[DESCRIPTION]

[Invention Title]

LIQUEFIED GAS STORAGE TANK SYSTEM, AND DESIGN AND MANUFACTURING METHOD THEREOF

[Technical Field]

The present invention relates to a liquefied gas storage tank system of a ship, and a pressure design method and a manufacturing method thereof.

[Background Art]

In general, liquefied gas is carried or stored using a liquefied gas storage tank of maritime structures such as ships. Among these liquefied gases, liquefied natural gas (LNG) and liquefied petroleum gas (LPG) are stored in the liquefied gas storage tank in extremely low temperature states of -160°C and -45°C, respectively. Among the liquefied gas storage tanks, a thickness of a pressure vessel type C-type liquefied gas storage tank is designed for each part such as a head, a shell, a saddle, a dome, a sump, etc., of a tank by reflecting internal pressure and external pressure design conditions according to a use purpose. That is, the thickness is designed for each part so as to sufficiently endure internal and external design pressures and each part of the C-type liquefied gas storage tank is manufactured according to the thickness. Internal pressure and external pressure of the liquefied gas storage tank are designed by reflecting each item defined in International Code of safety for ships using Gases or other low-flashpoint Fuels (IGF Code).

[Disclosure]

[Technical Problem]

A C-type liquefied gas storage tank should endure external pressure thereof in

addition to internal pressure thereof. Therefore, when a pressure design for the C-type liquefied gas storage tank is conducted, design internal pressure Pi and design external pressure Pe should be independently considered. That is, after an internal pressure thickness Ti to endure the design internal pressure Pi and an external pressure thickness Te to endure the design external pressure Pe are calculated, a thickness for each part of the liquefied gas storage tank is designed by using a larger value of both calculated values.

However, under the conventional pressure design, the design internal pressure Pi (0.7 to 0.75 MPa(g)) is even higher than the design external pressure Pe (0.02 to 0.045 MPa(g)) (i.e., the internal pressure thickness Ti is even larger than the external pressure thickness Te), so a final thickness of the liquefied gas storage tank is determined by the design internal pressure Pi and fluctuation of the design external pressure Pe does not influence the final thickness of the liquefied gas storage tank. Even though the design external pressure is changed, the resulting change of the external pressure thickness Te is smaller than the change of the internal pressure thickness Ti, so the change of the design external pressure is thus irrespective of the thickness for each part of the liquefied gas storage tank and a weight.

Therefore, conventionally, when the external pressure is designed, all external pressure items defined in the IGF Code are reflected habitually without any doubt. In the extremely reflecting all external pressure items defined in the IGF Code in the design external pressure, in spite of reflecting a value larger than a value generally set for each item defined in the IGF Code, the internal pressure is still large, so even though the external pressure is designed with a value which deviates from general perception, the external pressure does not influence the thickness and the weight of the liquefied gas storage tank, and the thickness of each part of the liquefied gas storage is determined by

the design internal pressure. That is, conventionally, in designing the liquefied gas storage tank, since the external pressure is irrespective of the thickness and the weight of the liquefied gas storage tank (may be matters accepted as a technical common sense in designing and manufacturing the liquefied gas storage tank), the design external pressure is not an interest target, and moreover, the reduction of the thickness and the weight of the liquefied gas storage tank through reduction of the design external pressure is inconceivable.

However, the present inventors provide new technology which can reduce the thickness and the weight of the liquefied gas storage tank by a new scheme by departing from a technical common sense or prejudice or common idea in designing and manufacturing the liquefied gas storage tank as described above. The present inventors provide new technology that enhances design and manufacturing competitiveness of the liquefied gas storage tank through optimization of the thickness for each part of the liquefied gas storage tank.

[Technical Solution]

The new technology that can reduce the thickness and weight of the liquefied gas storage tank provided by the present inventors is based on a technical idea in which the design external pressure determines the thickness of the liquefied gas storage, with departing from the conventional technical common sense, prejudice, or the common idea. Therefore, the design external pressure may be reduced by removing some items of the items constituting (defining) the design external pressure or reducing values of some items, and as a result, the thickness and weight of the liquefied gas storage tank may be reduced.

Without being bound by any particular theory, the present inventors, reveal that

even when the design internal pressure is still even larger than the design external pressure, the thickness and weight of the liquefied gas storage tank are determined as follows when the design internal pressure is within a specific range.

(1) Condition in which the design internal pressure is about 0.65 MPa(g) or more (about 6.5 bar(g) or more) (e.g., about 0.65 to 0.70 MPa(g)):

Similar to the prior art, the thickness and the weight of the liquefied gas storage tank are determined by the design internal pressure regardless of a change in design external pressure (e.g., a change between about 0.045 and 0.020 MPa(g)).

(2) Condition in which the design internal pressure is less than about 0.65 MPa(g) (less than about 6.5 bar(g)):

The reduction of the design external pressure reduces the thickness and weight of the liquefied gas storage tank.

(i) When the design internal pressure is larger than about 0.45 MPa(g) (i.e., when the design internal pressure is larger than 0.45 MPa(g) and smaller than about 0.65 MPa(g)): The thickness and weight of the liquefied gas storage tank are determined by both the design external pressure and the design internal pressure. For example, in the case that the design external pressure is in the range of about 0.045 to 0.03 MPa(g), when the design internal pressure is about 0.55 MPa(g), the thickness and weight of the liquefied gas storage tank are fully determined by the change in design external pressure, but when the design external pressure is a range smaller than the above range, e.g., the range of about 0.03 to 0.02 MPa(g), the change in design external pressure in the range is irrespective of the thickness and weight of the liquefied gas storage tank and the thickness and weight of the liquefied gas storage tank are determined by the design internal pressure;

(ii) When the design internal pressure is equal to or smaller than about 0.45

MPa(g):

The thickness and weight of the liquefied gas storage tank are fully determined by the design external pressure.

The fluctuation of the design external pressure in the range of about 0.045 to 0.02 MPa(g) determines the thickness and weight of the liquefied gas storage tank.

Accordingly, in the case of Condition (2) for the design internal pressure (i.e., when the design internal pressure is less than about 0.65 MPa(g)), the thickness and weight of the liquefied gas storage tank may be reduced by lowering the design pressure (design internal pressure/design external pressure). For example, when the design internal pressure is less than about 0.65 MPa(g), the design external pressure is lowered to reduce the thickness and weight of the liquefied gas storage tank. When the external pressure is designed, some items are removed among items constituting the design external pressure or values of the items are reduced to thereby reduce the thickness and weight of the liquefied gas storage tank.

For example, while operating the liquid gas storage tank, the vacuum pressure may be generated. Accordingly, when the liquid gas storage tank is designed, a minimum of about 0.025 MPa(g) for the vacuum pressure item P1 considering the vacuum pressure inside the liquefied gas storage tank should be at least considered as one external pressure item of the external pressure in addition to other items for external pressure (P2: the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels, P3: compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected, and P4: external pressure due to head of water for

pressure vessels or part of pressure vessels on exposed decks). Accordingly, the external pressure will be designed as at least about 0.040 MPa(g). Here, the vacuum pressure item considering the vacuum pressure inside the liquefied gas storage tank is at least about 0.025 MPa(g) and occupies a half or more in the design external pressure, 0.040 MPa(g).

Therefore, in the case of condition (2) for the design internal pressure (i.e., when the design internal pressure is less than about 0.65 MPa(g)), reducing or illuminating a vacuum pressure inside the liquefied gas storage tank, that is, removing or reducing the vacuum pressure item P1 among external pressure constituting items P1 to P4, allows for reducing the design external pressure and thereby reducing the thickness and weight of the liquefied gas storage tank.

Therefore, one aspect of the present invention provides a pressure design method, a method for manufacturing a liquefied gas storage tank system, and the resulting liquefied gas storage tank system which are capable of reducing a thickness of a liquefied gas storage tank, and reducing a weight and cost of the liquefied gas storage tank.

Further, another aspect of the present invention provides a liquefied gas storage tank system which effectively respond to both positive pressure and negative pressure, and simplify a facility for responding to the positive pressure and the negative pressure and reduce cost.

A liquefied gas storage tank system according to an embodiment of the present invention includes: a liquefied gas storage tank designed by design internal pressure and design external pressure under design internal condition which allows at least the design external pressure to determine a thickness of the liquefied gas storage tank; and a vacuum pressure relief valve coupled to the liquefied gas storage tank and relieving the vacuum pressure generated inside the liquefied gas storage tank.

A pressure designing method for manufacturing a liquefied gas storage tank according to an embodiment of the present invention includes: judging whether design internal pressure is within a reference pressure range in which a thickness of the liquefied gas storage tank is determined at least by design external pressure; and determining, when the design internal pressure is within the reference pressure range, the design external by removing or reducing a vacuum pressure item defined for a vacuum pressure inside the liquefied gas storage tank from pressure items defining the design external pressure.

A method for manufacturing a liquefied gas storage tank according to an embodiment of the present invention includes: manufacturing a liquefied gas storage tank according to determined design internal pressure and determined design external pressure under a design internal pressure condition which allows at least the design external pressure to determine a thickness of the liquefied gas storage tank; and coupling a pressure control valve for controlling internal pressure of the liquefied gas storage tank to the liquefied gas storage tank.

[Advantageous Effects]

According to an embodiment of the present invention, a thickness of a liquefied gas storage tank can be reduced, and a weight and cost of the liquefied gas storage tank can be reduced.

Further, according to an embodiment of the present invention, it is possible to effectively respond to both positive pressure and vacuum pressure in the liquefied gas storage tank, and a facility for responding to the positive pressure and the vacuum pressure can be simplified and cost can be reduced.

Further, according to an embodiment of the present invention, it is possible to prevent liquefied gas stored in the liquefied gas storage tank from flowing back to the

outside, and it is possible to effectively respond to both the positive pressure and the vacuum pressure in the liquefied gas storage tank, and the facility for responding to the positive pressure and the vacuum pressure can be simplified and the cost can be reduced.

Problems to be solved by the preset invention, and effects are not limited to objects and effects mentioned above. Other technical problems and effects not mentioned will be able to be apparently appreciated by those skilled in the art to which the present invention belongs from the following description.

[Description of Drawings]

FIG. 1 schematically illustrates a design external pressure range exerted on a thickness and a weight of a liquefied gas storage tank, which is derived from a result a research result based on a new scheme related to a pressure design for a liquefied gas storage tank by the present inventors.

FIG. 2 schematically illustrates a pressure design method of determining a thickness of a liquefied gas storage tank according to an embodiment of the present invention.

FIG. 3 schematically illustrates a manufacturing method of a liquefied gas storage tank system according to a pressure design of FIG. 2.

FIG. 4 schematically illustrates a liquefied gas storage tank system according to an embodiment of the present invention.

FIG. 5 illustrates a combination of a vacuum pressure relief valve and a liquefied gas storage tank according to an embodiment of the present invention.

FIG. 6 is a diagram for schematically describing an operation of the vacuum pressure relief valve according to an embodiment of the present invention.

FIG. 7 schematically illustrates a liquefied gas storage tank system according to

another embodiment of the present invention.

FIG. 8 is a diagram schematically illustrating a liquefied gas storage tank system according to yet another embodiment of the present invention.

FIG. 9 is a diagram schematically illustrating a liquefied gas storage tank system having an isolation valve according to an embodiment of the present invention.

FIG. 10 is a diagram schematically illustrating a liquefied gas storage tank system according to still yet another embodiment of the present invention.

FIG. 11 illustrates a combinational relationship between a positive pressure derivation valve, and a liquefied gas storage tank and a vacuum pressure resolution source of FIG. 10.

FIG. 12 is a graph for describing an effect according to an embodiment of the present invention.

FIG. 13 is a diagram schematically illustrating a liquefied gas storage tank system according to still yet another embodiment of the present invention.

FIG. 14 is a diagram schematically illustrating a liquefied gas storage tank system according to still yet another embodiment of the present invention.

FIG. 15 is a diagram schematically illustrating a liquefied gas storage tank system according to still yet another embodiment of the present invention.

FIGS. 16 and 17 are diagrams illustrating an operating state of the liquefied gas storage tank system according to the embodiment of FIG. 15, and FIG. 16 illustrates a state in which a vacuum pressure relief valve performs a pressure derivation operation and FIG. 17 illustrates a state in which the vacuum pressure relief valve performs a vacuum derivation operation.

[Modes for the Invention]

Advantages and features of the present invention, and methods for accomplishing the same will be more clearly understood from embodiments described in detail below with reference to the accompanying drawings. However, the present invention is not limited to the embodiments disclosed below, and the present invention is just defined by a category of the claims. Even if it is not defined, all terms used here (including technology or scientific terms) have the same meaning as commonly accepted by universal technology in the prior art in which this invention belongs. The general description of the known configuration can be omitted to avoid blurring the point of the present invention. In the drawing of the present invention, the same reference numeral is used for the same or corresponding component. In order to help understand the present invention, some components in the drawing may be somewhat exaggerated or reduced.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the inventive concept. As used herein, the singular forms “a”, “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

It will be understood that, although the terms “first”, “second”, “third”, etc., may be used herein to describe various elements, components, these elements, components, should not be limited by these terms. These terms are only used to distinguish one element, component from another element, component. Thus, a first pipe and a first pipe part in

one embodiment could be termed a second pipe and a second pipe part in another embodiment, respectively without departing from the teachings of the inventive concept.

For the purposes of this specification and appended claims, unless otherwise indicated, all numbers expressing quantities, percentages or proportions, and other numerical values used in the specification and claims, are to be understood as being modified in all instances by the term “about.” The use of the term “about” applies to all numeric values, whether or not explicitly indicated. This term generally refers to a range of numbers that one of ordinary skill in the art would consider as a reasonable amount of deviation to the recited numeric values (i.e., having the equivalent function or result). For example, this term can be construed as including a deviation of ±10 percent, alternatively ±5 percent, alternatively ±1 percent, alternatively ±0.5 percent, and alternatively ±0.1 percent of the given numeric value provided such a deviation does not alter the end function or result of the value. Accordingly, unless indicated to the contrary, the numerical parameters set forth in this specification and attached claims are approximations that can vary depending upon the desired properties sought to be obtained by the present invention.

Contents disclosed in the present invention relate to a liquefied gas storage tank system, and provide technology that can reduce a thickness of a liquefied gas storage tank, and reduces a weight and cost of the liquefied gas storage tank.

The thickness of the liquefied gas storage tank depends on design pressure for internal pressure and external pressure of the liquefied gas storage tank, and embodiments of the present invention provide a method that reduces the thickness or a weight of the liquefied gas storage tank by decreasing a design pressure value for the external pressure of the liquefied gas storage tank consequently through a technical idea capable of removing or minimizing some of items constituting the external pressure at the time of

designing the external pressure of the liquefied gas storage tank.

A C-type liquefied gas storage tank should endure an internal pressure thereof in addition to external pressure thereof. That is, after an internal pressure thickness Ti to endure design internal pressure Pi and an external pressure thickness Te to endure design external pressure Pe are calculated by independently considering the design internal pressure Pi and the design external pressure Pe, the pressure for the C-Type liquefied gas storage tank is designed by using a larger value of both calculated values.

In general, the design internal pressure of the C-type liquefied gas storage tank which is about 0.7 to 0.75 MPa(g) (about 7 to 7.5 bar(g)), for example is at least 16 to 17 times or more larger than the design external pressure (average about 0.045 MPa(g)). Therefore, a design thickness of each part of the liquefied gas storage tank, e.g., a head, a shell, a saddle, a dome, a sump, etc., is determined by the design internal pressure. That is, under the conventional design internal pressure (0.7 to 0.75 MPa(g)), the thickness and weight of the liquefied gas storage tank are determined according to the design internal pressure regardless of the size of the design external pressure. Conventionally, since a change in design external pressure does not influence the thickness and weight of the liquefied gas storage tank, all external pressure items defined in the IGF Code are habitually reflected without any doubt when designing the external pressure.

The design external pressure being irrespective of the thickness and weight of the liquefied gas storage tank in designing the liquefied gas storage tank is a technical common sense, prejudice, or a common idea, and thus the design external pressure is not a target of interest, and moreover, it is unimaginable to promote the reduction of the thickness and weight of the liquefied gas storage tank through a change in design external

pressure (e.g., reduction of the design external pressure).

However, the present inventors provide new technology which can reduce the thickness and the weight of the liquefied gas storage tank by a new scheme by departing from a technical common sense or prejudice or common idea of the industry. The present inventors provide new technology that enhances design and manufacturing competitiveness of the liquefied gas storage tank through optimization of the thickness for each part of the liquefied gas storage tank.

The new technology that can reduce the thickness and weight of the liquefied gas storage tank provided by the present inventors is based on a technical idea in which the design external pressure determines the thickness of the liquefied gas storage, with departing from the conventional technical common sense, prejudice, or the common idea. Therefore, the design external pressure may be reduced by removing some items of the items constituting the design external pressure or reducing values of some items, and as a result, the thickness and weight of the liquefied gas storage tank may be reduced.

Without being bound by any particular theory , the present inventors reveal that even when the design internal pressure is still even larger than the design external pressure, the reduction of the design external pressure reduces the thickness and weight of the liquefied gas storage tank when the design internal pressure is within a specific range. A correlation between the design pressure derived by the present inventors and the thickness and weight of the liquefied gas storage tank is as follows.

(1) Condition in which the design internal pressure is about 0.65 MPa(g) or more (about 6.5 bar(g) or more) (e.g., about 0.65 to 0.70 MPa(g)):

The fluctuation of the design external pressure in the range of about 0.045 to 0.02 MPa(g) does not influence the thickness and weight of the liquefied gas storage tank, and

the thickness and weight of the liquefied gas storage tank are fully determined by the design internal pressure.

(2) Condition in which the design internal pressure is less than about 0.65 MPa(g) (less than about 6.5 bar(g)):

The reduction of the design external pressure reduces the thickness and weight of the liquefied gas storage tank.

(i) When the design internal pressure is larger than about 0.45 MPa(g) under the condition in which the design internal pressure is less than about 0.65 MPa(g) (i.e., when the design internal pressure is larger than 0.45 MPa(g) and smaller than about 0.65 MPa(g)):

The thickness and weight of the liquefied gas storage tank are determined by both the design external pressure and the design internal pressure. That is, the thickness and weight of the liquefied gas storage tank are determined by the design external pressure in design external pressure in a specific range, and the thickness and weight of the liquefied gas storage tank are determined by the design internal pressure in a design external pressure range of the design external pressure or less. For example, in the case that the design external pressure is in the range of about 0.045 to 0.03 MPa(g), when the design internal pressure is about 0.55 MPa(g), the thickness and weight of the liquefied gas storage tank are fully determined by the change in design external pressure, but when the design external pressure is a range smaller than the above range, e.g., the range of about 0.03 to 0.02 MPa(g), the change in design external pressure in the range is irrespective of the thickness and weight of the liquefied gas storage tank and the thickness and weight of the liquefied gas storage tank are determined by the design internal pressure.

(2) When the design internal pressure is equal to or smaller than about 0.45

MPa(g):

The thickness and weight of the liquefied gas storage tank are fully determined by the design external pressure.

The fluctuation of the design external pressure in the range of about 0.045 to 0.02 MPa(g) determines the thickness and weight of the liquefied gas storage tank.

That is, as the design internal pressure is reduced under the condition in which the design internal pressure is still even larger than the design external pressure, a factor in which the thickness and weight of the liquefied gas storage tank are determined changes in the order of the design internal pressure, both the design external pressure and the design internal pressure, and the design external pressure.

Accordingly, in the case of Condition (2) for the design internal pressure (i.e., when the design internal pressure is less than about 0.65 MPa(g)), the thickness and weight of the liquefied gas storage tank may be reduced by lowering the design pressure.

For example, when the design internal pressure is less than about 0.65 MPa(g), a vacuum pressure item P1 among external pressure constituting items P1 to P4 is removed or reduced to reduce the design external pressure and reduce the thickness and weight of the liquefied gas storage tank in response thereto. The removal or reduction of the vacuum pressure item P1 of the design external pressure may be compensated by installing a vacuum pressure relief valve in the liquefied gas storage tank. Accordingly, when the design internal pressure is less than about 0.65 MPa(g), the vacuum pressure relief valve is installed in the liquefied gas storage tank, which causes an unexpected result of the reduction of the thickness and weight of the liquefied gas storage tank. In other words, when the design internal pressure is less than about 0.65 MPa(g), there may be an effect that the vacuum pressure relief valve reduces the thickness and weight of the

liquefied gas storage tank.

Accordingly, when the liquid gas storage tank is designed, a minimum of about 0.025 MPa(g) for the vacuum pressure item P1 considering the vacuum pressure inside the liquefied gas storage tank should be at least considered as one external pressure item of the external pressure in addition to other items for external pressure (P2: the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels, P3: compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected, and P4: external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks). Accordingly, the external pressure will be designed as at least about 0.040 MPa(g). Here, the vacuum pressure item, as at least about 0.025 MPa(g), considering the vacuum pressure inside the liquefied gas storage tank occupies a half or more in the design external pressure, 0.040 MPa(g).

Here, the present inventors notice that the vacuum pressure item considering the vacuum pressure inside the liquefied gas storage tank is at least about 0.025 MPa(g) and occupies a half or more in the design external pressure. Therefore, in an embodiment of the present invention, when vacuum pressure related items are removed or minimized from the items constituting the design external pressure, the effect of reducing the thickness and weight of the liquefied gas storage tank may be maximized. Meanwhile, since the removal/reduction of the vacuum pressure item in the design pressure requires prevention of a vacuum pressure generation situation when operating the liquefied gas storage tank, the liquefied gas storage tank according to an embodiment of the present invention has a means for removing/reducing the vacuum pressure which may be

generated therein. For example, the vacuum pressure relief valve (vacuum relief valve in other words) is used to remove/reduce the vacuum pressure inside the liquefied gas storage tank. The vacuum pressure relief valve is configured to operate to be automatically opened when the pressure in the liquefied gas storage tank is predetermined pressure so as to prevent the inside of the liquefied gas storage tank from being vacuum. For example, vacuum pressure of about 0.005 MPa(g) is generated inside the liquefied gas storage tank, the vacuum pressure relief valve may be configured to be automatically opened. In this case, it will be appreciated that a value of the vacuum pressure item constituting the design external pressure is about 0.005 MPa(g).

Further, in the present invention, a part of a reduction of the vacuum pressure item value constituting the design external pressure is reflected to other items of the design external pressure, e.g., the P3 item (compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected), the P4 item (external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks), etc., to enhance manufacturing flexibility of the liquefied gas storage tank.

Contents disclosed in the present specification provide a method for reducing the thickness and weight of the liquid gas storage tank by reducing the design pressure value for the external pressure of the liquefied gas storage tank, so the embodiments of the present invention will be usefully applied, in particular, to a case where the thickness of the liquefied gas storage tank is determined primarily by the external pressure.

A condition under which the thickness of the liquefied gas storage tank is determined by the design external pressure may include a case where the design internal

pressure is a predetermined rang e, e.g., less than about 0.65 MPa(g), and as the design internal pressure decreases, the influence of the design external pressure on the thickness of the liquefied gas storage tank gradually increases, and when the design internal pressure is about 0.45 MPa(g), the thickness of the liquefied gas storage tank is fully determined by the design external pressure. Therefore, the embodiments of the present invention may be usefully applied to the case where the design pressure for the internal pressure of the liquefied gas storage tank is less than about 0.65 MPa(g), for example.

One specific example of the present invention provides a method for manufacturing a liquefied gas storage tank considering that the design external pressure of the liquefied gas storage tank is a minimum of about 0.020 MPa(g) and the design internal pressure is less than about 0.65 MPa(g).

Hereinafter, the method will be descried with reference to the drawings.

FIG. 1 schematically illustrates a design external pressure range exerted on a thickness and a weight of a liquefied gas storage tank, which is derived from a result a research result based on a new scheme related to a pressure design for a liquefied gas storage tank by the present inventors. FIG. 1 illustrates a weight change (unit: %) (vertical axis) of the liquefied gas storage tank depending on a change in design external pressure Pe (0.045 MPa(g) -> 0.02 MPa(g)) (horizontal axis) when design internal pressure Pi is variously changed like about 0.45 MPa(g), about 0.55 MPa(g), and about 0.65 MPa(g).

In FIG. 1, the case where the design external pressure is 0.045 MPa(g) is displayed 100% by setting a reference weight in relation to the weight change of the liquefied gas storage tank, and for example, 90% means that the weight of the liquefied gas storage tank is reduced as compared with the case where the design external pressure

is 0.045 MPa(g) by about 10%.

Referring to FIG. 1, it may be verified that under design internal pressure in a specific range, as the design external pressure is changed (i.e., as the design external pressure is reduced), the weight of the liquefied gas storage tank is changed (reduced).

Specifically, it can be seen that when the design internal pressure is about 0.65 MPa(g) or larger than 0.65 MPa(g), even though the design external pressure is changed (i.e., even though the design external pressure is reduced from about 0.045 MPa(g) to about 0.02 MPa(g)), there is no change in weight of the liquefied gas storage tank. That is, when the design internal pressure is about 0.65 MPa(g) or larger than 0.65 MPa(g), the thickness and weight of the liquefied gas storage tank fully depend on the design internal pressure.

However, it can be seen that when the design internal pressure is about 0.45 MPa(g) or lower than 0.45 MPa(g), the weight of the liquefied gas storage tank is reduced in proportion to the reduction in the design external pressure. That is, it may be verified that as the design external pressure is reduced as in 0.045 MPa(g) -> 0.04 MPa(g) -> 0.035 MPa(g) -> 0.030 MPa(g) -> 0.025 MPa(g) -> 0.020 MPa(g), the weight of the liquefied gas storage tank is gradually reduced as in 100% -> 99% -> 92% -> 88% -> 84% -> 80%. For example, in the case where the design internal pressure is about 0.45 MPa(g), when the design external pressure is reduced from about 0.045 MPa(g) to about 0.025 MPa(g), the weight of the liquefied gas storage tank is reduced by about 16% and when the design external pressure is reduced to about 0.020 MPa(g), the weight of the liquefied gas storage tank is reduced by about 20%.

Meanwhile, when the design internal pressure is lower than about 0.65 MPa(g), but higher than about 0.45 MPa(g), the weight of the liquefied gas storage tank is

influenced by the design external pressure in the specific range. In the range of the design external pressure of about 0.045 MPa(g) to 0.030 MPa(g), as the design external pressure is reduced, the weight of the liquefied gas storage tank is reduced. However, in the case that the design external pressure is in the range of 0.030 MPa(g) to 0.020 MPa(g), there is no change in liquefied gas storage tank in response to the reduction in the design external pressure.

Referring to FIG. 1, it can be seen that when the design internal pressure is equal to or larger than 0.65MPa(g), the change in design external pressure does not influence the weight of the liquefied gas storage tank, but when the design internal pressure is smaller than about 0.65MPa(g), the weight of the liquefied gas storage tank is reduced with the change in design external pressure (with the reduction in design external pressure).

That is, the present inventors derive an unexpected surprising result that the design external pressure influences the thickness and thus the weight of the liquefied gas storage tank when the design internal pressure is in a specific range, unlike a general technical common sense known to the industry.

Therefore, when the present inventors utilize the technical idea or an invention concept which may be verified in FIG. 1 presented, the weight of the liquefied gas storage tank may be reduced and the cost may be reduced. This will be described in detail by referring back to FIG. 1. When the design internal pressure is set to less than 0.65 MPa(g), the design external pressure can be reduced to reduce the thickness and thus weight of the liquefied gas storage tank in response to the reduction of the design external pressure. In particular, since the external pressure component P1 (about 0.025 MPa(g), considering the vacuum pressure which may be generated while operating the liquefied

gas storage tank) is a half or more of a total external pressure P1 to P4 (about 0.045MPa(g) on average), simply removing or reducing vacuum pressure component P1 from the design external pressure components can reduce the weight of the liquefied gas storage tank in a large range. Further, since the vacuum pressure item in the design external pressure is considered in view of the vacuum pressure generation situation inside the liquefied gas storage tank, exclusion of the vacuum pressure related item requires that the vacuum pressure should not be generated inside the liquefied gas storage tank, and this may be implemented by providing the vacuum pressure relief valve in the liquefied gas storage tank.

For example, when it is assumed that the design internal pressure is set to about 0.45 MPa(g) and the vacuum pressure relief valve is installed in the liquefied gas storage tank, the vacuum pressure related item P1 among the items constituting the design external pressure may be reduced, and the design external pressure may be substantially reduced by about 0.020MPa(g) by considering an operating tolerance of the vacuum pressure relief valve, and as a result, the weight of the liquefied gas storage tank may be reduced by about 16% as illustrated in FIG. 1.

On the contrary, as can be determined in FIG. 1, the thickness and weight of the liquefied gas storage tank fully depend on the design internal pressure when the design internal pressure is about 0.65 MPa(g) or larger than 0.65 MPa(g). Accordingly, when the conventional design internal pressure is designed as 0.7 to 0.75 MPa(g), the reduction of the weight of the liquefied gas storage tank may not be achieved, unlike the embodiments of the present invention, in spite of reducing the design external pressure by installing the vacuum pressure relief valve. Therefore, in the conventional case, reducing the weight of the liquefied gas storage tank by coupling the vacuum pressure

relief valve to the liquefied gas storage tank goes beyond technical common sense and rule of thumb and is inconceivable.

An embodiment of the present invention provides a method for designing the pressure to determine the thickness of the liquefied gas storage tank based on a basic concept or the technical idea of the present invention described above, and accordingly manufacturing the liquefied gas storage tank system.

FIG. 2 schematically illustrates a pressure design method of determining a thickness of a liquefied gas storage tank according to an embodiment of the present invention.

In step S11, design internal pressure P_{d_int} is determined in a pressure design associated with the thickness of the liquefied gas storage tank, and it is determined whether the determined design internal pressure P_{d_int} is a reference pressure value or is within a reference pressure range P_{ref} in which the thickness of the liquefied gas storage tank is determined by the design external pressure P_{d_ext}. In the step S10, the reference pressure range P_{ref} may be less than 0.65 MPa(g), for example in an embodiment. In the step S11, the reference pressure range may be, for example, equal to or larger than about 0.45 MPa(g) and less than about 0.65 MPa(g), for example, equal to or larger than about 0.45 MPa(g) and smaller than about 0.55 MPa(g), for example, equal to or larger than about 0.45 MPa(g) and less than about 0.50 MPa(g), and for example, equal to or larger than about 0.45 MPa(g) and smaller than 0.60 Pa.

In step S13, when the design internal pressure P_{d_int} is within the reference pressure range P_{ref}, vacuum pressure P_{vac} considering the vacuum pressure inside the liquefied gas storage tank is excluded or minimized from pressure items defining (constituting) the design external pressure P_{d_ext} to determine the design external pressure

P_{d_ext}. Conventionally, the vacuum pressure P_{vac} which is one item constituting design external pressure may be a minimum of 0.025 MPa(g) and other external pressure items except the vacuum pressure P_{vac} may be 0.015 MPa(g). However, according to an embodiment of the present invention, in the step S13, the vacuum pressure P_{vac} may be removed or reduced up to 0.005 MPa(g) (i.e., the vacuum pressure P_{vac} may be reduced by a minimum of 0.02 MPa(g)) – this means that the design external pressure is reduced by 0.02 MPa(g) as compared with the conventional design external pressure, and the thickness of the liquefied gas storage tank may be reduced in response to the reduced amount, and as a result, the weight of the liquefied gas storage tank may be reduced.

Therefore, according to an embodiment of the present invention, the determined design external pressure P_{ext} may be a minimum of about 0.020 MPa(g), and the design internal pressure P_{d_int} may be a maximum of about 0.65 MPa(g). In an embodiment, the design external pressure P_{ext} may be, for example, a minimum of about 0.020 MPa(g), equal to or larger than about 0.020 MPa(g) and smaller than about 0.045 MPa(g), equal to or larger than about 0.020 MPa(g) and equal to or smaller than about 0.030 MPa(g), and equal to or larger than about 0.020 MPa(g) and equal to or smaller than about 0.040 MPa(g).

In an embodiment, the design internal pressure P_{d_int} may be smaller than about 0.65 MPa(g). The design internal pressure P_{d_int} may be, for example, equal to or larger than about 0.45 MPa(g) and smaller than about 0.65 MPa(g), for example, equal to or larger than about 0.45 MPa(g) and smaller than about 0.55 MPa(g), for example, equal to or larger than about 0.45 MPa(g) and smaller than about 0.50 MPa(g), and for example, equal to or larger than about 0.45 MPa(g) and smaller than 0.60 MPa(g).

Further, the design internal pressure P_{d_int} may be set to various pressure ranges

(unit: MPa(g)) between 0.45 and 0.65 (including 0.45, but not including 0.65) as a lower limit value and an upper limit value, respectively. Similarly, the design external pressure P_{ext} may be set to various pressure ranges (unit: MPa(g)) between 0.02 and 0.045 (including 0.02, but not including 0.045) a lower limit value and an upper limit value, respectively.

Any set of the design internal pressure P_{d_int} value or ranges and the design external pressure P_{ext} value or range without causing conflict in value in the pressure design of the liquefied gas storage tank, may be selected as the design internal pressure and the design external pressure.

In the method for designing the storage tank described with reference to FIG. 2, the design internal pressure P_{d_int} may be equal to the reference pressure range P_{ref} which becomes a reference for determining the weight of the liquefied gas storage tank by the design external pressure.

Next, referring to FIG. 3, the manufacturing method of the liquefied gas storage tank system according to an embodiment of the present invention by the pressure design of FIG. 2 will be described.

In step S21, the liquefied gas storage tank (to endure the design pressure) is manufactured according to the design internal pressure P_{d_int} and the design external pressure P_{d_ext} determined by the pressure design of FIG. 2. As described above, according to the embodiment, the thickness of the liquefied gas storage tank may be reduced in response to the reduced or removed (external pressure value of) vacuum pressure item among the items constituting the design external pressure in the pressure design, and the weight of the liquefied gas storage tank may be reduced in response to the reduced thickness.

Meanwhile, since the vacuum pressure item is excluded from the items constituting the design external pressure, it should be guaranteed that a vacuum generation situation in the liquefied gas storage tank is excluded. To this end, in step S23, means for preventing /removing a vacuum (vacuum pressure) generation is prepared. For example, as the means for preventing/removing a vacuum pressure generation, the vacuum pressure relief valve may be prepared.

In step S25, the means for preventing/removing a vacuum pressure generation is coupled to the liquefied gas storage tank. For example, the means for preventing/removing a vacuum pressure generation is coupled to an upper portion of the liquefied gas storage tank. In the manufacturing method of the liquefied gas storage tank according to the embodiment, prevention of vacuum generation inside the liquefied gas storage tank may be easily implemented simply by coupling the vacuum pressure relief valve to the liquefied gas storage tank. In the manufacturing method of the liquefied gas storage tank, the order of steps S21 and S23 is not important, and it doesn't matter even though steps S21 and S23 are conducted in a predetermined order. A scheme of coupling the means for preventing/removing a vacuum pressure generation to the liquefied gas storage tank will be able to be appreciated from FIG. 5 and a related following description.

FIG. 4 schematically illustrates a liquefied gas storage tank system according to an embodiment of the present invention. The liquefied gas storage tank system according to the embodiment may be manufactured by the method described with reference to FIG. 3.

Referring to FIG. 4, the liquefied gas storage tank system 1000 includes a liquefied gas storage tank 100 and a vacuum pressure generation preventing/relieving

means 10. Specifically, as the vacuum pressure generation preventing/relieving means, a vacuum pressure relief valve 10 is provided in the liquefied gas storage tank 100. The liquefied gas storage tank 100 includes an internal space for storing liquefied gas, and may be configured to include a pressure vessel type C-type tank having a cylindrical structure of a circular cross section and an insulator covering an exterior of the C-type tank. The C-type tank may accommodate ultra-low temperature state liquefied gas such as liquefied natural gas (LNG), liquefied petroleum gas (LPG), etc., therein. The liquefied gas storage tank 100 may be supported by support devices installed in a ship body. The support devices may be configured to include one or more support devices supporting the C-type liquefied gas storage tank in a fixation state and a support device which may slidably support the C-type tank so as to respond to thermal contraction/expansion of the C-type liquefied gas storage tank.

The vacuum pressure relief valve 10 may be coupled to the upper portion of the liquefied gas storage tank 100. The vacuum pressure relief valve 10 includes a first entrance 10A and a second entrance 10B. The first entrance 10A of the vacuum pressure relief valve 10 is coupled to be fluid communication with the inside at the upper portion of the liquefied gas storage tank 100. The second entrance 10B of the vacuum pressure relief valve 10 is exposed to a vacuum pressure relieving source, e.g., atmosphere or air, or inert gas to be in communication with the vacuum pressure relieving source. For example, an end of the second entrance 10B of the vacuum pressure relief valve 10 is opened to be in communication with the atmosphere or air, or inert gas. Therefore, according to the embodiment, the vacuum pressure relief valve 10 is in an opened state (a state in which the first entrance and the second entrance which are in communication with the inside of the liquefied gas storage tank 100, and as a result, a fluid may flow)

when the vacuum pressure is generated in an internal space of the liquefied gas storage tank 100, and as a result, the atmosphere or inert gas which is in communication with the second entrance 10B is introduced into the liquefied gas storage tank 100 through the first entrance 10A t relieve (remove) the vacuum pressure (vacuum state) of the internal space of the liquefied gas storage tank 100. In the embodiment, the first entrance 10A and the second entrance 10B of the vacuum pressure relief valve 10 may be referred to as an inlet and an outlet, respectively based on a direction in which a fluid such as the atmosphere flows through the vacuum pressure relief valve 10 during operating.

Meanwhile, the vacuum pressure may be pressure of 0 MPa(g) (0 bar(g)) or less, for example. The vacuum pressure relief valve 10 may be configured to be automatically opened to relieve the vacuum pressure when the internal pressure is less than set pressure relation to the vacuum pressure. As an example, the vacuum pressure relief valve 10 may be automatically opened when the pressure of the liquefied gas storage tank 10 is reduced and becomes 0 barg, for example. Alternatively, when a difference between the internal pressure and the external pressure of the liquefied gas storage tank 100 is about 0.005 MPa(g), i.e., when the internal pressure of the liquefied gas storage tank 100 is lower than atmospheric pressure by about 0.005 MPa(g), the vacuum pressure relief valve 10 may be automatically opened, and this corresponds to the case where the vacuum pressure P_{vac} is reduced up to 0.005 MPa(g) in the pressure design method described with reference to FIG. 2. That is, when the liquefied gas storage tank is manufactured according to the embodiment of designing the vacuum pressure item of the design external pressure to 0.005 MPa(g) from conventional 0.025 MPa(g) by 0.002 MPa(g) in the pressure design method described with reference to FIG. 2, the vacuum pressure relief valve coupled to the liquefied gas storage tank is configured

to be automatically opened when the internal pressure of the liquefied gas storage tank is lower than the atmospheric pressure by about 0.005 MPa(g).

A detailed structure of the vacuum pressure relief valve 10 and coupling to the liquefied gas storage tank 100 will be described with reference to FIG. 5.

Referring to FIG. 5, the vacuum pressure relief valve 10 may be configured to include a valve body 10C defining the second entrance 10B (inlet) and the first entrance 10A (outlet), a valve plate 10D, a valve lid 10E, a valve nozzle 10F, and a valve plate guide G. The second entrance 10B and the first entrance 10A are configured to change a flow direction of a fluid such as gas, e.g., change the fluid flow direction at about 90 degrees. The first entrance 10A is coupled to the liquefied gas storage tank 100 to be in fluid communication with the liquefied gas storage tank 100. For example, the first entrance 10A may be coupled to the liquefied gas storage tank 100 through a pipe. The second entrance 10B is in communication with external air, atmosphere, or inert gas. For example, when the vacuum pressure is generated inside the liquefied gas storage tank 100, the external air, atmosphere, or inert gas introduced into the second entrance 10B (inlet) may be introduced into the liquefied gas storage tank 100 through the first entrance 10A (outlet), and as a result, the vacuum pressure inside the liquefied gas storage tank 100 is relieved.

The valve plate 10D is disposed inside the valve body 10C, and is configured to close the second entrance 10B (inlet) (in this case, the valve is in a closed state). The valve lid 10E closes an upper portion of the valve body 10C at an opposite side to the second entrance 10B. A valve plate guide 10G is fixedly coupled to the valve lid 10E, the valve plate 10D is movably coupled to the valve plate guide 10G (vertically movable), and in an idle state, the valve plate 10D is disposed to close the second entrance 10B.

As an example, the valve nozzle 10F may be coupled to an inner wall of the second entrance 10B, and in this case, the valve plate 10D closes one end of the valve nozzle 10F in the valve body 10C to close the second entrance 10B.

The valve plate 10D is configured to move between one end of the valve nozzle 10F and the valve lid 10E according to an internal pressure condition of the liquefied gas storage tank 100. An area ds of a bottom surface (a portion exposed to the second entrance 10B) of the valve plate 10D and a self-weight of the valve plate 10D are set according to a predetermined pressure range or pressure value. That is, when vacuum pressure of a predetermined range or value is generated inside the liquefied gas storage tank 10, the thickness (self-weight) and the area of the bottom surface are accordingly set so that the valve plate 10D seated on the valve nozzle 10F is raised upward toward the valve lid 10E.

When the pressure of the liquefied gas fuel tank 100 is high, force is applied in a lower direction (gravity direction) by the self-weight of the valve plate 10D and the high pressure of the fuel tank 100 (see an arrow on a screen), and as a result, the valve plate 10D is seated on the valve nozzle 10F to keep the valve plate in the closed state.

However, when the internal pressure of the liquefied gas fuel tank 100 is reduced and reaches the vacuum pressure (see FIG. 6A), atmospheric force applied to the area ds becomes larger than the self-weight of the valve plate 10D, so the atmosphere raises the valve plate 10C upward (toward the valve lid 10E) to be in the opened state (a state in which a fluid passage is formed between the first entrance 10A and the second entrance 10B). When the valve is opened, the atmosphere or air is introduced into the liquefied gas fuel tank 100, and as a result, the internal pressure of the fuel gas fuel tank 100 increases and the vacuum pressure is relieved.

When the internal pressure of the fuel gas fuel tank 100 increases by the introduction of the atmosphere and the vacuum pressure is relieved (see FIG. 6B), force applied in a lower direction (in the gravity direction, toward the second entrance 10B) becomes larger than force applied to the area ds of the bottom surface of the valve plate 10D by the self-weight of the valve plate 10D and high pressure of the fuel gas fuel tank 100, and as a result, the valve plate 10D moves downward toward the valve nozzle 10F and is seated on the valve nozzle 10F again and the valve plate is thus closed.

A predetermined pressure range or pressure value inside the liquefied gas storage tank 100 for making the valve plate 10D in the opened state may be, for example, a range of about 0.025 to 0.000 MPa(g) or for example, about -0.040 MPa(g). The predetermined pressure value may be, for example, about 0.050 MPa(g).

The structure of the vacuum pressure relief valve 10 in FIGS. 5 and 6 is just illustrated as an example, and if the vacuum pressure relief valve 10 is automatically opened/closed according to an internal pressure condition of the liquefied gas storage tank 100 to perform an operation of reducing/relieving the vacuum pressure, there is no limit in detailed structure thereof. For example, the structure of the vacuum pressure relief valve 10 may be implemented as a structure in which the valve plate 10D is directly seated on the first entrance 10A in the valve body 10C to close the first entrance 10A.

FIG. 7 illustrates another embodiment of the liquefied gas storage tank system 1000. In the embodiment, the vacuum pressure relief valve 10 is installed adjacent to the upper portion of the liquefied gas storage tank 100 on a pipe 200 connecting the liquefied gas storage tank 100 and a vent mast 300. Specifically, the first entrance 10A of the vacuum pressure relief valve 10 according to the embodiment is in fluid communication with the liquefied gas storage tank 100 through a pipe part 200A of the

pipe 200 at the upper portion of the liquefied gas storage tank 100, and the second entrance 10B is in fluid communication with the vent mast 300 through a pipe part 200B of the pipe 200. Therefore, when the internal pressure of the liquefied gas storage tank 100 is the vacuum pressure of the predetermined range or predetermined value, the vacuum pressure relief valve 10 is opened, and the atmosphere is introduced into the liquefied gas storage tank 100 through the vent mast 300 to relieve (remove/reduce) the internal vacuum pressure.

In the embodiment, the pipe 10 between the vent mast 300 and the vacuum pressure relief valve 10, i.e., the pipe part 200B is filled with nitrogen gas and inert gas, and as a result, it is possible to block a contamination source introduced into the vacuum pressure relief valve 10 from the atmosphere through the bent mast 300. Further, for such a purpose, a filter may also be provided inside the pipe part 200B.

In the embodiment of FIG. 7, the atmosphere is used to relieve the internal vacuum pressure of the liquefied gas storage tank 100, but as illustrated in FIG. 8, the inert gas such as the nitrogen gas may be used. Referring to FIG. 8, in the embodiment, the second entrance 10B of the vacuum pressure relief valve 10 is in communication with an inert gas storage tank 400 through a pipe part 200'B. In the embodiment, the pressure of the inert gas storage tank 400 may also be set to about 0.7 to 1.0 MPa(g). In order to prevent backflow to the inert gas storage tank 400 from the liquefied gas storage tank 100, a check valve may also be provided in the pipe part 200'B between the vacuum pressure relief valve 10 and the inert gas storage tank 400.

In the embodiments described above, in order to maintain and repair the vacuum pressure relief valve 10 between the vacuum pressure relief valve 10 and the liquefied gas storage tank 100, an isolation valve 20 may be provided as illustrated in FIG. 9. As the

isolation valve 2, a ball valve which is manually manipulated may be used.

In all or some of the embodiments, when the internal pressure of the liquefied gas storage tank is positive pressure of a predetermined range or a predetermined value, a positive pressure relief valve (or pressure relief valve) for relieving the internal positive pressure may be further provided, and schematically illustrated in FIG. 10.

FIG. 10 is a diagram schematically illustrating a liquefied gas storage tank system according to still yet another embodiment of the present invention. The liquefied gas storage tank system 1000 according to the embodiment further includes a positive pressure relief valve 30 in addition to the liquefied gas storage tank 100 and the vacuum pressure relief valve 10.

In the case of the embodiment, a rear end part 200B of the pipe 200 connected to the vent mast 300 is branched into a pipe part 200B1 connected to the vacuum pressure relief valve 10 and a pipe part 200B2 connected to the positive pressure relief valve 30 at a branch point 200P. Meanwhile, the positive pressure relief valve 30 includes a first entrance 10'A connected to the pipe part 200B2 and a second entrance 10'B connected to the liquefied gas storage tank 100 through the pipe part 200C.

Since the vacuum pressure relief valve 10 is substantially the same as the vacuum pressure relief valve 10 according to the embodiment described with reference to FIGS. 4 to 9 in terms of a structure, a connection type, and a function, a description thereof will be omitted.

The positive pressure relief valve 30 according to the embodiment operates in pressure higher than the vacuum pressure of the predetermined range or value in which the vacuum pressure relief valve 10 operates, e.g., a positive pressure value or a positive pressure range. That is, when the internal pressure of the liquefied gas storage tank 100

exceeds a predetermined pressure range or pressure value set in relation to the positive pressure, the positive pressure relief valve 30 is set to be automatically opened. Therefore, the positive pressure relief valve 30 according to the embodiment adopts the same structure as the vacuum pressure relief valve 10, but may be implemented as a valve which is different in terms of the connection type, and a thickness and a size of the valve plate, and this will be described with reference to FIG. 11.

Referring to FIG. 11, in the embodiment, the positive pressure relief valve 30 is configured to include the valve body 10C, the first entrance 10'A, the second entrance 10'B, a valve plate 10'D, the valve lid 10E, the valve nozzle 10F, and the valve plate guide 10G. In the embodiment, the second entrance 10'B (inlet) (an entrance opened/closed by the valve plate 10D) of the positive pressure relief valve 30 is configured to be in fluid communication with the liquefied gas storage tank 100, and the first entrance 10'A (outlet) is configured to be in fluid communication with the vent mast 300. Therefore, when the inside of the liquefied gas storage tank 100 is in a predetermined positive pressure or positive pressure range, the valve plate 10'D is raised by the pressure and opened, and as a result, the inside of the liquefied gas storage tank 100 is in communication with external atmosphere to relieve predetermined positive pressure inside the liquefied gas storage tank 100. For example, when the pressure in the liquefied gas storage tank 100 reaches, for example, 100 mbarg, the self-weight (thickness) and a bottom area (ds;) of the valve plate 10'D of the positive pressure relief valve 30 may be set so that the positive pressure relief valve 30 is opened.

In the embodiment, when the self-weight (thickness) and the bottom area ds of the valve plate of each of the vacuum pressure relief valve 10 and the positive pressure relief valve 30 are appropriately set to be automatically opened/closed in response to a

predetermined vacuum pressure range (value) and a predetermined positive pressure range (value) inside the liquefied gas storage tank 100, respectively.

Hereinabove, according to the embodiment, it is possible to respond to the vacuum pressure when the negative pressure is generated in the liquefied gas storage tank 100 and it is also possible to respond to the positive pressure when the positive pressure is generated by the vacuum pressure relief valve 10 and the positive pressure relief valve 30.

Even in the embodiment described with reference to FIGS. 10 and 11, the valves 10 and 30 may be coupled to the inert gas storage tank 400 instead of the vent mast 300. Further, the isolation valve (see FIG. 9) may be further provided between the vacuum pressure relief valve 10 and the liquefied gas storage tank 100 and/or between the positive pressure relief valve 30 and the liquefied gas storage tank 100 for maintenance and repairing.

Next, effects according to the embodiments of the present invention may be verified in FIG. 12. FIG. 12 is a diagram in which a design weight change of the liquefied gas storage tank is represented by % when the design external pressure is changed to 0.02 to 0.045 MPa(g) in a state in which the design internal pressure is fixed to 0.49 MPa(g) when a liquefied gas storage tank having a capacity of 1750m^3 is manufactured. Referring to FIG. 12, according to an embodiment of the present invention, when the vacuum pressure item is reduced from 0.025 MPa(g) to 0.005 MPa(g) and the design external pressure is reduced from 0.040 MPa(g) to 0.020 MPa(g), the weight of the liquefied gas storage tank may be reduced by 15% points.

Hereinafter, other embodiments of the present invention will be described with reference to FIGS. 13 to 17. In embodiments described below, the vacuum pressure

relief valve and the positive pressure relief valve may also be configured similarly to the vacuum pressure relief vale and the positive pressure relief valve of the embodiments described with reference to FIGS. 1 to 12.

The liquefied gas storage tank system according to another embodiment of the present invention may include the liquefied gas storage tank, the vacuum pressure relief valve relieving the vacuum pressure (removing the vacuum pressure state) inside the liquefied gas storage tank when the vacuum is generated in the internal space of the liquefied gas storage tank, and an inert gas supply line supplying the inert gas such as nitrogen to the internal space of the liquefied gas storage tank while the vacuum state is removed by the vacuum pressure relief valve.

According to the embodiment, the thickness of the liquefied gas storage tank may be reduced by effectively responding to the vacuum pressure of the liquefied gas storage tank, and the weight and the cost of the liquefied gas storage tank may be reduced, and oxygen in the atmosphere is prevented from being introduced into the liquefied gas storage tank through a line in which the vacuum pressure relief valve is installed, which may cause ignition to prevent fire occurrence and secure safety.

FIG. 13 is a diagram schematically illustrating a liquefied gas storage tank system according to an embodiment of the present invention. Referring to FIG. 13, the liquefied gas storage tank system 1000 may include the liquefied gas storage tank, a vacuum pressure relief valve 510, an inert gas storage tank 520, an inert gas supply line 530, and a check valve 540.

The liquefied gas storage tank 100 may include an internal space for storing liquefied gas. The C-type tank 20 may accommodate ultra-low temperature state liquefied gas such as liquefied natural gas (LNG), liquefied petroleum gas (LPG), etc.,

therein.

The liquefied gas storage tank 100 may include a pressure vessel type C-type tank 25 having a cylindrical structure of a circular cross section and an insulator 35 covering the exterior of the C-type tank 25. The liquefied gas storage tank 100 may be supported by support devices 45 and 55 installed in a ship body 65.

At least one support device 45 of the support devices 45 and 55 may support the C-type liquefied gas storage tank in a fixation state, and the other one support device 55 may slidably support the C-type tank 25 to respond to thermal contraction/expansion of the C-type liquefied gas storage tank.

The vacuum pressure relief valve 510 may be provided at the upper portion of the liquefied gas storage tank 100. The vacuum pressure relief valve 510 may be installed on the inert gas supply line 530. The vacuum pressure relief valve 510 may relieve (remove) the vacuum pressure (vacuum sate) of the internal space of the liquefied gas storage tank when the vacuum pressure is generated in the internal space of the liquefied gas storage tank. In the embodiment, the vacuum pressure may be pressure of about 0 MPa(g) or less. The vacuum pressure relief valve 510 may be set to be automatically opened to relieve the vacuum pressure when the internal pressure is less than set pressure relation to the vacuum pressure.

The inert gas storage tank 520 may supply the inert gas through the inert gas supply line 530. In the embodiment, the inert gas may include nitrogen (N_2) gas. The inert gas storage tank 520 may be set to pressure of about 0.7 to 1.0 MPa(g) so that the inert gas is supplied to the liquefied gas storage tank 100 through the inert gas supply line 530 by a natural flow.

The inert gas supply line 530 may supply the inert gas to the internal space of the

liquefied gas storage tank 100 while the vacuum state is removed by the vacuum pressure relief valve 510. The check valve 540 may be provided in the inert gas supply line 530 so as to prevent the liquefied gas stored in the liquefied gas storage tank 100 from flowing back to the inert gas storage tank 520. The check valve 540 may be installed between the vacuum pressure relief valve 510 and the inert gas storage tank 520.

According to the embodiment of the present invention, the thickness of the liquefied gas storage tank 100, and the weight and cost of the liquefied gas storage tank 100 may be reduced by refilling the pressure by applying the vacuum pressure relief valve 510 and the inert gas supply line 530, and the pressure is refilled in the liquefied gas storage tank 100 through supply of the inert gas such as nitrogen to prevent oxygen (O_2) which may cause the ignition in the atmosphere from being introduced into the liquefied gas storage tank 100 and prevent the fire occurrence. Further, the liquefied gas may be prevented from flowing back to the inert gas storage tank 520 by the check valve 540.

FIG. 14 is a diagram schematically illustrating a liquefied gas storage tank system according to another embodiment of the present invention. In describing the embodiment of FIG. 14, a duplicated description of the same or corresponding components as or to the above-described embodiment may be omitted. The embodiment of FIG. 14 is different from the above-described embodiment in that the liquefied gas storage tank system 1000 further includes a vent line 560 and a positive pressure relief valve 550.

The vent line 560 may be provided to remove the positive pressure in the liquefied gas storage tank 100 when positive pressure higher than reference pressure in the liquefied gas storage tank 100 is generated. The positive pressure relief valve 550 may be provided in the vent line 560. The positive pressure relief valve 510 may be set

to be automatically opened when the internal pressure of the liquefied gas storage tank 100 exceeds pressure set in relation to the positive pressure. According to the embodiment of FIG. 14, the vacuum pressure relief valve 510 and the positive pressure relief valve 550 may control the internal pressure of the liquefied gas storage tank 100 in response to both the vacuum pressure and the positive pressure of the liquefied gas storage tank 100.

FIG. 15 is a diagram schematically illustrating a liquefied gas storage tank system according to yet another embodiment of the present invention. FIGS. 16 and 17 are diagrams illustrating an operating state of the liquefied gas storage tank system according to the embodiment of FIG. 15, and FIG. 16 illustrates a state in which a negative pressure derivation valve performs a pressure derivation operation and FIG. 17 illustrates a state in which the negative pressure derivation valve performs a vacuum derivation operation.

In describing the embodiment of FIGS. 15 to 17, a duplicated description of the same or corresponding components as or to the above-described embodiments may be omitted. The embodiment of FIGS. 15 to 17 is different from the above-described embodiment in that in the liquefied gas storage tank system 1000, a vacuum pressure relief valve 510a is installed in the vent line 560 and operates to remove the negative pressure when the negative pressure is generated in the liquefied gas storage tank 100 and also operates to remove the positive pressure when the positive pressure is generated in the liquefied gas storage tank 100, and the liquefied gas storage tank system 1000 further includes a first control valve, a second control valve 589, and a pressure measurer 590.

The pressure measurer 590 may measure vapor pressure in the liquefied gas storage tank 100. The first control valve 570 may be installed between the check valve 540 and the inert gas storage tank 520 in the inert gas supply line 530. As a result, since

the check valve 540 may prevent the liquefied gas from being leaked to the first control valve 570, the first control valve 570 may be implemented as a control valve for a room temperature, and the cost of the first control valve 570 may be reduced.

The first control valve 570 may be opened/closed according to the vapor pressure in the liquefied gas storage tank 100 measured by the pressure measurer 590. The second control valve 580 may be installed at a rear end of a vacuum pressure relief valve 110a in the vent line 160. The second control valve 180 may be opened/closed according to the vapor pressure in the liquefied gas storage tank 100 measured by the pressure measurer 590.

When the vapor pressure in the liquefied gas storage tank 100 measured by the pressure measurer 590 exceeds first reference pressure, the first control valve 570 may be blocked and the second control valve 580 may be opened. For example, when the pressure of the liquefied gas storage tank 100 exceeds 0 MPa(g), the first control valve 570 is blocked and the second control valve 580 is opened to emit the positive pressure in the liquefied gas storage tank 100 to the atmosphere. In this case, the vacuum pressure relief valve 510a performs a positive pressure relief valve function in order to relieve the positive pressure of the liquefied gas storage tank 100.

When the vapor pressure in the liquefied gas storage tank 100 measured by the pressure measurer 590 is equal to or lower than second reference pressure lower than the first reference pressure, the first control valve 570 may be opened and the second control valve 580 may be blocked. For example, when the pressure of the liquefied gas storage tank 100 is 0 barg, the second control valve 580 is blocked to block air introduction to an external vent side, and the vacuum pressure relief valve 510a may perform a vacuum relief function.

When the pressure of the liquefied gas storage tank 100 reaches set pressure (e.g., 100 mbarg) for vacuum relieving, the inert gas (e.g., nitrogen gas) is supplied from the inert gas storage tank 120 through the inert gas supply line 530 and introduced into the liquefied gas storage tank by opening the first control valve 570, and as a result, vacuum pressure of the liquefied gas storage tank 100 may be effectively relieved, and a risk such as a fire accident due to introduction of oxygen in the atmosphere may be prevented.

Further, according to the embodiment of FIGS. 15 to 17, the vacuum pressure relief valve 110a may perform the vacuum relieving function and also relieve excessive positive pressure generated in the liquefied gas storage tank 100 through the vent line 560. Further, even though the valve misoperates and is opened due to local or temporary pressure drop on the periphery of the vacuum pressure relief valve 510a in the liquefied gas storage tank 100, the first control valve 570 maintains a close state in a normal operation situation, so the inert gas such as nitrogen (N_2) may be prevented from being unnecessarily introduced into the liquefied gas storage tank 100.

The above embodiments are presented to help understand the present invention, and it should be understood that the scope of the present invention is not limited, and that various modified embodiments belong to the scope of the present invention. The protection scope of the protection of the present invention should be determined by the technical idea of the claim, and it should be understood that the protection scope of the present invention is not limited to the literary description of the claim itself, but actually influences the invention of the invention of category of an uneven technical value.

[Industrial Applicability]

The embodiments of the present invention can be usefully applied to the case where the design pressure for the internal pressure of the liquefied gas storage tank is less

than about 0.65 MPa(g), for example.

[CLAIMS]

[Claim 1]

A liquefied gas storage tank system comprising:

a liquefied gas storage tank designed by a design internal pressure and a design external pressure under a design internal pressure condition which allows at least the design external pressure to determine a thickness of the liquefied gas storage tank; and

a vacuum pressure relief valve coupled to the liquefied gas storage tank and relieving the vacuum pressure generated inside the liquefied gas storage tank,

wherein the liquefied gas storage tank is a C-type liquefied gas storage tank.

[Claim 2]

The liquefied gas storage tank system of claim 1, wherein the liquefied gas storage tank is designed by a design internal pressure of less than about 0.65 MPa(g).

[Claim 3]

The liquefied gas storage tank system of claim 2, wherein the liquefied gas storage tank is designed by a design internal pressure of equal to or larger than about 0.45 MPa(g) and less than about 0.65 MPa(g) and a design external pressure of equal to or larger than about 0.020 MPa(g) and less than about 0.045 MPa(g).

[Claim 4]

The liquefied gas storage tank system of claim 2, wherein the liquefied gas storage tank is designed by a design internal pressure of equal to or larger than about 0.45 MPa(g) and equal to or smaller than about 0.55 MPa(g) and a design external pressure of equal to or larger than about 0.020 MPa(g) and equal to or smaller than about 0.025 MPa(g).

[Claim 5]

The liquefied gas storage tank system of any one of claims 1 to 4, wherein a first entrance of the vacuum pressure relief valve is coupled to be in communication with the inside of the liquefied gas storage tank through a first pipe and the second entrance is coupled to be in communication with a vent mast or an inert gas storage tank through a second pipe or is in direct communication with the atmosphere.

[Claim 6]

The liquefied gas storage tank system of claim 5, further comprising:

a positive pressure relief valve relieving positive pressure which is generated inside the liquefied gas storage tank and is higher than reference pressure.

[Claim 7]

The liquefied gas storage tank system of claim 6, wherein a second entrance of the positive pressure relief valve is coupled to be in communication with the inside of the liquefied gas storage tank through a third pipe and a first entrance of the positive pressure relief valve is coupled to be in communication with the vent mast or the inert gas storage tank through a fourth pipe or is in direct communication with the atmosphere or connected to the second pipe connected to the second entrance of the vacuum pressure relief valve.

[Claim 8]

A pressure designing method for manufacturing a liquefied gas storage tank, comprising:

judging whether a design internal pressure is within a reference pressure range in which a thickness of the liquefied gas storage tank is determined at least by a design external pressure; and

determining, when the design internal pressure is within the reference pressure range, the design external pressure by removing or reducing a vacuum pressure item

defined for a vacuum pressure inside the liquefied gas storage tank from pressure items defining the design external pressure, wherein the liquefied gas storage tank is a C-type liquefied gas storage tank.

[Claim 9]

The pressure designing method for manufacturing a liquefied gas storage tank of claim 8, wherein the reference pressure range is less than about 0.65 MPa(g).

[Claim 10]

The pressure designing method for manufacturing a liquefied gas storage tank of claim 9, wherein the reference pressure range is equal to or larger than about 0.45 MPa(g) and less than about 0.65 MPa(g).

[Claim 11]

The pressure designing method for manufacturing a liquefied gas storage tank of any one of claims 8 to 10, wherein the design internal pressure is equal to or larger than about 0.45 MPa(g) and less than about 0.65 MPa(g), and

the determined design external pressure is equal to or larger than about 0.20 MPa(g) and equal to or smaller than about 0.030 MPa(g).

[Claim 12]

A method for manufacturing a liquefied gas storage tank, the method comprising:

manufacturing a liquefied gas storage tank according to a determined design internal pressure and a determined design external pressure under a design internal pressure condition which allows at least a design external pressure to determine a thickness of the liquefied gas storage tank; and

coupling a pressure control valve controlling an internal pressure of the liquefied gas storage tank to the liquefied gas storage tank, wherein the liquefied gas storage tank

is a C-type liquefied gas storage tank.

[Claim 13]

The method for manufacturing a liquefied gas storage tank of claim 12, wherein the determined design internal pressure is less than about 0.65 MPa(g) and the determined design external pressure is equal to or larger than about 0.020MPa(g).

[Claim 14]

The method for manufacturing a liquefied gas storage tank of claim 13, wherein the determined design internal pressure is equal to or larger than about 0.45 MPa(g) and less than about 0.65 MPa(g), and

the determined design external pressure is equal to or larger than about 0.20 MPa(g) and less than about 0.045 MPa(g).