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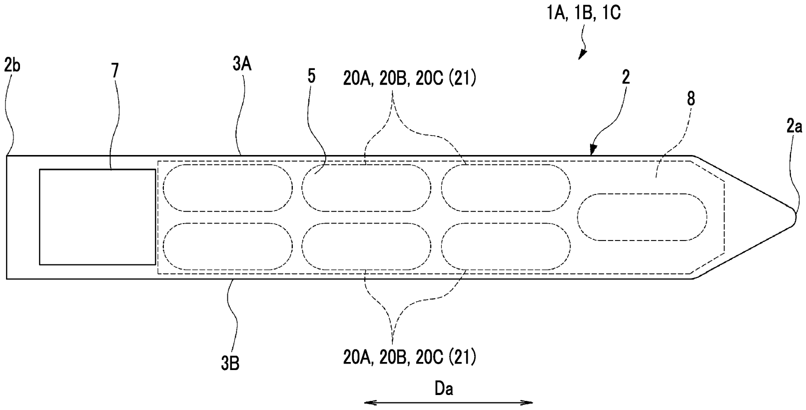
(54) TANK SYSTEM AND SHIP

(57) A tank system comprises a tank, a loading pipe, and a pipe pressure resistance part. The tank holds liquefied carbon dioxide. The loading pipe extends in a vertical direction, and a bottom end thereof opens into the tank. The loading pipe discharges the liquefied carbon dioxide, which is supplied from the exterior, into the tank from the bottom end. The pipe pressure resistance part is provided closer to the bottom end of the loading pipe than a pipe top part located at the highest point of the loading pipe. The pipe pressure resistance part produces pressure loss in the liquefied carbon dioxide flowing through the loading pipe.

FIG. 1



EP 4 059 828 A1

Description

Technical Field

[0001] The present disclosure relates to a tank system and a ship.

[0002] This application claims the right of priority based on Japanese Patent Application No. 2019-231720 filed with the Japan Patent Office on December 22, 2019, the content of which is incorporated herein by reference.

Background Art

[0003] PTL 1 discloses loading a liquefied gas such as LNG (Liquefied Natural Gas) into a tank through a gas loading pipe system.

Citation List

Patent Literature

[0004] [PTL 1] Japanese Patent No. 5769445

Summary of Invention

Technical Problem

[0005] Incidentally, there is a demand for carrying liquefied carbon dioxide by using a tank as in PTL 1. In the liquefied carbon dioxide, the pressure of a triple point (hereinafter referred to as triple point pressure) at which a gas phase, a liquid phase, and a solid phase coexist is higher than the triple point pressure of LNG or LPG. Therefore, the triple point pressure becomes close to the operating pressure of the tank. In a case where the liquefied carbon dioxide is contained in the tank, for the following reasons, there is a possibility that the liquefied carbon dioxide may be solidified to generate dry ice.

[0006] In the tank containing the liquefied gas as in PTL 1, there is a case where a lower end of a loading pipe, which is open in the tank, is disposed at a lower portion in the tank. With such disposition, the vicinity of the opening of the loading pipe is pressurized with an increase in liquid head. Therefore, flash evaporation of the liquefied gas discharged from the opening of the loading pipe can be suppressed. However, in a pipe top portion disposed at the highest position of the loading pipe, the pressure of the liquefied carbon dioxide inside is reduced by the amount corresponds to the height difference between the pipe lower end and the pipe top portion with respect to the pressure of the liquefied carbon dioxide at the pipe lower end.

[0007] As a result, depending on the tank operating pressure, the pressure of the liquefied carbon dioxide becomes equal to or lower than the triple point pressure in the pipe top portion of the loading pipe where the pressure of the liquefied carbon dioxide becomes the lowest, or the liquefied carbon dioxide evaporates, and due to the evaporation latent heat thereof, the temperature of the liquefied carbon dioxide remaining without evaporating is lowered, so that there is a possibility that the liquefied carbon dioxide may be solidified to generate dry ice.

[0008] Then, in this manner, if dry ice is generated in the loading pipe, the flow of the liquefied carbon dioxide in the loading pipe is obstructed, so that there is a possibility that the operation of the tank may be affected.

[0009] The present disclosure has been made in order to solve the above problem, and has an object to provide a tank system and a ship, in which it is possible to suppress the generation of dry ice in a loading pipe and smoothly perform the operation of a tank.

Solution to Problem

[0010] In order to solve the above problem, a tank system according to the present disclosure includes a tank, a loading pipe, and a pipe pressure resistance part. The tank contains liquefied carbon dioxide therein. The loading pipe extends in an up-down direction and a lower end thereof is open into the tank. The loading pipe discharges liquefied carbon dioxide that is supplied from the outside, from the lower end into the tank. The pipe pressure resistance part is provided on the lower end side with respect to a pipe top portion that is located at the highest position in the loading pipe. The pipe pressure resistance part generates a pressure loss in the liquefied carbon dioxide flowing through the loading pipe.

[0011] A ship according to the present disclosure includes a hull, and the tank system as described above, which is provided in the hull.

Advantageous Effects of Invention

[0012] According to the tank system and the ship of the present disclosure, it is possible to suppress the generation of dry ice in the loading pipe and smoothly perform the operation of the tank.

Brief Description of Drawings

[0013]

Fig. 1 is a plan view showing the overall configuration of a ship in an embodiment of the present disclosure.

Fig. 2 is a sectional view of a tank system provided in a ship according to a first embodiment of the present disclosure.

Fig. 3 is a sectional view showing a pipe pressure resistance part provided in the tank system according to the first embodiment of the present disclosure.

Fig. 4 is a sectional view showing a pipe pressure resistance part according to a modification example of the first embodiment of the present disclosure.

Fig. 5 is a sectional view showing a pipe pressure resistance part according to a modification example of the first embodiment of the present disclosure.

Fig. 6 is a sectional view of a tank system provided in a ship according to a second embodiment of the present disclosure.

Fig. 7 is a sectional view of a tank system provided in a ship according to a third embodiment of the present disclosure.

Fig. 8 is a sectional view showing a pipe pressure resistance part provided in the tank system according to the third embodiment of the present disclosure.

Fig. 9 is a diagram showing a hardware configuration of a control device provided in the tank system according to the third embodiment of the present disclosure.

Fig. 10 is a functional block diagram of the control device provided in the tank system according to the third embodiment of the present disclosure.

Fig. 11 is a flowchart showing a procedure for opening degree adjustment processing of a control valve in the control device provided in the tank system according to the third embodiment of the present disclosure.

Description of Embodiments

<First Embodiment>

[0014] Hereinafter, a tank system and a ship according to an embodiment of the present disclosure will be described with reference to Figs. 1 to 3.

(Hull Composition of Ship)

[0015] As shown in Fig. 1, a ship 1A of an embodiment of the present disclosure carries liquefied carbon dioxide or various liquefied gases including liquefied carbon dioxide. The ship 1A includes at least a hull 2 and a tank system 20A.

(Configuration of Hull)

[0016] The hull 2 has a pair of broadsides 3A and 3B forming an outer shell thereof, a ship bottom (not shown), and an upper deck 5. The broadsides 3A and 3B are provided with a pair of broadside outer plates forming the left and right broadsides respectively. The ship bottom (not shown) is provided with a ship bottom outer plate connecting the broadsides 3A and 3B. Due to the pair of broadsides 3A and 3B and the ship bottom (not shown), the outer shell of the hull 2 has a U-shape in a cross-section orthogonal to a bow-stern direction Da. The upper deck 5 is an all-deck that is exposed to the outside. In the hull 2, a superstructure 7 having an accommodation space is formed on the upper deck 5 on the stern 2b side.

[0017] In the hull 2, a tank system storage compartment (a hold) 8 is formed on the bow 2a side with respect to the superstructure (the accommodation space) 7. The tank system storage compartment 8 is a closed compartment that is recessed toward the ship bottom (not shown) below the upper deck 5 and protrudes upward or has the upper deck 5 as a ceiling.

(Composition of Tank System)

[0018] As shown in Fig. 2, the tank system 20A includes a tank 21, a loading pipe 25, and a pipe pressure resistance part 30A.

(Configuration of Tank)

[0019] As shown in Fig. 1, a plurality of tanks 21 are provided in the tank system storage compartment 8. In this embodiment, for example, a total of seven tanks 21 are provided in the tank system storage compartment 8. The layout and the number of tanks 21 installed in the tank system storage compartment 8 are not limited in any way. In this embodiment, each tank 21 has, for example, a cylindrical shape extending in the horizontal direction (specifically, the bow-stern direction). The tank 21 contains liquefied carbon dioxide L inside.

[0020] The tank 21 is not limited to a cylindrical shape, and the tank 21 may be a spherical shape or the like.

(Configuration of Loading Pipe)

[0021] As shown in Fig. 2, the loading pipe 25 loads the liquefied carbon dioxide L, which is supplied from the outside such as a liquefied carbon dioxide supply facility on land or a bunker ship, into the tank 21. The loading pipe 25 in this embodiment is inserted into the tank 21 by penetrating the upper portion of the tank 21 from the outside of the tank 21. The loading pipe 25 extends in an up-down direction Dv in the tank 21. A lower end 25b of the loading pipe 25 is open in the tank 21. The loading pipe 25 discharges the liquefied carbon dioxide L that is supplied from the outside into the tank 21 from the lower end 25b. In the loading pipe 25, a pipe top portion 25t that is located at the highest position is disposed outside the tank 21.

[0022] The lower end 25b of the loading pipe 25 is disposed in the vicinity of a bottom portion of the tank 21. The vicinity of the bottom portion is a position closer to the bottom portion than the center of the tank 21 in the up-down direction Dv. Fig. 2 illustrates a situation in which the lower end 25b of the loading pipe 25 is submerged in the liquefied carbon dioxide L stored in the tank 21. Further, in Fig. 2, the lower end 25b is open downward. However, the opening direction thereof is not limited to the downward direction.

(Configuration of Pipe Pressure Resistance Part)

[0023] The pipe pressure resistance part 30A acts as a pipe pressure resistance on the liquefied carbon dioxide L flowing through the loading pipe 25. The pipe pressure resistance part 30A is provided on the lower end

25b side with respect to the pipe top portion 25t which is located at the highest position in the loading pipe 25. In this embodiment, the pipe pressure resistance part 30A is provided at the lower end 25b of the loading pipe 25. However, there is no limitation to the lower end 25b. As shown in Fig. 3, the pipe pressure resistance part 30A has a flow opening portion 30a through which the liquefied carbon dioxide L flows. The flow opening portion 30a has an opening area A2 smaller than a flow path cross-sectional area A1 in the loading pipe 25.

[0024] In this embodiment, the pipe pressure resistance part 30A is configured using an orifice 31. The orifice 31 is mounted to the lower end 25b of the loading pipe 25. The orifice 31 includes a plate portion 31a provided so as to close the opening of the lower end 25b of the loading pipe 25, and a through-hole 31b formed in the plate portion 31a. The through-hole 31b forms the flow opening portion 30a. The through-hole 31b is formed to penetrate in a plate thickness direction of the plate portion 31a (a pipe axis direction at the lower end 25b of the loading pipe 25). In this embodiment, only one through-hole 31b is formed in the central portion of the plate portion 31a.

[0025] A pressure Pc in the pipe top portion 25t of the liquefied carbon dioxide L flowing through the loading pipe 25 having the pipe pressure resistance part 30A provided at the lower end 25b has a value obtained by subtracting a pressure corresponding to the height difference between the liquid level of the liquefied carbon dioxide L in the tank 21 and the pipe top portion 25t from a value obtained by adding a pressure loss ΔP that is generated by the pipe pressure resistance part to a tank operating pressure Pt. However, in a case where the dynamic pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 is significant, it is necessary to consider the influence thereof.

[0026] In order to prevent the liquefied carbon dioxide L from falling below the triple point pressure of the liquefied carbon dioxide L in the pipe top portion 25t of the loading pipe 25, the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t needs to exceed a setting pressure lower limit value Ps of the liquefied carbon dioxide L set in advance, as in the following expression (1).

$$Pc > Ps \dots (1)$$

[0027] Here, the setting pressure lower limit value Ps can be a value obtained by adding a safety margin value to the triple point pressure value of the liquefied carbon dioxide L.

[0028] In the pipe pressure resistance part 30A (the orifice 31), the opening area A2 of the flow opening portion 30a is set so as to satisfy the condition expressed by the above expression (1) by utilizing the fact that the generated pressure loss ΔP increases the pressure Pc in the pipe top portion 25t.

(Specific Study Example)

[0029] Here, for example, the operating pressure of the tank 21 is set to be 580 [kPa(G)], the density ρ of the liquefied carbon dioxide L is set to be 1150 [kg/m^3], a liquid level height H1 of the liquefied carbon dioxide L in the tank 21 is set to be 0 [m], and a height H2 of the pipe top portion 25t of the loading pipe 25 from a tank bottom surface 21b is set to be 30 [m]. Then, the pressure of the liquefied carbon dioxide L in the pipe top portion 25t of the loading pipe 25 in a state of having no pipe pressure resistance part 30A becomes 242 [kPa(G)]. The triple point pressure of the liquefied carbon dioxide L is 417 [kPa(G)], and therefore, in a state where the pipe pressure resistance part 30A is not provided, the pressure of the liquefied carbon dioxide L in the pipe top portion 25t of the loading pipe 25 becomes equal to or lower than the triple point pressure, and thus there is a possibility that dry ice may be generated.

[0030] In contrast, in the loading pipe 25 provided with the pipe pressure resistance part 30A, the pressure loss ΔP is generated by the pipe pressure resistance part 30A so as to satisfy the above expression (1), and the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t always exceeds the setting pressure lower limit value Ps, and can sufficiently exceed the triple point pressure.

(Operation and Effects)

[0031] The tank system 20A of the first embodiment includes the tank 21, the loading pipe 25, and the pipe pressure resistance part 30A. The pipe pressure resistance part 30A is provided on the lower end 25b side with respect to the pipe top portion 25t that is located at the highest position in the loading pipe 25. Due to the pipe pressure resistance part 30A, the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 is increased by the amount corresponding to the pressure loss ΔP, and the pressure Pc of the liquefied carbon dioxide L is restrained from approaching the triple point pressure. In this way, it is possible to suppress the generation of dry ice due to solidification of the liquefied carbon dioxide L in the loading pipe 25. As a result, in a case where the liquefied carbon dioxide L is contained in the tank 21, it becomes possible to suppress the generation of dry ice in the loading pipe 25 and smoothly perform the operation of the tank 21.

[0032] In the tank system 20A of the first embodiment, the pipe pressure resistance part 30A generates the pressure loss ΔP satisfying the above expression (1).

[0033] Therefore, according to the tank system 20A of the embodiment, an appropriate pressure loss ΔP according to the height H2 of the pipe top portion 25t of the loading pipe 25 is generated by the pipe pressure resistance part 30A to be able to increase the pressure of the liquefied carbon dioxide L. In this way, the pressure of the liquefied carbon dioxide L becomes equal to or higher than the setting pressure lower limit value Ps set according to the triple point pressure of the liquefied carbon dioxide L in the entire area in the loading pipe 25. In this way, it is possible to suppress the generation of dry ice in the loading pipe 25.

[0034] In the tank system 20A of the first embodiment, the pipe pressure resistance part 30A is provided at the lower end 25b of the loading pipe 25.

[0035] Therefore, according to the tank system 20A of the embodiment, due to the pipe pressure resistance part 30A provided at the lower end 25b of the loading pipe 25, the generation of dry ice in the loading pipe 25 is suppressed. Further, the pipe pressure resistance part 30A can be additionally provided even with respect to the lower end 25b of the loading pipe 25 of the existing tank system 20A.

[0036] In the tank system 20A of the first embodiment, the pipe pressure resistance part 30A (the orifice 31) has the flow opening portion 30a which has the opening area A2 smaller than the flow path cross-sectional area A1 in the loading pipe 25 and through which the liquefied carbon dioxide L flows.

[0037] The pipe pressure resistance part 30A as described above has a simple configuration having the flow opening portion 30a, and can realize suppression of the generation of dry ice in liquefied carbon dioxide L at low cost.

[0038] The ship 1A of the first embodiment includes the hull 2 and the tank system 20A provided in the hull 2.

[0039] Therefore, according to the ship 1A of the embodiment, it is possible to provide the ship 1A provided with the tank system 20A in which in a case where the liquefied carbon dioxide L is contained in the tank 21, the generation of dry ice in the loading pipe 25 is suppressed and the operation of the tank 21 can be performed smoothly.

<Modification Examples>

[0040] In the first embodiment, a configuration is made in which the orifice 31 is provided as the pipe pressure resistance part 30A. However, there is no limitation thereto.

[0041] For example, as shown in Fig. 4, a perforated plate 32 may be provided as the pipe pressure resistance part 30A. The perforated plate 32 is mounted to the lower end 25b of the loading pipe 25. The perforated plate 32 includes a plate portion 32a provided so as to close the opening of the lower end 25b of the loading pipe 25, and a plurality of (many) through-holes 32b formed in the plate portion 32a. Each of the through-holes 32b penetrates in the plate thickness direction of the plate portion 32a. The flow opening portion 30a is configured by the plurality of through-holes 32b. In the flow opening portion 30a, a total opening area A3 of the plurality of through-holes 32b is smaller than the flow path cross-sectional area A1 in the loading pipe 25.

[0042] The pipe pressure resistance part 30A using the perforated plate 32 as described above can increase the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 by the amount corresponding to the pressure loss ΔP.

[0043] Further, as shown in Fig. 5, a flap 33 may be provided as the pipe pressure resistance part 30A. The flap 33 is mounted on the inside of the lower end 25b of the loading pipe 25. The flap 33 has a plate shape and is provided to be inclined with respect to a plane orthogonal to a pipe axis direction Dp at the lower end 25b of the loading pipe 25. The flap 33 is provided to have a gap 33b between an outer peripheral edge 33a thereof and an inner peripheral surface 25f of the lower end 25b of the loading pipe 25. The gap 33b between the outer peripheral edge 33a of the flap 33 and the inner peripheral surface 25f of the loading pipe 25 forms the flow opening portion 30a. An opening area A4 of the gap 33b forming the flow opening portion 30a is smaller than the flow path cross-sectional area A1 in the loading pipe 25.

[0044] The pipe pressure resistance part 30A using the flap 33 as described above can increase the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 by the amount corresponding to the pressure loss ΔP.

<Second Embodiment>

[0045] Next, a tank system and a ship according to a second embodiment of the present disclosure will be described with reference to Fig. 6. In the second embodiment of the present disclosure that is described below, only the position of a pipe pressure resistance part 30B is different from that in the first embodiment of the present disclosure, and therefore, the same portions as those in the first embodiment will be denoted by the same reference numerals, and overlapping description will be omitted.

(Hull Composition of Ship)

[0046] As shown in Fig. 1, a ship 1B of this embodiment carries liquefied carbon dioxide or various liquefied gases including liquefied carbon dioxide. The ship 1B includes at least the hull 2 and a tank system 20B.

(Composition of Tank System)

[0047] As shown in Fig. 6, the tank system 20B includes the tank 21, the loading pipe 25, and the pipe pressure resistance part 30B.

(Configuration of Pipe Pressure Resistance Part)

[0048] The pipe pressure resistance part 30B can increase the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 by the amount corresponding to the pressure loss. The pipe pressure resistance part 30B is provided on the lower end 25b side with respect to the pipe top portion 25t that is located at the highest position in the loading pipe 25. In the second embodiment, the pipe pressure resistance part 30B is provided between the pipe top portion 25t and the lower end 25b of the loading pipe 25. The pipe pressure resistance part 30B is provided at a position higher than the lower end 25b of the loading pipe 25.

[0049] The pipe pressure resistance part 30B is formed using one of the orifice 31 (refer to Fig. 3), the perforated plate 32 (refer to Fig. 4), and the flap 33 (refer to Fig. 5) shown in the first embodiment. The pipe pressure resistance part 30B is provided such that the generated pressure loss ΔP satisfies the condition expressed by the above expression (1).

[0050] Further, in a case where the pipe pressure resistance part 30B is provided at a position higher than the lower end 25b of the loading pipe 25, it is necessary to prevent the pressure of the liquefied carbon dioxide L that has passed through the pipe pressure resistance part 30B from falling below the triple point pressure on the lower side (the lower end 25b side) of the pipe pressure resistance part 30B.

[0051] Therefore, in a case where the pipe pressure resistance part 30B is provided at a height H [mm] from the tank bottom surface 21b of the tank 21, it is necessary to make the pressure of the liquefied carbon dioxide L at the height H of the pipe pressure resistance part 30B exceed the setting pressure lower limit value Ps.

[0052] The height H [mm] from the tank bottom surface 21b where the pipe pressure resistance part 30B is installed is limited such that the pressure of the liquefied carbon dioxide L passing through the pipe pressure resistance part 30B does not fall below the triple point pressure, in consideration of the fact that the pressure of the liquefied carbon dioxide L decreases according to the height difference between the height H and the liquid level height H1 of the liquefied carbon dioxide L in the tank 21.

(Operation and Effects)

[0053] The tank system 20B of the second embodiment includes the tank 21, the loading pipe 25, and the pipe pressure resistance part 30B. The pipe pressure resistance part 30B is provided on the lower end 25b side with respect to the pipe top portion 25t that is located at the highest position in the loading pipe 25. Due to the pipe pressure resistance part 30B, the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 is increased by the amount corresponding to the pressure loss ΔP, and the pressure Pc of the liquefied carbon dioxide L is restrained from approaching the triple point pressure. As a result, in a case where the liquefied carbon dioxide L is contained in the tank 21, it becomes possible to suppress the generation of dry ice in the loading pipe 25 and smoothly perform the operation of the tank 21.

[0054] In the tank system 20B of the second embodiment, the pipe pressure resistance part 30B generates the pressure loss ΔP satisfying the above expression (1).

[0055] Therefore, according to the tank system 20B of the embodiment, an appropriate pressure loss ΔP according to the height H2 of the pipe top portion 25t of the loading pipe 25 is generated by the pipe pressure resistance part 30B to be able to increase the pressure of the liquefied carbon dioxide L. In this way, it is possible to suppress the generation of dry ice due to solidification of the liquefied carbon dioxide L in the loading pipe 25.

[0056] In the tank system 20B of the second embodiment, the pipe pressure resistance part 30B is higher than the lower end 25b of the loading pipe 25, and the height H [mm] thereof from the tank bottom surface 21b of the tank 21 is limited such that the pressure of the liquefied carbon dioxide L that has passed through the pipe pressure resistance part 30B does not fall below the triple point pressure, in consideration of the fact that the pressure of the liquefied carbon dioxide L decreases according to the height difference between the height H from the tank bottom surface 21b and the liquid level height H1 of the liquefied carbon dioxide L in the tank 21.

[0057] Therefore, according to the tank system 20B of the embodiment, the pressure of the liquefied carbon dioxide L becomes equal to or higher than the setting pressure lower limit value Ps on the lower side (the lower end 25b side) with respect to the pipe pressure resistance part 30B. In this way, it is possible to suppress the generation of dry ice due to the occurrence of a pressure drop of the liquefied carbon dioxide L that has passed through the pipe pressure resistance part 30B.

[0058] The ship 1B of the second embodiment includes the hull 2 and the tank system 20B provided in the hull 2.

[0059] Therefore, according to the ship 1B of the second embodiment, it is possible to provide the ship 1B provided with the tank system 20B in which in a case where the liquefied carbon dioxide L is contained in the tank 21, the generation of dry ice in the loading pipe 25 is suppressed and the operation of the tank 21 can be performed smoothly.

[Third Embodiment]

[0060] Next, a tank system and a ship according to a third embodiment of the present disclosure will be described with reference to Figs. 7 to 11. In the third embodiment of the present disclosure that is described below, only the configuration of a pipe pressure resistance part 30C is different from those in the first and second embodiments of the present disclosure, and therefore, the same portions as those in the first and second embodiments will be denoted by the same reference numerals, and overlapping description will be omitted.

(Hull Composition of Ship)

[0061] As shown in Fig. 1, a ship 1C of this embodiment carries liquefied carbon dioxide or various liquefied gases including liquefied carbon dioxide. The ship 1C includes at least the hull 2 and a tank system 20C.

(Composition of Tank System)

[0062] As shown in Fig. 7, the tank system 20C includes the tank 21, the loading pipe 25, and a pipe pressure resistance part 30C.

(Configuration of Pipe Pressure Resistance Part)

[0063] The pipe pressure resistance part 30C can increase the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 by the amount corresponding to the pressure loss. In this embodiment, the pipe pressure resistance part 30C includes a control valve 35 and a control device 60.

[0064] The control valve 35 of the pipe pressure resistance part 30C is provided on the lower end 25b side with respect to the pipe top portion 25t that is located at the highest position in the loading pipe 25. In the third embodiment, the control valve 35 is provided at the lower end 25b of the loading pipe 25. The control valve 35 may be provided at a position higher than the lower end 25b of the loading pipe 25, as in the second embodiment.

[0065] The control valve 35 shown in Fig. 8 makes an opening area A5 of the flow opening portion 30a variable. The control valve 35 has a valve body 35a rotatably provided in the flow path of the liquefied carbon dioxide L in the loading pipe 25. The valve body 35a opens and closes the flow path in the loading pipe 25 by rotating around a valve shaft. The valve body 35a increases or decreases a gap 35b formed between the valve body 35a and the inner peripheral surface 25f of the loading pipe 25 by adjusting the opening degree around the valve shaft. The gap 35b between the valve body 35a and the inner peripheral surface 25f of the loading pipe 25 forms the flow opening portion 30a. The opening area A5 of the gap 35b forming the flow opening portion 30a is smaller than the flow path cross-sectional area A1 in the loading pipe 25. As the control valve 35, it is preferable to use a submersible low-temperature resistant valve that can operate even in the liquefied carbon dioxide L having a low-temperature.

[0066] The pipe pressure resistance part 30C using the control valve 35 as described above can increase the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 by the amount corresponding to the pressure loss ΔP.

[0067] In the control valve 35 of the pipe pressure resistance part 30C, the opening area A5 of the flow opening portion 30a is set so as to satisfy the condition expressed by the above expression (1) by utilizing the fact that the generated pressure loss ΔP increases the pressure Pc in the pipe top portion 25t.

(Configuration of Control Device)

[0068] The control device 60 adjusts the opening degree of the flow opening portion 30a in the control valve 35. In order to adjust the opening degree of the control valve 35 by the control device 60, the tank system 20C includes a tank internal pressure sensor 51 and a pipe top portion pressure sensor 52. The tank internal pressure sensor 51 detects the internal pressure of the tank 21. The pipe top portion pressure sensor 52 detects the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t.

(Hardware Configuration Diagram of Control Device)

[0069] As shown in Fig. 9, the control device 60 is a computer that includes a CPU 61 (Central Processing Unit), a ROM 62 (Read Only Memory), a RAM 63 (Random Access Memory), an HDD 64 (Hard Disk Drive), and a signal receiving module 65. The signal receiving module 65 receives the detection signals from the tank internal pressure sensor 51 and the pipe top portion pressure sensor 52.

(Functional Block Diagram of Control Device)

[0070] As shown in Fig. 10, the CPU 61 of the control device 60 executes a program stored in the HDD 64, the ROM 62, or the like in advance to realize a functional configuration of each of a signal receiving unit 71, an opening degree control unit 72, and a command signal output unit 73.

[0071] The signal receiving unit 71 receives the detection signals from the tank internal pressure sensor 51 and the pipe top portion pressure sensor 52, that is, the data of the detection value of the internal pressure of the tank 21 in the tank internal pressure sensor 51 and the detection value of the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t, through the signal receiving module 65.

[0072] The opening degree control unit 72 executes control for adjusting the opening degree of the control valve 35, based on the detection value in the pipe top portion pressure sensor 52.

[0073] The command signal output unit 73 outputs a command signal for changing the opening degree of the control valve 35 to the control valve 35 under the control of the opening degree control unit 72.

(Processing Procedure)

[0074] Next, a procedure for adjusting the opening degree of the control valve 35 by the control device 60 in the tank system 20C will be described.

[0075] As shown in Fig. 11, the signal receiving unit 71 of the control device 60 receives the data of the detection value of the internal pressure (the operating pressure Pt) of the tank 21 in the tank internal pressure sensor 51 and the detection value of the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t from the tank internal pressure sensor 51 and the pipe top portion pressure sensor 52 at time intervals set in advance (step S1).

[0076] Subsequently, the opening degree control unit 72 determines whether or not the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t received in step S1 is lower than a threshold value set in advance (for example, the setting pressure lower limit value Ps) (step S2). As a result, if the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t is not lower than the threshold value, the processing returns to step S1.

[0077] In step S2, in a case where the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t is lower than the threshold value, that is, in a case where the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t is lower than the setting pressure lower limit value Ps, the opening degree control unit 72 reduces the opening degree of the control valve 35 (step S3). To this end, the opening degree control unit 72 outputs a command signal for reducing the opening degree of the valve body 35a by a predetermined angle to the control valve 35 through the command signal output unit 73. After outputting the command signal, the control device 60 ends the processing and returns to step S1.

(Operation and Effects)

[0078] The tank system 20C of the above embodiment includes the tank 21, the loading pipe 25, and the pipe pressure resistance part 30C. Further, the pipe pressure resistance part 30C is provided on the lower end 25b side with respect to the pipe top portion 25t that is located at the highest position in the loading pipe 25. Due to the pipe pressure resistance part 30C, the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 is increased by the amount corresponding to the pressure loss ΔP, and the pressure Pc of the liquefied carbon dioxide L is restrained from approaching the triple point pressure. As a result, in a case where the liquefied carbon dioxide L is contained in the tank 21, it becomes possible to suppress the generation of dry ice in the loading pipe 25 and smoothly perform the operation of the tank 21.

[0079] In the tank system 20C of the above embodiment, the pipe pressure resistance part 30C generates the pressure loss ΔP satisfying the above expression (1).

[0080] Therefore, according to the tank system 20C of the embodiment, an appropriate pressure loss ΔP according to the height H2 of the pipe top portion 25t of the loading pipe 25 is generated by the pipe pressure resistance part 30C to be able to increase the pressure of the liquefied carbon dioxide L. In this way, it is possible to suppress the generation of dry ice due to solidification of the liquefied carbon dioxide L in the loading pipe 25.

[0081] In the tank system 20C of the above embodiment, the pipe pressure resistance part 30C has the flow opening portion 30a which has the opening area A5 smaller than the flow path cross-sectional area A1 in the loading pipe 25 and through which the liquefied carbon dioxide L flows.

[0082] The pipe pressure resistance part 30C as described above has a simple configuration having the flow opening portion 30a, and can realize suppression of the generation of dry ice in the liquefied carbon dioxide L at low cost.

[0083] In the tank system 20C of the above embodiment, the pipe pressure resistance part 30C includes the control valve 35 that makes the opening area A5 of the flow opening portion 30a variable, and the control device 60 that adjusts the opening degree of the flow opening portion 30a in the control valve 35.

[0084] Therefore, according to the tank system 20C of the embodiment, the pressure loss ΔP that is generated by the pipe pressure resistance part 30C can be adjusted by adjusting the opening degree of the flow opening portion 30a in the control valve 35 by the control device 60. In this way, it becomes possible to appropriately adjust the pressure loss ΔP that increases the pressure of the liquefied carbon dioxide L according to the operating condition or the like of the tank system 20C.

[0085] The tank system 20C of the above embodiment further includes the pipe top portion pressure sensor 52 that detects the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t of the loading pipe 25, and the control device 60 adjusts the opening degree of the control valve 35, based on the detection value in the pipe top portion pressure sensor 52.

[0086] Therefore, according to the tank system 20C of the embodiment, the pressure loss ΔP that increases the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 can be adjusted at the pipe pressure resistance part 30C according to the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t detected by the pipe top portion pressure sensor 52. Therefore, it becomes possible to appropriately adjust the pressure loss ΔP that increases the pressure of the liquefied carbon dioxide L such that the pressure of the liquefied carbon dioxide L in the pipe top portion 25t does not fall below the setting pressure lower limit value Ps.

[0087] The ship 1C of the above embodiment includes the hull 2 and the tank system 20C provided in the hull 2.

[0088] Therefore, according to the ship 1C of the embodiment, it is possible to provide the ship 1C provided with the tank system 20C in which in a case where the liquefied carbon dioxide L is contained in the tank 21, the generation of dry ice in the loading pipe 25 is suppressed and the operation of the tank 21 can be performed smoothly.

<Other Embodiments>

[0089] The embodiments of the present disclosure have been described in detail above with reference to the drawings. However, the specific configurations are not limited to the embodiments, and also include design changes or the like within a scope which does not deviate from the gist of the present disclosure.

[0090] In the embodiments described above, a configuration is made in which the tank 21 is provided in the tank system storage compartment 8 formed in the hull 2. However, there is no limitation thereto, and for example, the tank 21 is provided on the upper deck 5.

[0091] Further, in the embodiments described above, the tank 21 is provided in the ship 1A, 1B, or 1C. However, there is no limitation thereto, and, for example, the tank 21 may be installed in a place other than the ships 1A to 1C, for example, on land or in marine facility, or in a vehicle such as a tank lorry.

<Additional Remark>

[0092] The tank systems 20A, 20B, and 20C and the ships 1A to 1C described in the embodiment are grasped as follows, for example.

[0093] (1) The tank system 20A, 20B, or 20C according to a first aspect includes the tank 21 that contains the liquefied carbon dioxide L therein, the loading pipe 25 that extends in the up-down direction Dv, has the lower end 25b that is open into the tank 21, and discharges the liquefied carbon dioxide L that is supplied from the outside, from the lower end 25b into the tank 21, and the pipe pressure resistance part 30A, 30B, or 30C that is provided on the lower end 25b side with respect to the pipe top portion 25t that is located at the highest position in the loading pipe 25, and generates the pressure loss ΔP in the liquefied carbon dioxide L flowing through the loading pipe 25.

[0094] As an example of the pipe pressure resistance part 30A, 30B, or 30C, there is the orifice 31, the perforated plate 32, or the flap 33.

[0095] In the tank system 20A, 20B, or 20C, due to the pipe pressure resistance part 30A, 30B, or 30C, the pressure of the liquefied carbon dioxide L flowing through the loading pipe 25 is increased by the amount corresponding to the pressure loss ΔP. The pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t of the loading pipe 25 is increased, so that the pressure Pc of the liquefied carbon dioxide L is restrained from approaching the triple point pressure. In this way, it is possible to suppress the generation of dry ice due to solidification of the liquefied carbon dioxide L in the loading pipe 25. As a result, in a case where the liquefied carbon dioxide L is contained in the tank 21, it becomes possible to suppress the generation of dry ice in the loading pipe 25 and smoothly perform the operation of the tank 21.

[0096] (2) In the tank system 20A, 20B, or 20C according to a second aspect, in the tank system 20A, 20B, or 20C of the above (1), the pipe pressure resistance part 30A, 30B, or 30C generates the pressure loss ΔP that is determined such that a value obtained by subtracting a pressure corresponding to the height difference between the liquid level of the liquefied carbon dioxide L in the tank 21 and the pipe top portion 25t from a value obtained by adding the pressure loss ΔP that is generated by the pipe pressure resistance part 30A, 30B, or 30C to the tank operating pressure Pt exceeds the setting pressure lower limit value Ps obtained by adding a safety margin value to the triple point pressure value of the liquefied carbon dioxide L.

[0097] In this way, an appropriate pressure loss ΔP according to the height of the pipe top portion 25t of the loading pipe 25 is generated by the pipe pressure resistance part 30A, 30B, or 30C to be able to increase the pressure Pc of the liquefied carbon dioxide L. In this way, the pressure Pc of the liquefied carbon dioxide L in the loading pipe 25 becomes equal to or higher than the setting pressure lower limit value Ps that is set according to the triple point pressure of the liquefied carbon dioxide L. In this way, it is possible to suppress the generation of dry ice due to solidification of the liquefied carbon dioxide L in the loading pipe 25.

[0098] (3) In the tank system 20A or 20C according to a third aspect, in the tank system 20A or 20C of the above (2), the pipe pressure resistance part 30A or 30C is provided at the lower end 25b of the loading pipe 25.

[0099] In this way, due to the pipe pressure resistance part 30A or 30C provided at the lower end 25b of the loading pipe 25, the generation of dry ice due to the solidification of the liquefied carbon dioxide L in the loading pipe 25 is suppressed. Further, the pipe pressure resistance part 30A or 30C can be additionally provided even with respect to the lower end 25b of the loading pipe 25 of the existing tank system.

[0100] (4) In the tank system 20B according to a fourth aspect, in the tank system 20B of the above (2), the pipe pressure resistance part 30B is higher than the lower end 25b of the loading pipe 25, and the height H thereof from the tank bottom surface 21b of the tank 21 is provided such that the pressure of the liquefied carbon dioxide L that has passed through the pipe pressure resistance part 30B does not fall below the triple point pressure value.

[0101] In this way, in a case where the pipe pressure resistance part 30B is installed at a position higher than the lower end 25b of the loading pipe 25 and lower than the pipe top portion 25t, the pressure of the liquefied carbon dioxide L becomes equal to or higher than the setting pressure lower limit value Ps even on the lower side (the lower end 25b side) with respect to the pipe pressure resistance part 30B. In this way, it is possible to suppress the generation of dry ice due to the occurrence of a pressure drop of the liquefied carbon dioxide L that has passed through the pipe pressure resistance part 30B on the lower side with respect to the pipe pressure resistance part 30B.

[0102] (5) In the tank system 20A, 20B, or 20C according to a fifth aspect, in the tank system 20A, 20B, or 20C of any one of the above (1) to (4), the pipe pressure resistance part 30A, 30B, or 30C has the flow opening portion 30a which has the opening area A2, A3, A4, or A5 smaller than the flow path cross-sectional area A1 in the loading pipe 25 and through which the liquefied carbon dioxide L flows.

[0103] The pipe pressure resistance part 30A, 30B, or 30C has a simple configuration having the flow opening portion 30a, and can realize suppression of the generation of dry ice in the liquefied carbon dioxide L at low cost.

[0104] (6) In the tank system 20C according to a sixth aspect, in the tank system 20C of the above (5), the pipe pressure resistance part 30C includes the control valve 35 that makes the opening area A5 of the flow opening portion 30a variable, and the control device 60 that adjusts the opening degree of the flow opening portion 30a in the control valve 35.

[0105] In this way, the pressure loss ΔP that is generated by the pipe pressure resistance part 30C can be adjusted by adjusting the opening degree of the flow opening portion 30a in the control valve 35 by the control device 60. Therefore, it becomes possible to appropriately adjust the pressure loss ΔP that increases the pressure of the liquefied carbon dioxide L according to the operating condition or the like of the tank system 20C.

[0106] (7) In the tank system 20C according to a seventh aspect, the tank system 20C of the above (6) further includes the pipe top portion pressure sensor 52 that detects the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t of the loading pipe 25, in which the control device 60 adjusts the opening degree of the control valve 35, based on the detection value in the pipe top portion pressure sensor 52.

[0107] In this way, the pressure loss ΔP that is generated by the pipe pressure resistance part 30C can be adjusted according to the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t detected by the pipe top portion pressure sensor 52. Therefore, it becomes possible to appropriately adjust the pressure loss ΔP that increases the pressure of the liquefied carbon dioxide L such that the pressure Pc of the liquefied carbon dioxide L in the pipe top portion 25t does not fall below the setting pressure lower limit value Ps.

[0108] (8) The ship 1A. 1B, or 1C according to an eighth aspect includes the hull 2, and the tank system 20A, 20B, or 20C of any one of the above (1) to (7), which is provided in the hull 2.

[0109] In this way, it becomes possible to provide the ship 1A, 1B, or 1C provided with the tank system 20A, 20B, or 20C in which in a case where the liquefied carbon dioxide L is contained in the tank 21, the generation of dry ice in the loading pipe 25 is suppressed and the operation of the tank 21 can be performed smoothly.

Industrial Applicability

[0110] According to the present disclosure, it is possible to suppress the generation of dry ice in the loading pipe and smoothly perform the operation of the tank.

Reference Signs List

[0111]

1A, 1B, 1C: ship
2: hull
2a: bow
2b: stern
3A, 3B: broadside
5: upper deck
7: superstructure
8: tank system storage compartment
20A, 20B, 20C: tank system
21: tank
21b: tank bottom surface
25: loading pipe
25b: lower end
25f: inner peripheral surface
25t: pipe top portion
30A, 30B, 30C: pipe pressure resistance part
30a: flow opening portion
31: orifice
31a: plate portion
31b: through-hole
32: perforated plate
32a: plate portion
32b: through-hole
33: flap
33a: outer peripheral edge
33b: gap
35: control valve
35a: valve body
35b: gap
51: tank internal pressure sensor
52: pipe top portion pressure sensor
60: control device
61: CPU
62: ROM
63: RAM
64: HDD
65: signal receiving module
71: signal receiving unit
72: opening degree control unit
73: command signal output unit
A1: flow path cross-sectional area
A2, A3, A4, A5: opening area
Da: bow-stern direction
Dp: pipe axis direction
Dv: up-down direction
H: height of pipe pressure resistance part from tank bottom surface
H1: liquid level height of liquefied carbon dioxide in tank
H2: height of pipe top portion of loading pipe from tank bottom surface
L: liquefied carbon dioxide
ΔP: pressure loss
Pc: pressure

Ps: setting pressure lower limit value
Pt: operating pressure

Claims

1. A tank system comprising:

   a tank that contains liquefied carbon dioxide therein;
   a loading pipe that extends in an up-down direction, has a lower end that is open into the tank, and discharges liquefied carbon dioxide that is supplied from an outside, from the lower end into the tank; and
   a pipe pressure resistance part that is provided on a lower end side with respect to a pipe top portion that is located at a highest position in the loading pipe, and generates a pressure loss in the liquefied carbon dioxide flowing through the loading pipe.

2. The tank system according to claim 1, wherein the pipe pressure resistance part generates a pressure loss that is determined such that a value obtained by subtracting a pressure corresponding to a height difference between a liquid level of the liquefied carbon dioxide in the tank and the pipe top portion from a value obtained by adding the pressure loss that is generated by the pipe pressure resistance part to a tank operating pressure exceeds a setting pressure lower limit value obtained by adding a safety margin value to a triple point pressure value of the liquefied carbon dioxide.

3. The tank system according to claim 2, wherein the pipe pressure resistance part is provided at the lower end of the loading pipe.

4. The tank system according to claim 2, wherein the pipe pressure resistance part is higher than the lower end of the loading pipe, and a height thereof from a tank bottom surface of the tank is provided such that a pressure of the liquefied carbon dioxide that has passed through the pipe pressure resistance part does not fall below the triple point pressure value.

5. The tank system according to any one of claims 1 to 4, wherein the pipe pressure resistance part has a flow opening portion which has an opening area smaller than a flow path cross-sectional area in the loading pipe and through which the liquefied carbon dioxide flows.

6. The tank system according to claim 5, wherein the pipe pressure resistance part includes

   a control valve that makes an opening area of the flow opening portion variable, and
   a control device that adjusts an opening degree of the flow opening portion in the control valve.

7. The tank system according to claim 6, further comprising:

   a pipe top portion pressure sensor that detects a pressure of the liquefied carbon dioxide in the pipe top portion of the loading pipe,
   wherein the control device adjusts an opening degree of the control valve, based on a detection value in the pipe top portion pressure sensor.

8. A ship comprising:

   a hull; and
   the tank system according to any one of claims 1 to 7, which is provided in the hull.

FIG. 1

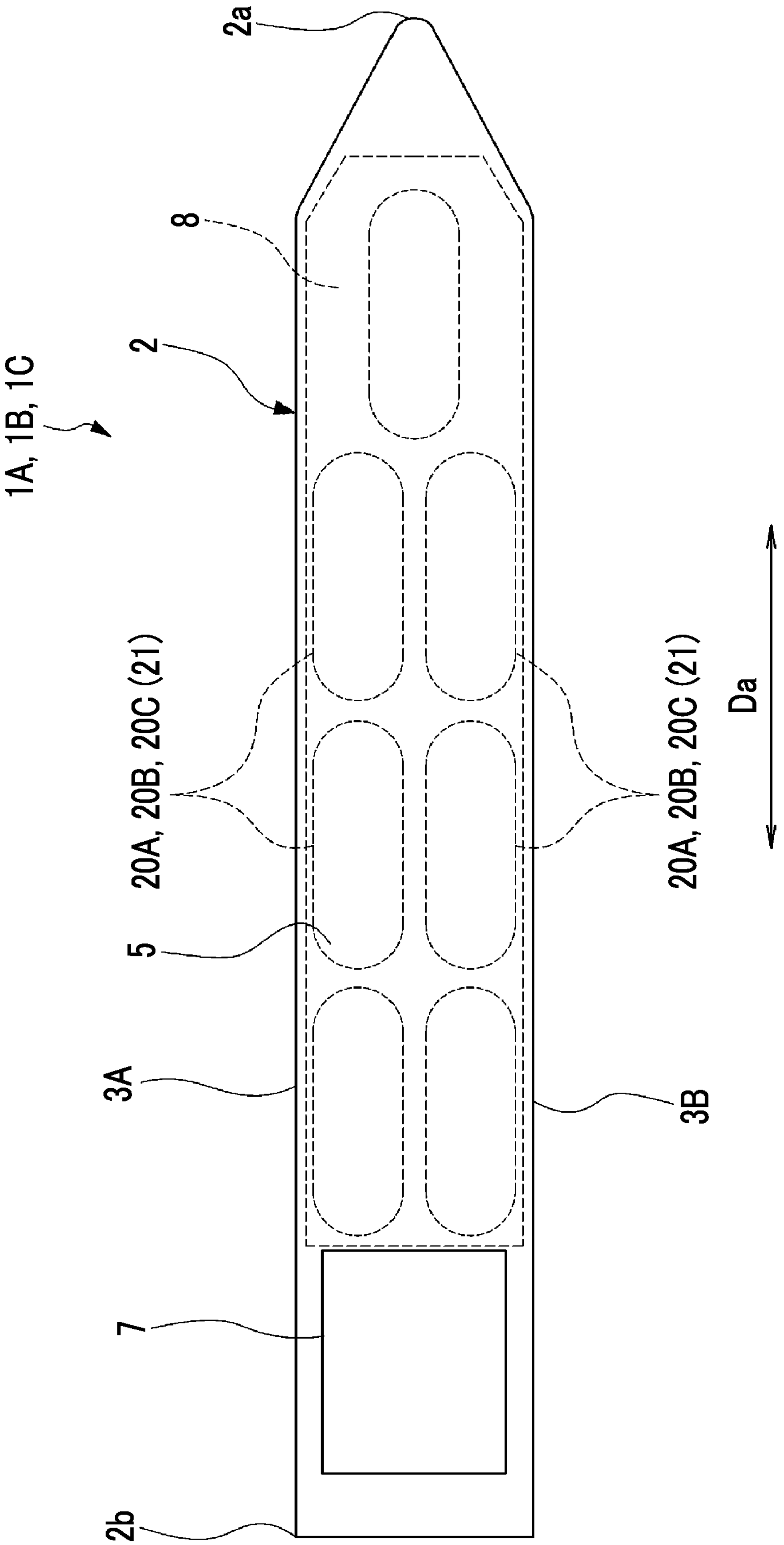


FIG. 2

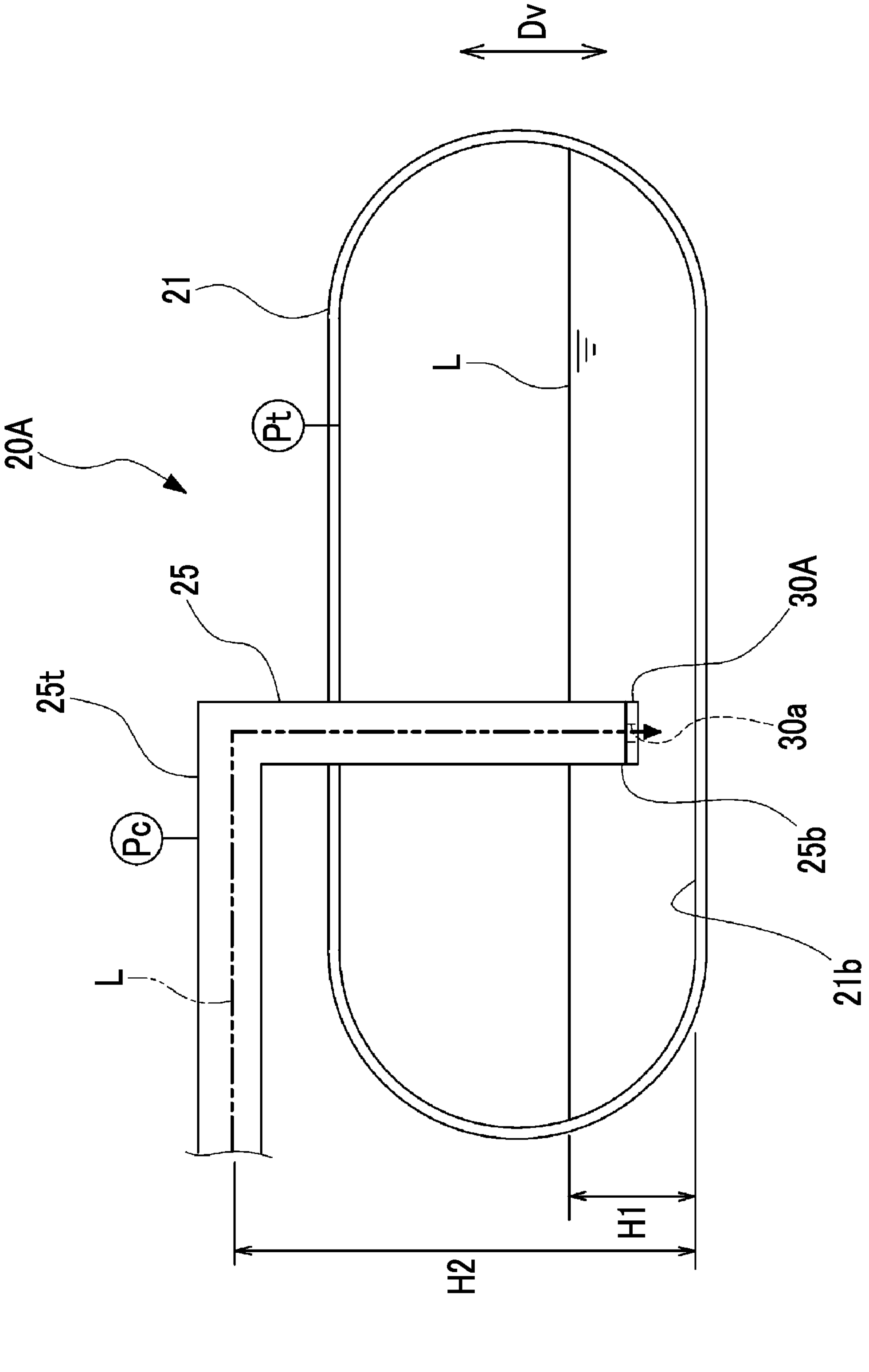


FIG. 3

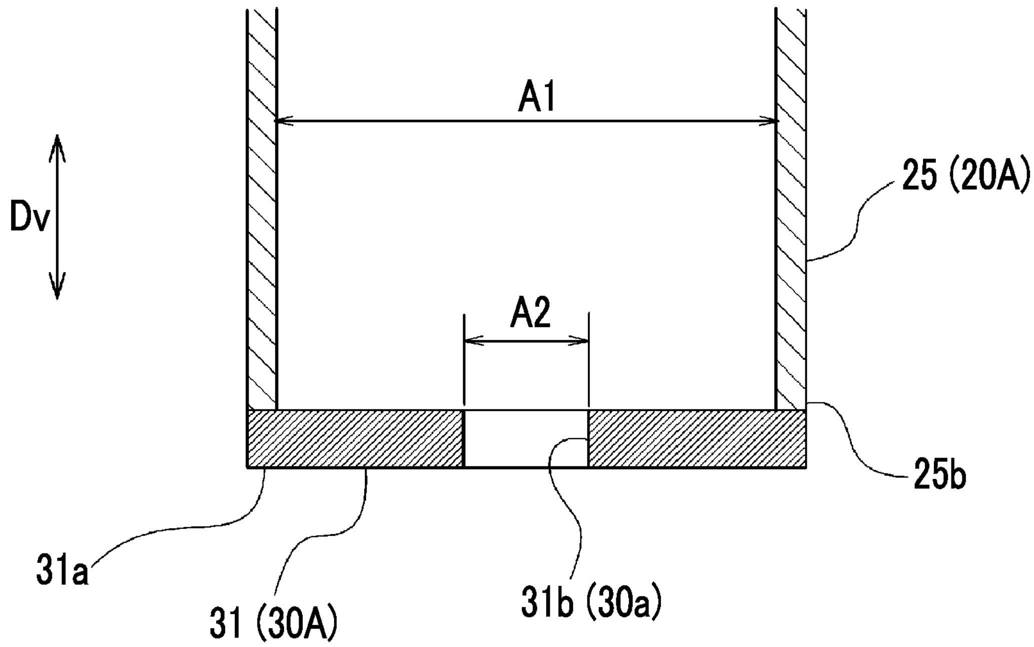

A1
Dv
A2
25 (20A)
25b
31a
31 (30A)
31b (30a)

FIG. 4

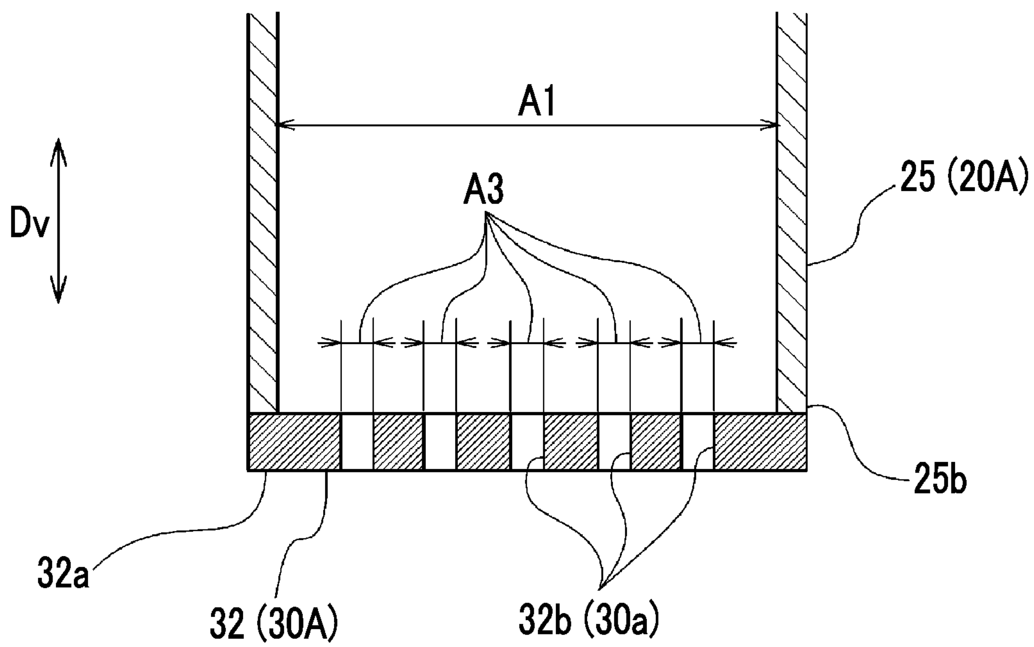

A1
A3
Dv
25 (20A)
25b
32a
32 (30A)
32b (30a)

FIG. 5

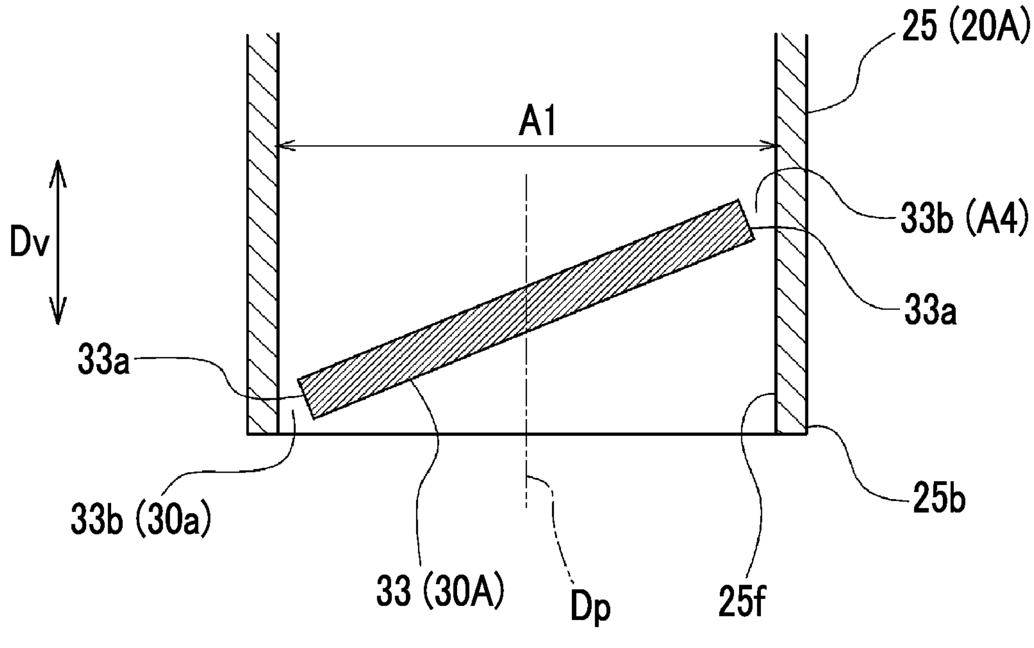


FIG. 6

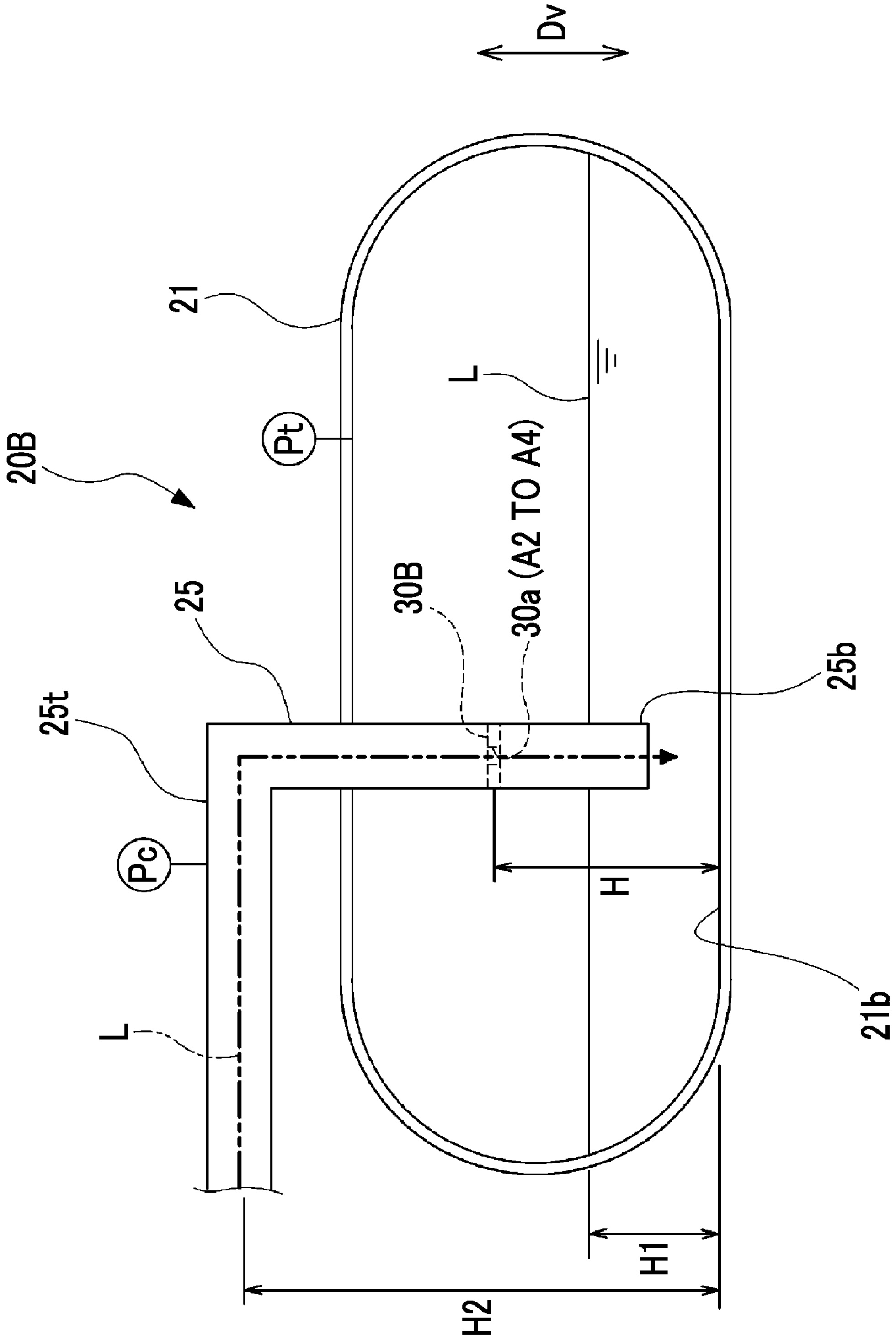


FIG. 7

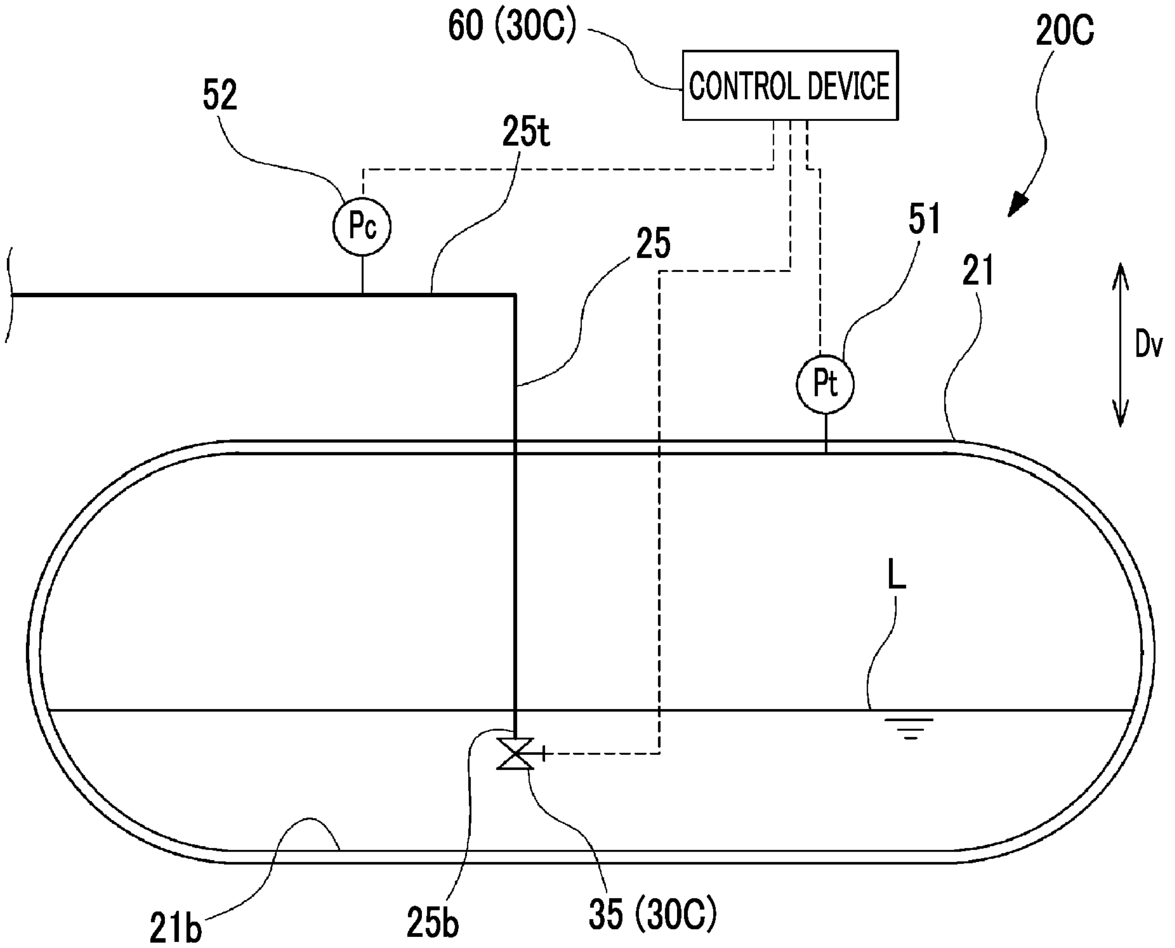

60 (30C)
CONTROL DEVICE
20C
52
25t
Pc
25
51
21
Dv
Pt
L
21b
25b
35 (30C)

FIG. 8

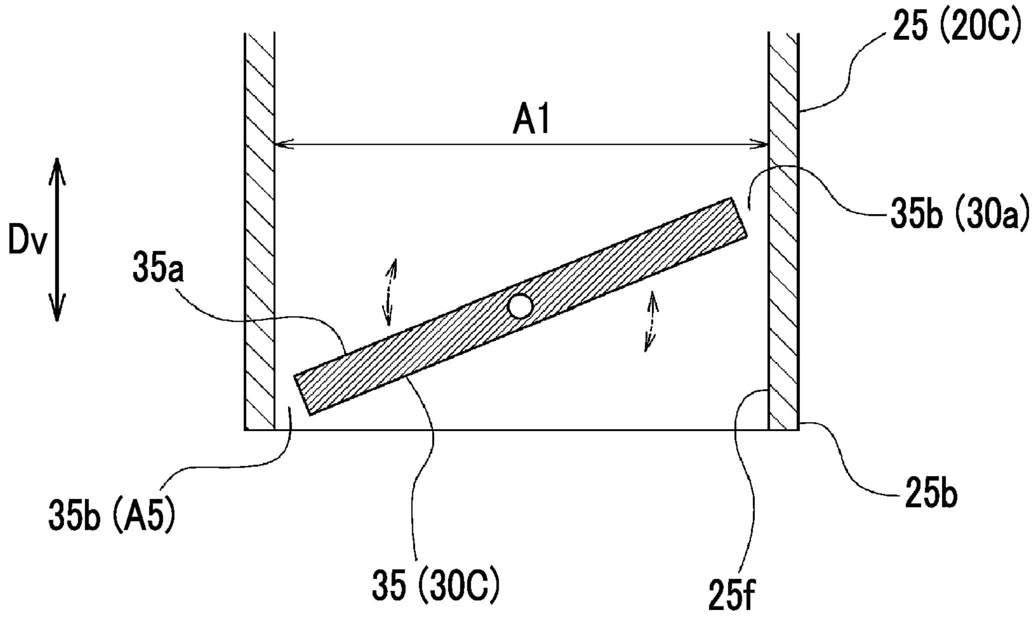

25 (20C)
A1
35b (30a)
Dv
35a
35b (A5)
25b
35 (30C)
25f

FIG. 9

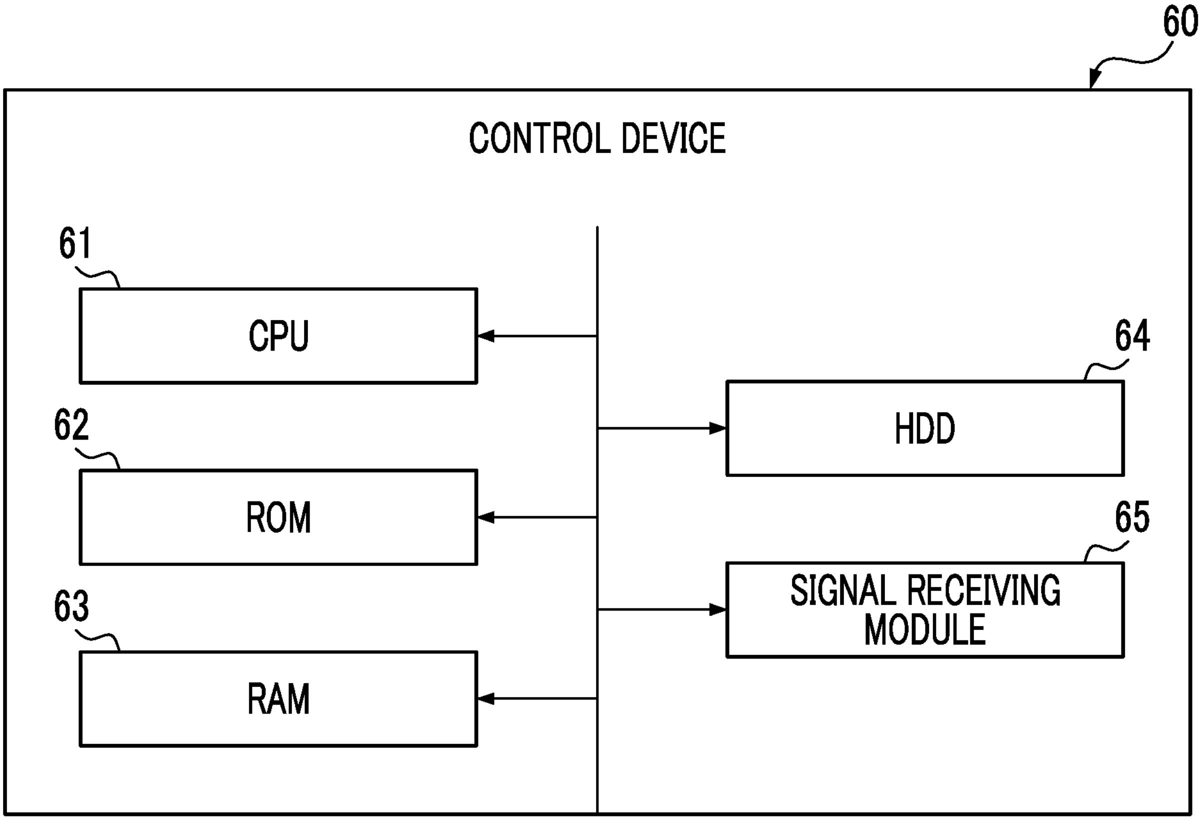

60
CONTROL DEVICE
61
CPU
62
ROM
63
RAM
64
HDD
65
SIGNAL RECEIVING MODULE

FIG. 10

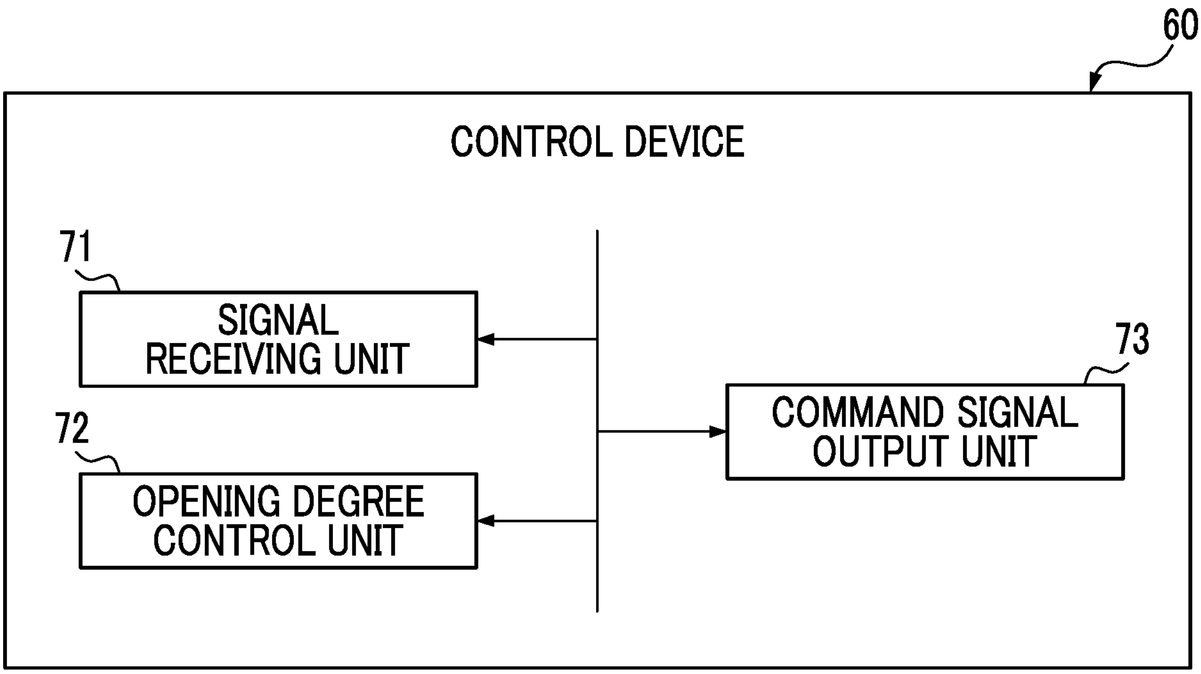
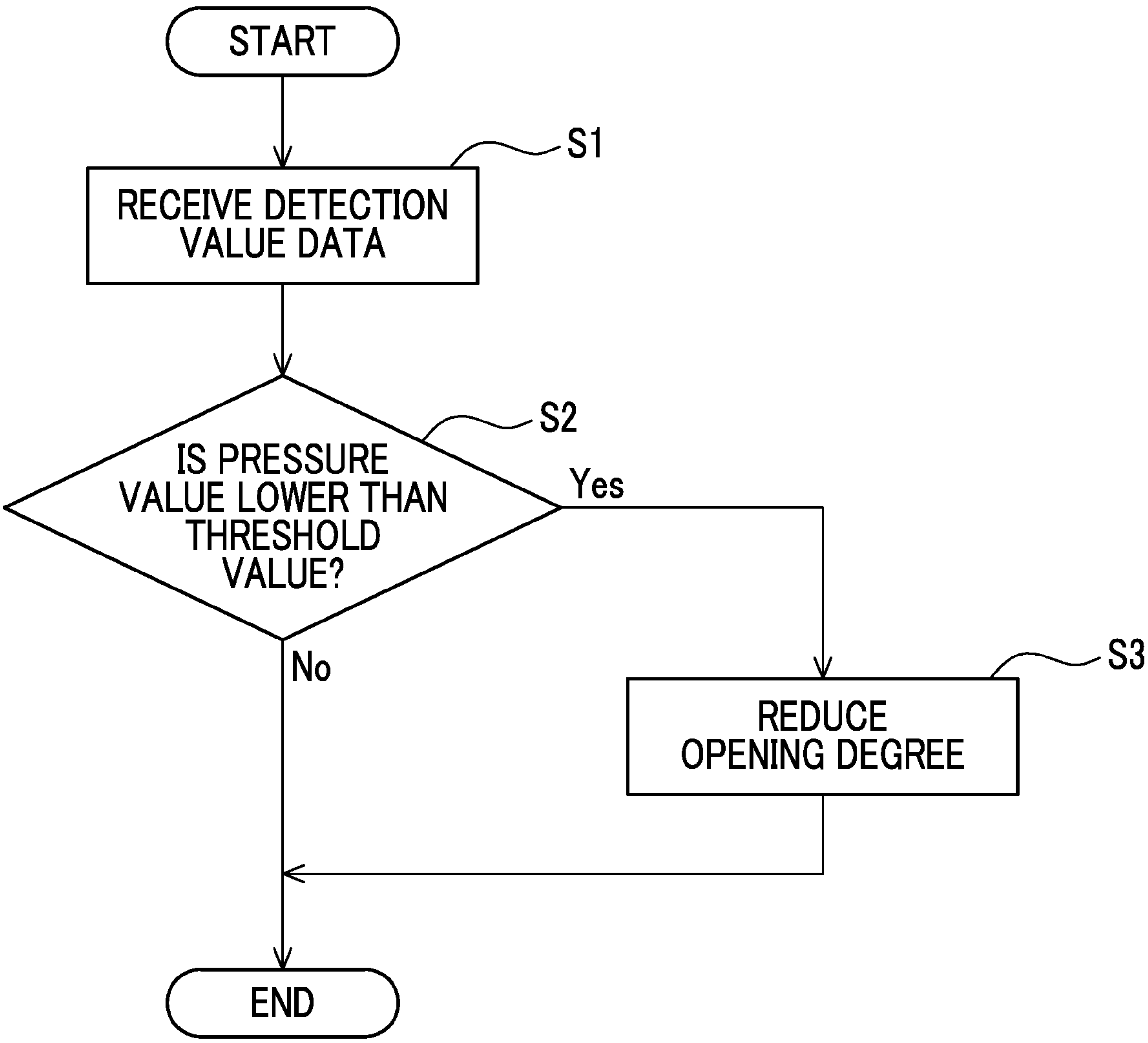

60
CONTROL DEVICE
71
SIGNAL RECEIVING UNIT
72
OPENING DEGREE CONTROL UNIT
73
COMMAND SIGNAL OUTPUT UNIT

FIG. 11


START
S1
RECEIVE DETECTION VALUE DATA
S2
IS PRESSURE VALUE LOWER THAN THRESHOLD VALUE?
Yes
No
S3
REDUCE OPENING DEGREE
END

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2020/048258

A. CLASSIFICATION OF SUBJECT MATTER
B63B 25/16(2006.01)i; F17C 5/02(2006.01)i; B65D 90/00(2006.01)i
FI: F17C5/02 Z; B63B25/16 Z; B65D90/00 H
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
B63B25/16; F17C5/02; B65D90/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2021
Registered utility model specifications of Japan	1996-2021
Published registered utility model applications of Japan	1994-2021

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 8-207989 A (ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.) 13 August 1996 (1996-08-13) paragraphs [0011]-[0025], fig. 1-2	1-8
A	JP 9-142576 A (ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.) 03 June 1997 (1997-06-03) paragraphs [0010]-[0022], fig. 1-4	1-8
A	JP 10-86995 A (ISHIKAWAJIMA-HARIMA HEAVY INDUSTRIES CO., LTD.) 07 April 1998 (1998-04-07) paragraphs [0019]-[0036], fig. 1-6	1-8
A	JP 2005-517144 A (L'AIR LIQUIDE, SOCIÉTÉ ANONYME À DIRECTOIRE ET CONSEIL DE SURVEILLANCE POUR L'ÉTUDE ET L'EXPLOITATION DES PROCÉDÉS GEORGES CLAUDE) 09 June 2005 (2005-06-09) paragraphs [0076]-[0098], fig. 1-2	1-8

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 February 2021 (17.02.2021)	02 March 2021 (02.03.2021)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2020/048258

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 8-207989 A	13 Aug. 1996	(Family: none)	
JP 9-142576 A	03 Jun. 1997	(Family: none)	
JP 10-86995 A	07 Apr. 1998	(Family: none)	
JP 2005-517144 A	09 Jun. 2005	US 2005/0126188 A1 paragraphs [0086]-[0107], fig. 1-2 WO 2003/067144 A2 EP 1474632 A2	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2019231720 A **[0002]**
- JP 5769445 B **[0004]**