72 by executing a program stored in advance in the ROM 62, the storage 64, or the like.

[0066]

The signal reception unit 70 receives the detection signals from the first pressure detection unit 111A, the second pressure detection unit 111B, and the pressure sensors 112 to 114 through the signal transmission/reception module 65 that is hardware.

[0067]

The switching control unit 71 controls an operation of the switching unit 120 based on the detection results in the first pressure detection unit 111A, the second pressure detection unit 111B, and the pressure sensors 112 to 114.

[0068]

FIG. 11 is a diagram showing a state in which the carbon dioxide gas flows through the first transfer line in the tank system according to the second embodiment of the present disclosure. FIG. 12 is a diagram showing a state in which the carbon dioxide gas flows through the first return line in the tank system according to the second embodiment of the present disclosure.

When the pressure in the first tank 11A detected by the first pressure detection unit 111A is lower than the first threshold value set in advance in a state in which the first transfer line 16A transfers the carbon dioxide gas G in the first tank 11A into the second tank 11B, the switching control unit 71 of the second embodiment causes the switching unit 120 to switch the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A, as shown in FIG. 11. In addition, when the pressure in the second tank 11B has become lower than the second threshold value set in advance in a state in which the first return line 17A takes out the carbon dioxide gas G in the second tank 11B, heat the carbon dioxide G, and returns the carbon dioxide G to the second tank 11B, the switching control unit 71 causes the switching unit 120 to switch the return of the carbon dioxide gas G by the first return line 17A to the transfer of the carbon dioxide gas G by the first transfer line 16A, as shown in FIG. 12.

[0069]

FIG. 13 is a diagram showing a state in which the carbon dioxide gas flows through the second transfer line in the tank system according to the second embodiment of the present disclosure. FIG. 14 is a diagram showing a state in which the carbon dioxide gas flows through the second return line in the tank system according to the second embodiment of the present disclosure.

When the pressure in the second tank 11B detected by the second pressure

detection unit 111B is lower than the first threshold value set in advance in a state in which the second transfer line 18A transfers the carbon dioxide gas G in the second tank 11B into the first tank 11A, the switching control unit 71 causes the switching unit 120 to switch the transfer of the carbon dioxide gas G by the second transfer line 18A to the return of the carbon dioxide gas G by the second return line 19A, as shown in FIG. 13. In addition, when the pressure in the first tank 11A has become lower than the second threshold value set in advance in a state in which the second return line 19A takes out the carbon dioxide gas G in the first tank 11A, heats the carbon dioxide G, and returns the carbon dioxide G to the first tank 11A, the switching control unit 71 causes the switching unit 120 to switch the return of the carbon dioxide gas G by the second return line 19A to the transfer of the carbon dioxide gas G by the second transfer line 18A, as shown in FIG. 14.

[0070]

The signal output unit 72 outputs a command signal for controlling the operations of the switching unit 120 and the compressor 31 to the switching unit 120 and the compressor 31 by the control in the switching control unit 71.

[0071]

(Procedure of Method for Transferring Liquefied Carbon Dioxide)

In the tank system 10B, the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside through the first discharge line 13A and the second discharge line 13B.

In a case where any one of the pump 132A of the first tank 11A or the pump 132B of the second tank 11B fails when the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside, the control device 60 receives a signal indicating that the pump 132A and the pump 132B are not operating normally.

In a case where the control device 60 receives the signal indicating that the pump 132A and the pump 132B are not operating normally, the control device 60 performs control of transferring the liquefied carbon dioxide between the first tank 11A and the second tank 11B in the following procedure based on a program set in advance.

[0072]

As shown in FIG. 7, the method S20 for transferring the liquefied carbon dioxide L in the tank system 10B according to the second embodiment described above includes a step S21 of transferring the liquefied carbon dioxide L, a step S22 of determining whether a pressure in a tank has become lower than a first threshold value, a step S23 of switching from transfer of the carbon dioxide gas G to return of the carbon dioxide gas G, a step S24 of determining whether the pressure in the tank has become higher than a second threshold value, a step S25 of returning the process from return of the carbon dioxide gas G to transfer of the carbon dioxide gas G, and a step S26 of determining whether transfer of the liquefied carbon dioxide L has ended.

[0073]

Hereinafter, for example, a case will be described in which the pump 132B of the second tank 11B fails when the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside.

(Case Where Pump of Second Tank Fails)

In the step S21 of transferring the liquefied carbon dioxide L (hereinafter, simply referred to as step S21), when the pump 132B of the second tank 11B fails, the control device 60 confirms that the available capacity in the second tank 11B is larger than the liquid amount of the liquefied carbon dioxide L in the first tank 11A, and then transfers the liquefied carbon dioxide L in the second tank 11B into the first tank 11A. In this case, as shown in FIG. 11, the carbon dioxide gas G in the first tank 11A is transferred

into the second tank 11B through the first transfer line 16A to pressurize the inside of the second tank 11B. In the step S21, the opening/closing valve 121 is opened, the third opening/closing valve 123 and the fourth opening/closing valve 124 are set to a closed state, the first opening/closing valve 122A and the second opening/closing valve 122B are set to an open state, and the compressor 31 is operated.

[0074]

Then, the first transfer line 16A sucks the carbon dioxide gas G in the first tank 11A and pressurizes the carbon dioxide gas G into the second tank 11B. In this case, the first transfer line 16A pressurizes (compresses) the carbon dioxide gas G by using the compressor 31 and heats the carbon dioxide gas G by using the heater 32 to expand the carbon dioxide gas G in the first tank 11A. Therefore, the pressure in the second tank 11B is increased, and the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B is increased. Due to the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B, the liquefied carbon dioxide L in the second tank 11B is pushed out through the liquid transfer pipe 21 of the connection line 15 and is transferred into the first tank 11A.

[0075]

In the step S22 of determining whether or not the pressure in the tank has become lower than the first threshold value (hereinafter, simply referred to as step S22), the switching control unit 71 monitors the detection value of the first pressure detection unit 111A while the carbon dioxide gas G in the second tank 11B is being transferred into the first tank 11A in the step S21. In the step S22, the switching control unit 71 determines whether or not the pressure in the first tank 11A has become lower than the first threshold value set in advance, based on the detection value of the first pressure detection unit 111A. It is preferable that the first threshold value is set to a triple point

or higher of the carbon dioxide gas.

When the detection value of the first pressure detection unit 111A has not become lower than the first threshold value (No in the step S22), the switching control unit 71 continues the step S21 and repeatedly performs the step S22 at predetermined time intervals.

When the detection value of the first pressure detection unit 111A has become lower than the first threshold value (Yes in the step S22), the switching control unit 71 proceeds to the step S23 of switching the transfer of the carbon dioxide gas G to the return of the carbon dioxide gas G.

[0076]

In the step S23 of switching the transfer of the carbon dioxide gas G to the return of the carbon dioxide gas G (hereinafter, simply referred to as step S23), the switching control unit 71 switches the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A. Specifically, as shown in FIG. 12, the first opening/closing valve 122A and the third opening/closing valve 123 are set to a closed state, and the second opening/closing valve 122B and the fourth opening/closing valve 124 are set to an open state from the state as shown in FIG. 11. As a result, the carbon dioxide gas G in the second tank 11B is sucked by using the compressor 31 through the second connection pipe 24 of the first return line 17A and is supplied to a portion of the first transfer line 16A on a side closer to the first tank 11A than the first pressure-feed unit 30. The carbon dioxide gas G supplied to the first transfer line 16A is pressurized by the compressor 31, heated by the heater 32, and then returned to the second tank 11B. In this manner, the carbon dioxide gas G sucked from the second tank 11B is expanded and returned to the second tank 11B, so that the pressure in the second tank 11B can be increased. By increasing the pressure

in the second tank 11B, the pressure difference between the pressure in the second tank 11B and the pressure in the first tank 11A is secured, and the transfer of the liquefied carbon dioxide L in the second tank 11B into the first tank 11A through the connection line 15 is continued. As a result, the amount of the liquefied carbon dioxide L in the first tank 11A is increased, so that the pressure in the first tank 11A is increased and is suppressed from approaching the triple point.

[0077]

In the step S24 of determining whether or not the pressure in the tank has become higher than the second threshold value (hereinafter, simply referred to as step S24), the switching control unit 71 confirms the pressure in the second tank 11B based on the detection value of the second pressure detection unit 111B, and determines whether or not the pressure has become higher than the second threshold value determined in advance. When the pressure in the second tank 11B has not become higher than the second threshold value set in advance (No in the step S24), the switching control unit 71 continues the step S23.

When the pressure in the second tank 11B has become higher than the second threshold value set in advance (Yes in the step S24), the switching control unit 71 proceeds to the step S25 of returning the process from the return of the carbon dioxide gas G to the transfer of the carbon dioxide gas G.

[0078]

In the step S25 of returning the process from the return of the carbon dioxide gas G to the transfer of the carbon dioxide gas G (hereinafter, simply referred to as step S25), the switching control unit 71 controls the switching unit 120 to return the state shown in FIG. 12 to the state shown in FIG. 11, and transfers the liquefied carbon dioxide L in the second tank 11B into the first tank 11A. In this case, as shown in FIG. 11, the switching

control unit 71 sets the third opening/closing valve 123 and the fourth opening/closing valve 124 to a closed state, and sets the first opening/closing valve 122A and the second opening/closing valve 122B to an open state. Therefore, the carbon dioxide gas G in the first tank 11A can be pressurized by the compressor 31, heated by the heater 32, and then returned to a state of being transferred into the second tank 11B through the first transfer line 16A. As a result, the inside of the second tank 11B is pressurized, and the liquefied carbon dioxide L in the second tank 11B is continuously transferred into the first tank 11A through the connection line 15.

[0079]

In the step S26 of determining whether or not the transfer of the liquefied carbon dioxide L has ended (hereinafter, simply referred to as step S26), the switching control unit 71 determines whether or not the transfer of the liquefied carbon dioxide L in the second tank 11B into the first tank 11A has ended, for example, based on the detection value of the pressure sensor 112. In a case where the detection value of the pressure sensor 112 is equal to or lower than a threshold value set in advance, it can be determined that the transfer of the liquefied carbon dioxide L in the second tank 11B into the first tank 11A through the connection line 15 has ended. The determination of whether or not the transfer of the liquefied carbon dioxide L has ended may be performed, for example, by the switching control unit 71 based on a liquid level gauge or the like that detects the liquid level in the second tank 11B.

In this manner, after the transfer of the liquefied carbon dioxide L has ended, the liquefied carbon dioxide L transferred from the inside of the second tank 11B to the inside of the first tank 11A is discharged through the first discharge line 13A.

[0080]

Here, when the liquefied carbon dioxide L in the first tank 11A is transferred

into the second tank 11B through the liquid transfer pipe 21 of the connection line 15, the control device 60 monitors the detection signal from the first pressure detection unit 111A. In a case where the pressure in the first tank 11A detected by the first pressure detection unit 111A exceeds an upper limit set value set in advance, the control device 60 stops the operation of the compressor 31 to prevent the pressure in the first tank 11A from excessively increasing.

[0081]

(Case Where Pump of First Tank Fails)

FIG. 13 is a diagram showing a state in which the carbon dioxide gas flows through the second transfer line in the tank system according to the second embodiment of the present disclosure.

For example, in a case where the pump 132A of the first tank 11A fails when the liquefied carbon dioxide L in the first tank 11A and the second tank 11B is discharged to the outside, the step S21 is performed, and the liquefied carbon dioxide L in the first tank 11A is transferred into the second tank 11B. In this case, as shown in FIG. 13, the carbon dioxide gas G in the second tank 11B is transferred into the first tank 11A through the second transfer line 18A to pressurize the inside of the first tank 11A. Therefore, the switching control unit 71 opens the opening/closing valve 121, sets the first opening/closing valve 122A and the second opening/closing valve 122B to a closed state, sets the third opening/closing valve 123 and the fourth opening/closing valve 124 to an open state, and operates the compressor 31.

[0082]

Then, the second transfer line 18A sucks the carbon dioxide gas G in the second tank 11B through the second connection pipe 24, pressurizes (compresses) the carbon dioxide gas G, and heats the carbon dioxide gas G to expand the carbon dioxide gas G in

the second tank 11B. Therefore, the pressure in the first tank 11A is increased, and the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B is increased. Due to the pressure difference between the inside of the first tank 11A and the inside of the second tank 11B, the liquefied carbon dioxide L in the first tank 11A is transferred into the second tank 11B through the liquid transfer pipe 21 of the connection line 15.

[0083]

In the step S22, the switching control unit 71 monitors the detection value of the second pressure detection unit 111B while the carbon dioxide gas G in the first tank 11A is being transferred into the second tank 11B in the step S21. In the step S22, the switching control unit 71 determines whether or not the pressure in the second tank 11B has become lower than the first threshold value set in advance, based on the detection value of the second pressure detection unit 111B.

When the detection value of the second pressure detection unit 111B has not become lower than the first threshold value (No in the step S22), the switching control unit 71 continues the step S21 and repeatedly performs the step S22 at predetermined time intervals.

When the detection value of the second pressure detection unit 111B has become lower than the first threshold value (Yes in the step S22), the switching control unit 71 performs the step S23.

[0084]

FIG. 14 is a diagram showing a state in which the carbon dioxide gas flows through the second return line in the tank system according to the second embodiment of the present disclosure.

In the step S23, the switching control unit 71 switches the transfer of the carbon

dioxide gas G by the second transfer line 18A to the return of the carbon dioxide gas G by the second return line 19A as shown in FIG. 14. Specifically, the switching control unit 71 sets the second opening/closing valve 122B and the fourth opening/closing valve 124 to a closed state, and sets the first opening/closing valve 122A and the third opening/closing valve 123 to an open state. As a result, the carbon dioxide gas G in the first tank 11A is sucked by using the compressor 31 through the second return line 19A, pressurized by the compressor 31, heated by the heater 32, and then returned to the first tank 11A. In this manner, the carbon dioxide gas G is expanded and returned to the first tank 11A, so that the pressure in the first tank 11A can be increased. By increasing the pressure in the first tank 11A, the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B is secured, and the transfer of the liquefied carbon dioxide L in the first tank 11A to the second tank 11B through the connection line 15 is continued. As a result, the amount of the liquefied carbon dioxide L in the second tank 11B is increased, so that the pressure in the second tank 11B is increased and is suppressed from approaching the triple point.

[0085]

In the step S24, the switching control unit 71 determines whether or not the pressure in the first tank 11A has become lower than the second threshold value determined in advance, based on the detection values of the first pressure detection unit 111A and the second pressure detection unit 111B.

When the pressure in the first tank 11A has not become higher than the second threshold value set in advance (No in the step S24), the switching control unit 71 continues the step S23.

When the pressure in the first tank 11A has become higher than the second threshold value set in advance (Yes in the step S24), the switching control unit 71

proceeds to the step S25.

[0086]

In the step S25, the switching control unit 71 returns the state shown in FIG. 14 to the state shown in FIG. 13, and transfers the liquefied carbon dioxide L in the first tank 11A into the second tank 11B. In this case, as shown in FIG. 13, the switching control unit 71 sets the first opening/closing valve 122A and the second opening/closing valve 122B to a closed state, and sets the third opening/closing valve 123 and the fourth opening/closing valve 124 to an open state. Therefore, the carbon dioxide gas G in the second tank 11B can be pressurized by the compressor 31 through the second transfer line 18A, heated by the heater 32, and then returned to a state of being transferred into the first tank 11A. As a result, the inside of the first tank 11A is pressurized, and the liquefied carbon dioxide L in the first tank 11A is continuously transferred into the second tank 11B through the connection line 15.

[0087]

In the step S26, the switching control unit 71 determines whether or not the transfer of the liquefied carbon dioxide L in the first tank 11A into the second tank 11B has ended, for example, based on the detection value of the pressure sensor 112. When the detection value of the pressure sensor 112 is equal to or lower than a threshold value set in advance, the transfer of the liquefied carbon dioxide L in the first tank 11A into the second tank 11B through the connection line 15 ends. The determination of whether or not the transfer of the liquefied carbon dioxide L has ended may be performed, for example, based on a liquid level gauge or the like that detects the liquid level in the first tank 11A.

In this manner, after the transfer of the liquefied carbon dioxide L is completed, the liquefied carbon dioxide L transferred from the inside of the first tank 11A to the

inside of the second tank 11B is discharged through the second discharge line 13B.

[0088]

When the liquefied carbon dioxide L in the second tank 11B is transferred into the first tank 11A through the liquid transfer pipe 21 of the connection line 15, the control device 60 monitors the detection signal from the second pressure detection unit 111B. In a case where the pressure in the second tank 11B detected by the second pressure detection unit 111B exceeds an upper limit set value set in advance, the control device 60 stops the operation of the compressor 31 to prevent the pressure in the second tank 11B from excessively increasing.

[0089]

Further, the control device 60 monitors the detection signals from the pressure sensors 113 and 114 during the operation of the compressor 31. The control device 60 stops the operation of the compressor 31 when a ratio between the inlet pressure of the compressor 31 detected by the pressure sensor 113 and the outlet pressure of the compressor 31 detected by the pressure sensor 114 becomes an abnormal value. In this case, the control device 60 may close the first opening/closing valve 122A, the second opening/closing valve 122B, the third opening/closing valve 123, and the fourth opening/closing valve 124 to maintain the differential pressure between the first tank 11A and the second tank 11B. Accordingly, a start-up time of the compressor 31 can be shortened during recovery.

[0090]

(Operations and Effects)

In the tank system 10B, the vessel 1, and the method S20 for transferring liquefied carbon dioxide of the second embodiment, in addition to the operations and effects of the first embodiment, when the pressure in the first tank 11A has become lower

than the first threshold value, the control device 60 can automatically switch the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A. Similarly, when the pressure in the second tank 11B has become lower than the first threshold value, the control device 60 can automatically switch the transfer of the carbon dioxide gas G by the second transfer line 18A to the return of the carbon dioxide gas G by the second return line 19A. Therefore, as in the first embodiment, in a case where the pressure in the first tank 11A or the pressure in the second tank 11B, which is the transfer destination, approaches the triple point, the transfer of the liquefied carbon dioxide L using the pressure difference between the tanks can be automatically continued while the take-out of the carbon dioxide gas G from the first tank 11A or the second tank 11B, which is the transfer destination, is automatically stopped. Therefore, it is possible to reduce a burden on the operator while enabling rapid transfer of liquefied carbon dioxide L.

[0091]

Further, in the second embodiment, when the pressure in the second tank 11B has become lower than the second threshold value, the control device 60 can automatically switch the return of the carbon dioxide gas G by the first return line 17A to the transfer of the carbon dioxide gas G by the first transfer line 16A. Accordingly, it is possible to further reduce the burden on the operator.

[0092]

(First Modification Example of Embodiment)

In each of the above embodiments, the transfer pipe unit 20A includes one set of the first pressure-feed unit 30 (compressor 31 and heater 32), and the first pressure-feed unit 30 is shared by the first transfer line 16A and the first return line 17A. However, the present disclosure is not limited thereto.

FIG. 15 is a diagram showing a tank system according to a first modification example of the embodiment of the present disclosure.

As shown in FIG. 15, a transfer pipe unit 20C of a tank system 10C transfers the liquefied carbon dioxide L in the second tank 11B into the first tank 11A, for example, in a case where the pump 132B of the second discharge line 13B cannot be used due to a failure or the like. The transfer pipe unit 20C includes a first transfer line 16C, a first return line 17C, and a switching unit 120C.

[0093]

The first transfer line 16C is capable of transferring the carbon dioxide gas G in the first tank 11A into the second tank 11B. The first transfer line 16C includes the gas transfer pipe 22 and the first pressure-feed unit 30. The first pressure-feed unit 30 includes the compressor 31 and the heater 32. The first transfer line 16C is provided with the first opening/closing valve 122A and the second opening/closing valve 122B as the switching unit 120C. The first opening/closing valve 122A is provided between one end 22a of the gas transfer pipe 22 and the compressor 31. The second opening/closing valve 122B is provided between the heater 32 and the other end 22b of the gas transfer pipe 22.

[0094]

In order to cause the carbon dioxide gas to flow through the first transfer line 16C, the first opening/closing valve 122A and the second opening/closing valve 122B are set to an open state, and the compressor 31 is operated. The first transfer line 16C sucks the carbon dioxide gas G in the first tank 11A by using the compressor 31 and pressurizes the carbon dioxide gas G into the second tank 11B. The first transfer line 16C pressurizes (compresses) the carbon dioxide gas G by using the compressor 31 and heats the carbon dioxide gas G by using the heater 32 to expand the carbon dioxide gas G in

the first tank 11A and transfer the carbon dioxide gas G into the second tank 11B. By transferring the carbon dioxide gas G expanded in this manner into the second tank 11B, a pressure in the second tank 11B increases.

[0095]

The first return line 17C can return the carbon dioxide gas G in the second tank 11B to the second tank 11B. The first return line 17C includes a first circulation pipe 201 and a second pressure-feed unit 200.

[0096]

The first circulation pipe 201 can return the carbon dioxide gas G in the second tank 11B to the second tank 11B via a path outside the second tank 11B. The first circulation pipe 201 is independently provided outside the second tank 11B separately from the first transfer line 16C. Each of one end 201a and the other end 201b of the first circulation pipe 201 is connected to the upper portion of the second tank 11B.

[0097]

The second pressure-feed unit 200 is provided partway along the first circulation pipe 201. The second pressure-feed unit 200 includes a compressor 231 and a heater 232. The first return line 17C is provided with a fifth opening/closing valve 212A and a sixth opening/closing valve 212B as the switching unit 120C. The fifth opening/closing valve 212A is provided between one end 201a of the first circulation pipe 201 and the compressor 231. The sixth opening/closing valve 212B is provided between the heater 232 and the other end 201b of the first circulation pipe 201.

[0098]

In order to cause the carbon dioxide gas to flow through the first return line 17C, the fifth opening/closing valve 212A and the sixth opening/closing valve 212B are set to an open state, and the compressor 231 is operated. The first return line 17C sucks and

pressurizes the carbon dioxide gas G in the second tank 11B by using the compressor 231 and returns the carbon dioxide gas G to the second tank 11B. The first return line 17C pressurizes (compresses) the carbon dioxide gas G by using the compressor 231 and heats the carbon dioxide gas G by using the heater 232 to expand the carbon dioxide gas G in the second tank 11B and return the carbon dioxide gas G to the second tank 11B. By returning the carbon dioxide gas G expanded in this way to the second tank 11B, the pressure in the second tank 11B is increased.

[0099]

The switching unit 120C includes the first opening/closing valve 122A, the second opening/closing valve 122B, a fifth opening/closing valve 222A, and a sixth opening/closing valve 222B. The switching unit 120C switches the flow mode (flow path) of the carbon dioxide gas in the transfer pipe unit 20C by opening and closing the first opening/closing valve 122A, the second opening/closing valve 122B, the fifth opening/closing valve 222A, and the sixth opening/closing valve 222B. The switching unit 120C can switch between the transfer of the carbon dioxide gas G by the first transfer line 16C and the return of the carbon dioxide gas G by the first return line 17C.

[0100]

FIG. 15 only shows the configuration for transferring the carbon dioxide gas G from the first tank 11A to the second tank 11B, but a configuration for transferring the carbon dioxide gas G from the second tank 11B to the first tank 11A may be similarly provided.

[0101]

With such a configuration, the first return line 17C includes the first circulation pipe 201 and the second pressure-feed unit 200 separately from the first pressure-feed unit 30, so that the carbon dioxide gas G in the second tank 11B can be taken out, heated,

and returned to the second tank 11B. Therefore, the pressure in the second tank 11B is increased, the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B is increased, and the liquefied carbon dioxide L inside the second tank 11B can be sent to the inside of the first tank 11A through the connection line 15. In such a configuration as well, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice.

[0102]

(Second Modification Example of Embodiment)

FIG. 16 is a diagram showing a tank system according to a modification example of the embodiment of the present disclosure.

As shown in FIG. 16, a transfer pipe unit 20D of a tank system 10D transfers the liquefied carbon dioxide L in the second tank 11B into the first tank 11A, for example, in a case where the pump 132B of the second discharge line 13B cannot be used due to a failure or the like.

The transfer pipe unit 20D according to the second modification example includes a bypass pipe 301 partway along the gas transfer pipe 22 constituting the first transfer line 16D. The bypass pipe 301 is provided partway along the gas transfer pipe 22 to bypass the compressor 31A and the heater 32A. The bypass pipe 301 is connected to the gas transfer pipe 22 between one end 22a of the gas transfer pipe 22 and the first opening/closing valve 122A through a coupling pipe 302. The bypass pipe 301 is connected to the gas transfer pipe 22 between the other end 22b of the gas transfer pipe 22 and the second opening/closing valve 122B through a coupling pipe 303.

[0103]

A compressor 31B and a heater 32B are provided partway along the bypass pipe 301. A first opening/closing valve 322A as the switching unit 120D is provided

between a position where the bypass pipe 301 is connected to the coupling pipe 302 and the compressor 31B. A second opening/closing valve 322B as the switching unit 120D is provided between a position where the bypass pipe 301 is connected to the coupling pipe 303 and the heater 32B.

In addition, an opening/closing valve 323 as the switching unit 120D is provided partway along the coupling pipe 302. An opening/closing valve 324 as the switching unit 120D is provided partway along the coupling pipe 303.

[0104]

The compressor 31B and the heater 32B provided in the bypass pipe 301 are provided as spares for the compressor 31A and the heater 32A provided in the gas transfer pipe 22 of the first transfer line 16D. In a case where at least one of the compressor 31A and the heater 32A provided in the gas transfer pipe 22 cannot be used due to a failure, maintenance, or the like, the first opening/closing valve 122A and the second opening/closing valve 122B are set to a closed state, and the first opening/closing valve 322A, the second opening/closing valve 322B, and the opening/closing valves 323 and 324 are set to an open state. As a result, the first transfer line 16D causes the carbon dioxide gas G to pass through the compressor 31B and the heater 32B provided in the bypass pipe 301, and pressure-feeds and heats the carbon dioxide gas G.

[0105]

The transfer pipe unit 20D according to the present modification example further includes a first connection pipe 333 and a second connection pipe 334. One end 333a of the first connection pipe 333 is connected to the upper portion of the first tank 11A. The other end 333b of the first connection pipe 333 is connected between the first opening/closing valve 322A and the opening/closing valve 323. An opening/closing valve 325 as the switching unit 120D is provided partway along the first connection pipe

333. One end 334a of the second connection pipe 334 is connected to the upper portion of the second tank 11B. The other end 334b of the second connection pipe 334 is connected, at the other end of the bypass pipe 301, between the second opening/closing valve 322B and the opening/closing valve 324. An opening/closing valve 326 as the switching unit 120D is provided partway along the second connection pipe 334.

[0106]

In such a transfer pipe unit 20D, the first return line 17D is configured by closing the first opening/closing valve 122A, the second opening/closing valve 122B, and the opening/closing valves 323 and 324, and opening the first opening/closing valve 322A, the second opening/closing valve 322B, and the opening/closing valves 325 and 326. The first return line 17D sucks out the carbon dioxide gas G in the second tank 11B through the first connection pipe 333 by using the compressor 31B. The sucked carbon dioxide gas G is pressure-fed and heated by the compressor 31B and the heater 32B as the second pressure-feed unit 300 provided in the bypass pipe 301, and is returned into the second tank 11B through the second connection pipe 334.

According to the second modification example, the compressor 31B and the heater 32B provided as spares can be effectively used to configure the first return line 17D.

[0107]

(Other Embodiments)

The embodiments of the present disclosure have been described above in detail with reference to the drawings. However, a specific configuration is not limited to the embodiment, and design modifications and the like within a scope not departing from the gist of the present disclosure are also included.

In the above-described embodiment, in the steps S14 and S24 of determining

whether or not the pressure in the tank has become higher than the second threshold value, when the pressure in the tank has become higher than the second threshold value set in advance, the process is returned from the return of the carbon dioxide gas G to the transfer of the carbon dioxide gas G. However, the present disclosure is not limited thereto. For example, in the steps S14 and S24, the pressure difference between the pressure in the second tank 11B and the pressure in the first tank 11A may be confirmed based on the detection values of the first pressure detection unit 111A and the second pressure detection unit 111B, and when the pressure difference has become lower than the reference differential pressure determined in advance, the process may be returned from the return of the carbon dioxide gas G to the transfer of the carbon dioxide gas G.

[0108]

In addition, in the above-described embodiment, the configurations of the tank systems 10A to 10D have been described, but the configuration of each unit can be changed as appropriate.

In addition, in the above-described embodiment, the configuration of the hull 2 has been described, but the configuration of each unit can be changed as appropriate.

[0109]

In addition, in the above-described embodiment, the configuration has been adopted in which the tank systems 10A to 10D are provided in the vessel 1. However, the tank systems 10A to 10D may be provided in a floating body main body of an offshore floating facility, a liquefied gas storage facility on land, or the like.

[0110]

<Supplementary Note>

The tank systems 10A to 10D, the floating body 1, and the method for transferring the liquefied carbon dioxide L described in each embodiment are understood,

for example, as follows.

[0111]

(1) A tank system 10A to 10D according to a first aspect including: a first tank 11A and a second tank 11B configured to store liquefied carbon dioxide L; a first discharge line 13A configured to discharge the liquefied carbon dioxide L in the first tank 11A to a location outside of the first tank 11A; a connection line 15 connecting an interior of the first tank 11A and an interior of the second tank 11B; a first transfer line 16A, 16C configured to transfer carbon dioxide gas G in the first tank 11A into the second tank 11B; a first return line 17A, 17C configured to take out carbon dioxide gas G in the second tank 11B, heat the carbon dioxide gas G, and return the carbon dioxide gas G to the second tank 11B; and a switching unit 120 configured to switch between transfer of the carbon dioxide gas G by the first transfer line 16A, 16C and return of the carbon dioxide gas G by the first return line 17A, 17C.

[0112]

The tank systems 10A to 10D can discharge the liquefied carbon dioxide L in the first tank 11A to a location outside of the first tank 11A through the first discharge line 13A. When the liquefied carbon dioxide L in the second tank 11B cannot be discharged to a location outside of the second tank 11B, the carbon dioxide gas G in the first tank 11A is transferred into the second tank 11B through the first transfer lines 16A and 16C. Therefore, the pressure in the second tank 11B increases, and a differential pressure is generated between the pressure in the first tank 11A and the pressure in the second tank 11B. Due to the differential pressure between the pressure in the first tank 11A and the pressure in the second tank 11B, the liquefied carbon dioxide L inside the second tank 11B is sent to the inside of the first tank 11A through the connection line 15. In a case where the pressure in the first tank 11A approaches the triple point, the switching unit

120 switches the transfer of the carbon dioxide gas G by the first transfer lines 16A and 16C to the return of the carbon dioxide gas G by the first return lines 17A and 17C. In the first return lines 17A and 17C, the carbon dioxide gas G in the second tank 11B is taken out and heated, and is returned to the second tank 11B. As a result, the pressure in the second tank 11B increases, the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B increases, and the liquefied carbon dioxide L inside the second tank 11B is sent to the inside of the first tank 11A through the connection line 15. In this manner, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice.

[0113]

(2) The tank system 10A, 10B according to a second aspect is the tank system 10A, 10B according to (1), in which the first transfer line 16A includes a first pressure-feed unit 30 configured to pressure-feed the carbon dioxide gas G into the second tank 11B by using a compressor 31, the first return line 17A includes a first gas discharge pipe 24 configured to supply the carbon dioxide gas G in the second tank 11B to a portion of the first transfer line 16A on a side closer to the first tank 11A than the first pressure-feed unit 30, and a portion of the first transfer line 16A on a side closer to the second tank 11B than a position, in the first transfer line 16A, to which the first gas discharge pipe 24 is connected also serves as the first return line 17A.

[0114]

Accordingly, a portion of the first transfer line 16A on a side closer to the second tank 11B than a position, in the first transfer line 16A, to which the first gas discharge pipe 24 is connected also serves as the first return line 17A. Therefore, the carbon dioxide gas G that passes through the first transfer line 16A and that is transferred from the first tank 11A toward the second tank 11B is pressure-fed by the first pressure-feed

unit 30. Further, the carbon dioxide gas G that is taken out from the second tank 11B and returned to the second tank 11B through the first return line 17A is pressure-fed by the first pressure-feed unit 30. In this manner, the first pressure-feed unit 30 can be shared between the first transfer line 16A and the first return line 17A, and an increase in equipment cost can be suppressed.

[0115]

(3) The tank system 10A, 10B according to a third aspect is the tank system 10A, 10B according to (2), in which the first pressure-feed unit 30 includes a compressor 31 configured to compress the carbon dioxide gas G and a heater 32 configured to heat the carbon dioxide gas G.

[0116]

Therefore, the carbon dioxide gas G passing through the first pressure-feed unit 30 is compressed by the compressor 31 and is heated by the heater 32 to expand. By expanding the carbon dioxide gas G by the first pressure-feed unit 30, the pressure in the second tank 11B can be increased, and the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B can be increased. Therefore, the liquefied carbon dioxide L in the second tank 11B can be satisfactorily transferred into the first tank 11A through the connection line 15.

[0117]

(4) The tank system 10C according to a fourth aspect is the tank system 10C according to (1), in which the first transfer line 16C includes a first pressure-feed unit 30C configured to pressure-feed the carbon dioxide gas G into the second tank 11B by using a compressor 31, and the first return line 17C includes a first circulation pipe 201 configured to return the carbon dioxide gas G in the second tank 11B to the interior of the second tank 11B through a path outside the second tank 11B, and a second pressure-feed

unit 200 provided partway along the first circulation pipe 201 and configured to pressure-feed the carbon dioxide gas G in the second tank 11B by using the compressor 31 and return the carbon dioxide gas G to the second tank 11B.

[0118]

Therefore, by providing the first circulation pipe 201 and the second pressure-feed unit 200 in the first return line 17C separately from the first pressure-feed unit 30C, the carbon dioxide gas G in the second tank 11B can be taken out, heated, and returned to the second tank 11B. Therefore, the pressure in the second tank 11B is increased, the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B is increased, and the liquefied carbon dioxide L inside the second tank 11B can be sent to the inside of the first tank 11A through the connection line 15. In such a configuration as well, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice.

[0119]

(5) The tank system 10C according to a fifth aspect is the tank system 10C according to (4), in which at least one of the first pressure-feed unit 30C and the second pressure-feed unit 200 includes a compressor 31 configured to compress the carbon dioxide gas G and a heater 32 configured to heat the carbon dioxide gas G.

[0120]

Therefore, the carbon dioxide gas G passing through at least one of the first pressure-feed unit 30C and the second pressure-feed unit 200 is compressed by the compressor 31 and is heated by the heater 32 to expand. Therefore, the carbon dioxide gas G can be expanded to increase the pressure in the second tank 11B, and the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B can be increased.

[0121]

(6) The tank system 10A, 10B according to a sixth aspect is the tank system 10A, 10B according to any one of (1) to (5), further including: a second discharge line 13B configured to discharge the liquefied carbon dioxide L in the second tank 11B to a location outside of the second tank 11B; a second transfer line 18A configured to transfer the carbon dioxide gas G in the second tank 11B into the first tank 11A; and a second return line 19A configured to take out the carbon dioxide gas G in the first tank 11A, heat the carbon dioxide gas G, and return the carbon dioxide gas G to the first tank 11A, in which the switching unit 120 is configured to switch between transfer of the carbon dioxide gas G by the second transfer line 18A and return of the carbon dioxide gas G by the second return line 19A.

[0122]

Therefore, the liquefied carbon dioxide L in the second tank 11B can be discharged to a location outside of the second tank 11B through the second discharge line 13B. In a case where the liquefied carbon dioxide L in the first tank 11A cannot be discharged to a location outside of the first tank 11A, the carbon dioxide gas G in the second tank 11B is transferred into the first tank 11A through the second transfer line 18A. Therefore, the pressure in the first tank 11A increases, and the pressure difference between the pressure in the second tank 11B and the pressure in the first tank 11A increases. The liquefied carbon dioxide L inside the first tank 11A is sent to the inside of the second tank 11B through the connection line 15 due to the pressure difference between the pressure in the second tank 11B and the pressure in the first tank 11A. Further, in a case where the pressure in the second tank 11B approaches the triple point, the switching unit 120 switches the transfer of the carbon dioxide gas G by the second transfer line 18A to the return of the carbon dioxide gas G by the second return line 19A.

In the second return line 19A, the carbon dioxide gas G in the first tank 11A is taken out and heated, and is returned to the first tank 11A. Therefore, the pressure in the first tank 11A increases, the pressure difference between the pressure in the second tank 11B and the pressure in the first tank 11A increases, and the liquefied carbon dioxide L inside the first tank 11A is sent to the inside of the second tank 11B through the connection line 15. In this manner, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice.

[0123]

(7) The tank system 10A, 10B according to a seventh aspect is the tank system 10A, 10B according to (6), in which the first transfer line 16A includes a first pressure-feed unit 30 configured to pressure-feed the carbon dioxide gas G into the second tank 11B by using a compressor 31, the first return line 17A includes a first gas discharge pipe 24 configured to supply the carbon dioxide gas G in the second tank 11B to a portion of the first transfer line 16A on a side closer to the first tank 11A than the first pressure-feed unit 30, the second return line 19A includes a return pipe 23 configured to return the carbon dioxide gas G pressure-fed by the first pressure-feed unit 30 into the first tank 11A, and the second transfer line 18A includes the first gas discharge pipe 24 of the first return line 17A, the return pipe 23 of the second return line 19A, and the first transfer line 16A including the first pressure-feed unit 30 between a position, in the first transfer line 16A, to which the first gas discharge pipe 24 is connected and a position, in the first transfer line 16A, to which the return pipe 23 is connected.

[0124]

Accordingly, the first transfer line 16A including the first pressure-feed unit 30 between the position, in the first transfer line 16A, to which the first gas discharge pipe 24 is connected and the position, in the first transfer line 16A, to which the return pipe 23

is connected also serves as the second transfer line 18A. The carbon dioxide gas G that passes through the second transfer line 18A and that is transferred from the second tank 11B toward the first tank 11A is pressure-fed by the first pressure-feed unit 30. In addition, the carbon dioxide gas G that is taken out from the first tank 11A and that is returned to the first tank 11A through the second transfer line 18A is pressure-fed by the first pressure-feed unit 30. In this manner, the first pressure-feed unit 30 can be shared between the first transfer line 16A and the second transfer line 18A, and an increase in equipment cost can be suppressed.

[0125]

(8) The tank system 10B according to a eighth aspect is the tank system 10B according to any one of (1) to (7), further including: a control device 60 configured to control an operation of the switching unit 120; and a first pressure detection unit 111A configured to detect a pressure in the first tank 11A, in which the control device 60 is configured to cause the switching unit 120 to switch from the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A, when the pressure in the first tank 11A detected by the first pressure detection unit 111A becomes lower than a preset first threshold value in a state in which the first transfer line 16A transfers the carbon dioxide gas G in the first tank 11A into the second tank 11B.

[0126]

Accordingly, when the pressure in the first tank 11A has become lower than the first threshold value, the control device 60 can automatically switch the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A.

[0127]

(9) The tank system 10B according to a ninth aspect is the tank system 10B according to (8), further including a second pressure detection unit 111B configured to detect a pressure in the second tank 11B, in which the control device 60 is configured to cause the switching unit 120 to switch from the return of the carbon dioxide gas G by the first return line 17A to the transfer of the carbon dioxide gas G by the first transfer line 16A, when the pressure in the second tank 11B detected by the second pressure detection unit 111B becomes lower than a preset second threshold value in a state in which the first return line 17A takes out the carbon dioxide gas G in the second tank 11B, heats the carbon dioxide gas G, and returns the carbon dioxide gas G to the second tank 11B.

[0128]

Accordingly, when the pressure in the second tank 11B has become lower than the second threshold value, the return of the carbon dioxide gas G by the first return line 17A can be automatically switched to the transfer of the carbon dioxide gas G by the first transfer line 16A.

[0129]

(10) A floating body 1 according to a tenth aspect including: a floating body main body 2; and the tank system 10A, 10B according to any one of (1) to (9) provided on the floating body main body 2.

[0130]

With such a configuration, it is possible to provide the floating body 1 including the tank system 10A or 10B capable of rapidly transferring the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice.

Examples of the floating body 1 include a vessel or an offshore floating facility. Examples of the floating body main body 2 include a hull or a floating body main body 2 of an offshore floating facility.

[0131]

(11) A method for transferring liquefied carbon dioxide according to an eleventh aspect is the method S10, S20 for transferring liquefied carbon dioxide L in the tank system 10A, 10B according to any one of (1) to (9), the method including: a step S11, S21 of transferring the carbon dioxide gas G in the first tank 11A into the second tank 11B through the first transfer line 16A to increase a pressure in the second tank 11B, and transferring the liquefied carbon dioxide L in the second tank 11B into the first tank 11A through the connection line 15 by a pressure difference between the pressure in the second tank 11B and a pressure in the first tank 11A; and a step S13, S23 of switching from the transfer of the carbon dioxide gas G by the first transfer line 16A to the return of the carbon dioxide gas G by the first return line 17A, when the pressure in the first tank 11A becomes lower than a preset first threshold value in a state in which the carbon dioxide gas G in the first tank 11A is transferred into the second tank 11B.

[0132]

In the method S10, S20 for transferring the liquefied carbon dioxide L, when the pressure in the second tank 11B has become lower than the first threshold value set in advance in a state in which the carbon dioxide gas G in the second tank 11B is transferred into the first tank 11A, the transfer of the carbon dioxide gas G by the first transfer line 16A is switched to the return of the carbon dioxide gas G by the first return line 17A. Therefore, the pressure in the second tank 11B increases, the pressure difference between the pressure in the first tank 11A and the pressure in the second tank 11B increases, and the liquefied carbon dioxide L inside the second tank 11B is sent to the inside of the first tank 11A through the connection line 15. In this manner, it is possible to rapidly transfer the liquefied carbon dioxide L in the tank to the outside while suppressing the generation of dry ice.

INDUSTRIAL APPLICABILITY

[0133]

With the tank system, the floating body, and the method for transferring liquefied carbon dioxide according to the present disclosure, it is possible to rapidly transfer the liquefied carbon dioxide in the tank to the outside while suppressing the generation of dry ice.

REFERENCE SIGNS LIST

[0134]

1 Vessel (floating body)

2 Hull (floating body main body)

2a Bow

2b Stern

3A, 3B Side shell

5 Upper deck

7 Superstructure

8 Cargo loading section

10A to 10D Tank system

11A First tank

11B Second tank

13A First discharge line

13B Second discharge line

15 Connection line

16A, 16C, 16D First transfer line

17A, 17C, 17D First return line

18A Second transfer line

19A Second return line

20A, 20C, 20D Transfer pipe unit

21 Liquid transfer pipe

21a One end

21b Other end

22 Gas transfer pipe

22a One end

22b Other end

23 First connection pipe (return pipe)

23a One end

23b Other end

24 Second connection pipe (first gas discharge pipe)

24a One end

24b Other end

30, 30C First pressure-feed unit

31, 31A, 31B Compressor

32, 32A, 32B Heater

60 Control device

61 Processor

62 ROM

63 RAM

64 Storage

65 Signal transmission/reception module

70 Signal reception unit

71 Switching control unit

72 Signal output unit

111A First pressure detection unit

111B Second pressure detection unit

112 to 114 Pressure sensor

120, 120C, 120D Switching unit

121 Opening/closing valve

122A First opening/closing valve

122B Second opening/closing valve

123 Third opening/closing valve

124 Fourth opening/closing valve

131A, 131B Unloading pipe

132A, 132B Pump

200, 300 Second pressure-feed unit

201 First circulation pipe

201a One end

201b Other end

212A, 222A Fifth opening/closing valve

212B, 222B Sixth opening/closing valve

231 Compressor

232 Heater

301 Bypass pipe

302, 303 Coupling pipe

322A First opening/closing valve

322B Second opening/closing valve

323 to 326 Opening/closing valve

333 First connection pipe

333a One end

333b Other end

334 Second connection pipe

334a One end

334b Other end

G Carbon dioxide gas

L Liquefied carbon dioxide

CLAIMS

[Claim 1] A tank system comprising:

a first tank and a second tank configured to store liquefied carbon dioxide;

a first discharge line configured to discharge the liquefied carbon dioxide in the first tank to a location outside of the first tank;

a connection line connecting an interior of the first tank and an interior of the second tank;

a first transfer line configured to transfer carbon dioxide gas in the first tank into the second tank;

a first return line configured to take out carbon dioxide gas in the second tank, heat the carbon dioxide gas, and return the carbon dioxide gas to the second tank; and

a switching unit configured to switch between transfer of the carbon dioxide gas by the first transfer line and return of the carbon dioxide gas by the first return line.

[Claim 2] The tank system according to Claim 1,

wherein the first transfer line includes a first pressure-feed unit configured to pressure-feed the carbon dioxide gas into the second tank by using a compressor,

the first return line includes a first gas discharge pipe configured to supply the carbon dioxide gas in the second tank to a portion of the first transfer line on a side closer to the first tank than the first pressure-feed unit, and

a portion of the first transfer line on a side closer to the second tank than a position, in the first transfer line, to which the first gas discharge pipe is connected also serves as the first return line.

[Claim 3] The tank system according to Claim 2,

wherein the first pressure-feed unit includes a compressor configured to compress the carbon dioxide gas and a heater configured to heat the carbon dioxide gas.

[Claim 4] The tank system according to Claim 1,

wherein the first transfer line includes a first pressure-feed unit configured to pressure-feed the carbon dioxide gas into the second tank by using a compressor, and

the first return line includes

a first circulation pipe configured to return the carbon dioxide gas in the second tank to the interior of the second tank through a path outside the second tank, and

a second pressure-feed unit provided partway along the first circulation pipe and configured to pressure-feed the carbon dioxide gas in the second tank by using a compressor and return the carbon dioxide gas to the second tank.

[Claim 5] The tank system according to Claim 4,

wherein at least one of the first pressure-feed unit and the second pressure-feed unit includes a compressor configured to compress the carbon dioxide gas and a heater configured to heat the carbon dioxide gas.

[Claim 6] The tank system according to Claim 1, further comprising:

a second discharge line configured to discharge the liquefied carbon dioxide in the second tank to a location outside of the second tank;

a second transfer line configured to transfer the carbon dioxide gas in the second tank into the first tank; and

a second return line configured to take out the carbon dioxide gas in the first tank, heat the carbon dioxide gas, and return the carbon dioxide gas to the first tank,

wherein the switching unit is configured to switch between transfer of the carbon dioxide gas by the second transfer line and return of the carbon dioxide gas by the second return line.

[Claim 7] The tank system according to Claim 6,

wherein the first transfer line includes a first pressure-feed unit configured to

pressure-feed the carbon dioxide gas into the second tank by using a compressor,

the first return line includes a first gas discharge pipe configured to supply the carbon dioxide gas in the second tank to a portion of the first transfer line on a side closer to the first tank than the first pressure-feed unit,

the second return line includes a return pipe configured to return the carbon dioxide gas pressure-fed by the first pressure-feed unit into the first tank, and

the second transfer line includes the first gas discharge pipe of the first return line, the return pipe of the second return line, and the first transfer line including the first pressure-feed unit between a position, in the first transfer line, to which the first gas discharge pipe is connected and a position, in the first transfer line, to which the return pipe is connected.

[Claim 8] The tank system according to Claim 1 or 2, further comprising:

a control device configured to control an operation of the switching unit; and

a first pressure detection unit configured to detect a pressure in the first tank,

wherein the control device is configured to cause the switching unit to switch from the transfer of the carbon dioxide gas by the first transfer line to the return of the carbon dioxide gas by the first return line, when the pressure in the first tank detected by the first pressure detection unit becomes lower than a preset first threshold value in a state in which the first transfer line transfers the carbon dioxide gas in the first tank into the second tank.

[Claim 9] The tank system according to Claim 8, further comprising:

a second pressure detection unit configured to detect a pressure in the second tank,

wherein the control device is configured to cause the switching unit to switch from the return of the carbon dioxide gas by the first return line to the transfer of the

carbon dioxide gas by the first transfer line, when the pressure in the second tank detected by the second pressure detection unit becomes higher than a preset second threshold value in a state in which the first return line takes out the carbon dioxide gas in the second tank, heats the carbon dioxide gas, and returns the carbon dioxide gas to the second tank.

[Claim 10] A floating body comprising:

a floating body main body; and

the tank system according to Claim 1 or 2 provided on the floating body main body.

[Claim 11] A method for transferring liquefied carbon dioxide in the tank system according to Claim 1 or 2, the method comprising:

a step of transferring the carbon dioxide gas in the first tank into the second tank through the first transfer line to increase a pressure in the second tank, and transferring the liquefied carbon dioxide in the second tank into the first tank through the connection line by a pressure difference between the pressure in the second tank and a pressure in the first tank; and

a step of switching from the transfer of the carbon dioxide gas by the first transfer line to the return of the carbon dioxide gas by the first return line, when the pressure in the first tank becomes lower than a preset first threshold value in a state in which the carbon dioxide gas in the first tank is transferred into the second tank.