DESCRIPTION

Title of invention:

AMMONIA GAS LEAKAGE SUPPRESSION METHOD AND LIQUEFIED AMMONIA STORAGE APPARATUS

Technical Field

[0001] The present invention relates to an ammonia gas leakage suppression method and a liquefied ammonia storage apparatus.

Background Art

[0002] In recent years, ammonia fuel has attracted attention as a carbon neutral fuel in order to reduce an environmental load, and it is expected that an ammonia liquefaction station and an ammonia reception station that handle a large amount of ammonia which is a combustible gas and a toxic gas will be constructed in the future.

[0003] As a type of a storage tank that stores a large volume of liquefied ammonia, it is considered to be advantageous to adopt a “bund wall outer tank integrated type/cylindrical vertical storage tank with flat bottom spherical roof made of PC” using prestressed concrete (hereinafter, referred to as PC) which is often adopted even in a ground tank that stores a large volume of a liquefied gas such as a liquefied natural gas or a liquefied petroleum gas from a viewpoint of safety

[0004] The liquefied gas in the storage tank is stored at a temperature close to a saturation temperature of the gas. Therefore, in the storage tank, a vaporized gas called a boil-off gas (BOG) is generated by being heated by inevitable heat input from external area from the outside or the like.

[0005] In this regard, a treatment method for re-liquefying a generated boil-off gas in a storage tank that stores a liquefied gas such as a liquefied natural gas or a liquefied petroleum gas at a low

temperature (see Patent Literature 1) is known.

[0006] However, when the storage tank is opened, for example, when a roof portion of the storage tank is damaged due to an unexpected accident or when maintenance of the storage tank is performed, in addition to inevitable heat input from external area, heat input from an open portion increases and a pressure of a storage tank gas phase portion decreases. Therefore, a boil-off gas generation amount increases.

As a measure for detoxification and safety at the time of opening, it is important to suppress leakage of an ammonia gas which is a combustible gas and a toxic gas from an open portion of the storage tank.

Citation List

Patent Literature

[0007] Patent Literature 1: JP H10-19199 A

Summary of Invention

Technical Problem

[0008] An object of the present invention is to provide an ammonia gas leakage suppression method capable of suppressing leakage of an ammonia gas to the outside of a storage tank that stores liquefied ammonia in a state where the storage tank is opened, and to provide a liquefied ammonia storage apparatus capable of suppressing leakage of an ammonia gas to the outside of a storage tank that stores stored liquefied ammonia in a state where the storage tank is opened.

Solution to Problem

[0009] Such an object is achieved by the present invention described in the following (1) to (12).

(1) An ammonia gas leakage suppression method including supplying, into a storage tank that stores liquefied ammonia, a low-temperature liquid having a temperature lower than

stored liquefied ammonia stored in the storage tank in a state where the storage tank is opened.

[0010] (2) The ammonia gas leakage suppression method according to (1), in which the temperature of the low-temperature liquid is -196°C or higher and -35°C or lower.

[0011] (3) The ammonia gas leakage suppression method according to (1) or (2), in which the low-temperature liquid is liquid nitrogen or liquefied ammonia in a subcooled state.

[0012] (4) The ammonia gas leakage suppression method according to any one of (1) to (3), in which the low-temperature liquid is supplied into a liquid phase in the storage tank.

[0013] (5) The ammonia gas leakage suppression method according to any one of (1) to (4), in which the low-temperature liquid is supplied into a gas phase in the storage tank.

[0014] (6) The ammonia gas leakage suppression method according to any one of (1) to (5), in which an inert gas is further supplied into a gas phase in the storage tank.

[0015] (7) The ammonia gas leakage suppression method according to (6), in which the inert gas is a nitrogen gas or a carbon dioxide gas.

[0016] (8) A liquefied ammonia storage apparatus including:

a storage tank that stores liquefied ammonia; and

a low-temperature liquid supply unit that supplies, into the storage tank, a low-temperature liquid having a temperature lower than stored liquefied ammonia stored in the storage tank, in which

the low-temperature liquid supply unit supplies the low-temperature liquid into the storage tank when the storage tank that stores the stored liquefied ammonia is opened.

[0017] (9) The liquefied ammonia storage apparatus according to (8), in which the low-temperature liquid supply unit is disposed so as to supply the low-temperature liquid into a liquid phase in the storage tank.

[0018] (10) The liquefied ammonia storage apparatus according to (8) or (9), in which the low-temperature liquid supply unit is disposed so as to supply the low-temperature liquid into a gas phase in the storage tank.

[0019] (11) The liquefied ammonia storage apparatus according to any one of (8) to (10), further including an inert gas supply unit that supplies an inert gas into a gas phase in the storage tank.

[0020] (12) The liquefied ammonia storage apparatus according to (11), in which the ammonia storage apparatus includes a plurality of the inert gas supply units.

Advantageous Effects of Invention

[0021] According to the present invention, it is possible to provide an ammonia gas leakage suppression method capable of suppressing leakage of an ammonia gas to the outside of a storage tank that stores liquefied ammonia in a state where the storage tank is opened, and to provide a liquefied ammonia storage apparatus capable of suppressing leakage of an ammonia gas to the outside of a storage tank that stores stored liquefied ammonia in a state where the storage tank is opened.

Brief Description of Drawings

[0022] FIG. 1 is a diagram schematically illustrating a first embodiment of a liquefied ammonia storage apparatus of the present invention.

FIG. 2 is a partially broken cross-sectional view illustrating a configuration example of a storage tank in the liquefied ammonia storage apparatus illustrated in FIG. 1.

FIG. 3 is a diagram for explaining a first embodiment of an ammonia gas leakage suppression method of the present invention.

FIG. 4 is a diagram for explaining a subcooled state, and is a diagram illustrating a state diagram.

FIG. 5 is a diagram schematically illustrating a second embodiment of the liquefied ammonia storage apparatus of the present invention.

FIG. 6 is a diagram for explaining a second embodiment of the ammonia gas leakage suppression method of the present invention.

FIG. 7 is a diagram for explaining an example of the ammonia gas leakage suppression method of the present invention.

FIG. 8 is a diagram schematically illustrating a state where a gaseous contaminant is diffused.

Description of Embodiments

[0023] Hereinafter, preferred embodiments of the present invention will be described in detail.

[0024] <First Embodiment>

[1] Liquefied ammonia storage apparatus

First, a liquefied ammonia storage apparatus of the present invention will be described.

FIG. 1 is a diagram schematically illustrating a first embodiment of the liquefied ammonia storage apparatus of the present invention. FIG. 2 is a partially broken cross-sectional view illustrating a configuration example of a storage tank in the liquefied ammonia storage apparatus illustrated in FIG. 1.

Note that, in the drawings, the same elements are denoted by the same reference numerals, and redundant description is omitted.

[0025] A liquefied ammonia storage apparatus 1 of the present invention includes: a storage tank 10 that stores liquefied ammonia; and a low-temperature liquid supply unit 30 that supplies a low-temperature liquid 3 having a temperature lower than stored liquefied ammonia 2 stored in the storage tank 10 into the storage tank 10. Note that, in the following description, the liquefied ammonia stored in the storage tank 10 is referred to as the stored liquefied ammonia 2.

In the liquefied ammonia storage apparatus 1, when the storage tank 10 that stores the stored liquefied ammonia 2 is opened, the low-temperature liquid supply unit 30 supplies the low-temperature liquid 3 into the storage tank 10 to suppress leakage of an ammonia gas to the outside of the storage tank 10.

[0026] In the liquefied ammonia storage apparatus 1, liquefied ammonia is stored in the storage

tank 10.

The inside of the storage tank 10 has a pressure close to atmospheric pressure, and the stored liquefied ammonia 2 is maintained at a temperature around -33°C, which is a saturation temperature of ammonia at atmospheric pressure.

[0027] In the storage tank 10, a boil-off gas generated by inevitable heat input from external area, in other words, an ammonia gas is present in a gas phase, and the boil-off gas is recovered and re-liquefied by a re-liquefying unit (not illustrated), and then returned to a liquid phase of the storage tank 10.

[0028] Examples of a method for re-liquefying the boil-off gas include a method in which a gas containing the boil-off gas is pressurized by a compressor and then cooled by a heat exchanger or the like to be liquefied, and a method in which the boil-off gas is injected into the delivered stored liquefied ammonia 2 to be liquefied and then pumped by a pump.

[0029] In general, in a state where the storage tank is opened, in addition to inevitable heat input from external area, heat input from the outside by opening of the storage tank increases, and a pressure of the storage tank gas phase portion decreases, and therefore the boil-off gas generation amount increases. If no countermeasure is taken, there is a problem that the ammonia gas as the boil-off gas leaks from an open portion of the storage tank.

[0030] Note that, in the present specification, the "state where the storage tank 10 is opened" refers to a state where an internal space of the storage tank 10 communicates with the atmosphere which is an external space, and specific examples thereof include a case where a roof portion of the storage tank 10 is damaged due to an unexpected accident such as collision of a flying object, and a hole H penetrating the roof portion is opened, and a case where maintenance of the storage tank 10 is performed by opening a management lid which is closed at a normal time.

The management lid is, for example, a head plate (not illustrated) of a pump barrel 20 described later.

[0031] In the following description, a case where a roof portion of the storage tank 10 is

damaged due to an unexpected accident will be mainly described as the “state where the storage tank 10 is opened”.

[0032] As described later, the damage of the roof portion of the storage tank 10 indicates such a damage that a hole penetrating a roof 15 of an outer tank 12 and a ceiling portion of an inner tank 11 illustrated in FIG. 2 is opened, and a case where the roof 15 of the outer tank 12 is damaged but a hole H penetrating the ceiling portion of the inner tank 11 is not opened is not included in the “state where the storage tank 10 is opened”.

[0033] In the liquefied ammonia storage apparatus 1 of the present invention, when the storage tank 10 that stores the stored liquefied ammonia 2 is opened, the low-temperature liquid supply unit 30 supplies the low-temperature liquid 3 into the storage tank 10, whereby the temperature in the storage tank 10 can be lowered to suppress generation of the boil-off gas.

As a result, in the liquefied ammonia storage apparatus 1, leakage of an ammonia gas to the outside of the storage tank 10 can be suppressed.

[0034] [1-1] Storage tank

The storage tank 10 stores liquefied ammonia therein.

[0035] As illustrated in FIG. 2, the storage tank 10 includes the inner tank 11 that stores liquefied ammonia, the outer tank 12 disposed so as to cover the inner tank 11, and a heat insulating material 16 disposed between the inner tank 11 and the outer tank 12.

[0036] The inside of the inner tank 11 has a pressure close to atmospheric pressure.

The inner tank 11 is a tank for storing liquefied ammonia at a low pressure close to atmospheric pressure and at a saturation temperature of ammonia.

The inner tank 11 is formed in a bottomed cylindrical shape using, for example, low-temperature steel having toughness in a low temperature range including temperatures equal to or lower than about -33°C, which is a saturation temperature of ammonia under atmospheric pressure. The ceiling portion of the inner tank 11 is formed in a dome shape.

[0037] Note that, in the present specification, the “inside of the storage tank 10” refers to the

“inside of the inner tank 11”.

[0038] The outer tank 12 is a structure including a bottom plate 13, a side wall 14, and the roof 15, and is disposed so as to cover an outer side of the inner tank 11. In particular, the bottom plate 13 and the side wall 14 serve as a bund wall that prevents leakage of a stored liquid to the outside when the inner tank 11 is damaged and the stored liquefied ammonia 2 leaks.

[0039] The side wall 14 is formed using, for example, pre-stressed concrete (PC) in which a sheath tube is embedded in concrete and pre-stress is introduced by a tension material inserted into the sheath tube.

[0040] The bottom plate 13 is formed in a disk shape. The bottom plate 13 is supported at a predetermined height from the ground by a plurality of foundation piles (not illustrated) embedded in the ground.

The side wall 14 is formed in a substantially cylindrical shape on the bottom plate 13.

[0041] The roof 15 is formed in a dome shape using forged steel or reinforced concrete.

The side wall 14 as a bund wall has a liner plate (thin iron plate) attached to the side wall 14 of the outer tank 12.

[0042] The heat insulating material 16 is disposed between the inner tank 11 and the outer tank 12, and the stored liquefied ammonia 2 stored in the inner tank 11 is cooled by the heat insulating material 16.

In addition, the pump barrel 20 for discharging liquefied ammonia from the storage tank 10 is disposed so as to penetrate the roof 15 and the ceiling portion of the inner tank 11 and to vertically extend to a bottom portion in the storage tank 10.

Note that the pump barrel 20 will be described in detail later.

[0043] In the present specification, “vertical” is not strict “vertical” in a mathematical sense, but allows a slight deviation.

In FIG. 1 and FIGs. 3, 5, and 6 described later, illustration of the pump barrel 20 is omitted.

[0044] [1-2] Low-temperature liquid supply unit

The low-temperature liquid supply unit 30 supplies the low-temperature liquid 3 having a temperature lower than the stored liquefied ammonia 2 stored in the storage tank 10 into the storage tank 10 when the storage tank 10 that stores the stored liquefied ammonia 2 is opened.

As a result, the temperature in the storage tank 10 can be lowered to suppress generation of the boil-off gas, and leakage of an ammonia gas to the outside of the storage tank 10 can be suppressed.

[0045] The low-temperature liquid supply unit 30 includes: a storage unit 31 that stores the low-temperature liquid 3; a pipe 32 for feeding the low-temperature liquid 3 to the storage tank 10; and a regulating valve 33 that is disposed in the middle of the pipe 32 and adjusts the amount of the low-temperature liquid 3 fed from the storage unit 31 to be supplied to the storage tank 10.

[0046] In the present embodiment, the low-temperature liquid supply unit 30 is disposed so as to supply the low-temperature liquid 3 into a liquid phase in the storage tank 10.

As a result, the temperature of the liquid phase itself in the storage tank 10 can be directly lowered by the low-temperature liquid 3 supplied by the low-temperature liquid supply unit 30, generation of the boil-off gas can be more efficiently suppressed, and leakage of an ammonia gas to the outside of the storage tank 10 can be more efficiently suppressed.

[0047] In addition, cold from the low-temperature liquid 3 can be stored in the liquid phase, and generation of the boil-off gas can be suppressed for a longer period of time.

For example, when an accident occurs in which the roof portion of the storage tank 10 is damaged and a hole H is opened, it is possible to gain a time until a large amount of ammonia gas leaks, and therefore during this time, the stored liquefied ammonia 2 in the storage tank 10 in which the accident has occurred is transferred to another storage tank, and the storage tank 10 in which the accident has occurred is emptied, whereby handling of the accident can be completed.

[0048] The low-temperature liquid supply unit 30 is preferably disposed so as to supply the low-temperature liquid 3 to a central portion of the storage tank 10 in plan view.

As a result, the temperature of the stored liquefied ammonia 2 can be further efficiently lowered, generation of the boil-off gas can be further efficiently suppressed, and leakage of the ammonia gas to the outside of the storage tank 10 can be further efficiently suppressed.

[0049] Note that, in the present specification, the "central portion of the storage tank 10" refers to the inside of a region having a similar shape with an area ratio of 30% that is common to a plan view shape of the inner tank 11 in a geometric center and a direction when the storage tank 10 is viewed in plan view.

[0050] When the low-temperature liquid 3 is supplied into the liquid phase, the pipe 32 for supplying the low-temperature liquid is disposed so as to extend in the vertical direction from the ceiling portion of the storage tank 10 in FIG. 1, but the present invention is not limited thereto. For example, the pipe 32 for supplying the low-temperature liquid may be disposed in the horizontal direction along a bottom surface of the storage tank 10.

[0051] Note that, in the present specification, "horizontal" is not strict "horizontal" in a mathematical sense, but allows a slight deviation.

[0052] [1-3] Inert gas supply unit

In the configuration illustrated in FIG. 1, the liquefied ammonia storage apparatus 1 includes an inert gas supply unit 40 as a more preferable mode.

The inert gas supply unit 40 supplies an inert gas 4 into a gas phase in the storage tank 10 when the storage tank 10 is opened.

[0053] By inclusion of the inert gas supply unit 40, as described later, a mixed gas of an ammonia gas present in the gas phase in the storage tank 10 and the atmosphere having entered the gas phase in the storage tank 10 from an open portion can be diluted by the inert gas 4. As a result, generation of a combustible mixed gas within a combustion range can be effectively suppressed.

[0054] The inert gas supply unit 40 includes: a storage unit 41 that stores the inert gas 4; a pipe 42 for transferring the inert gas 4 to the storage tank 10; and a regulating valve 43 that is disposed

in the middle of the pipe 42 and adjusts the amount of the inert gas 4 sent from the storage unit 41 to be supplied to the storage tank 10.

[0055] The liquefied ammonia storage apparatus 1 further includes a control unit (not illustrated) that controls supply amounts and the like of the low-temperature liquid 3 and the inert gas 4 in the low-temperature liquid supply units 30 and the inert gas supply units 40. The control unit controls opening and closing of the regulating valves 33 and 43. The control unit is, for example, a central processing unit (CPU).

[0056] The liquefied ammonia storage apparatus 1 preferably includes a plurality of inert gas supply units 40 (that is, units of supplying the inert gas 4 to the inside of the storage tank 10).

As a result, for example, a relatively large amount of the inert gas 4 can be supplied in a short time, and generation of a combustible mixed gas can be more effectively suppressed.

In addition, an appropriate inert gas supply unit 40 can be selected from among the plurality of inert gas supply units 40, and the inert gas 4 can be supplied from the appropriate inert gas supply unit 40. More specifically, for example, when the roof portion of the storage tank 10 is damaged and a hole is opened, by selectively supplying the inert gas 4 from an inert gas supply units 40 disposed at a position closer to the hole, inflow of the atmosphere can be more effectively suppressed while the use amount of the inert gas 4 is suppressed, and generation of a combustible mixed gas can be more effectively and reliably suppressed.

[0057] In addition, since the plurality of inert gas supply units 40 is disposed, even when some inert gas supply units 40 are damaged together with the roof portion when the roof portion is damaged, the inert gas 4 can be supplied from another inert gas supply unit 40 that is not damaged.

[0058] Note that when the liquefied ammonia storage apparatus 1 includes the plurality of inert gas supply units 40, some components (for example, the storage unit 41) may be shared by the plurality of inert gas supply units 40. In other words, the pipe 42 that sends the inert gas 4 from the storage unit 41 to the storage tank 10 may be branched, and may be able to supply the inert gas 4 to a plurality of different portions of the storage tank 10.

[0059] [2] Ammonia gas leakage suppression method

Next, with reference to FIGs. 3 and 4, an ammonia gas leakage suppression method when the storage tank 10 is opened in the liquefied ammonia storage apparatus 1 according to the present embodiment will be described.

[0060] FIG. 3 is a diagram for explaining a first embodiment of an ammonia gas leakage suppression method of the present invention. FIG. 4 is a diagram for explaining a subcooled state, and is a diagram illustrating a state diagram.

[0061] The ammonia gas leakage suppression method according to the present embodiment includes supplying the low-temperature liquid 3 having a temperature lower than the stored liquefied ammonia 2 stored in the storage tank 10 that stores liquefied ammonia into the storage tank 10 in a state where the storage tank 10 is opened to suppress leakage of an ammonia gas to the outside of the storage tank 10.

[0062] As described above, in the liquefied ammonia storage apparatus 1, when the storage tank 10 is opened, the low-temperature liquid supply unit 30 supplies the low-temperature liquid 3 into the storage tank 10, whereby the temperature in the storage tank 10 can be lowered to suppress generation of the boil-off gas.

As a result, in the ammonia gas leakage suppression method of the present invention, leakage of an ammonia gas to the outside of the storage tank 10 can be suppressed.

[0063] The temperature of the stored liquefied ammonia 2 stored in the storage tank 10 is maintained around -33°C, which is a saturation temperature of ammonia at atmospheric pressure.

Therefore, a liquid having a temperature lower than -33°C is used as the low-temperature liquid 3.

[0064] The temperature of the low-temperature liquid 3 is not particularly limited as long as it is lower than that of the stored liquefied ammonia 2, but is preferably -196°C or higher and -35°C or lower, more preferably -60°C or higher and -35°C or lower, and still more preferably -45°C or higher and -35°C or lower.

[0065] As a result, the temperature in the storage tank 10 can be more efficiently lowered to more effectively suppress generation of the boil-off gas, and leakage of an ammonia gas to the outside of the storage tank 10 can be more effectively suppressed. When the temperature of the low-temperature liquid 3 is -60°C or higher, low-temperature steel which is easily available and is relatively inexpensive can be used as a constituent material of the inner tank 11.

[0066] The low-temperature liquid 3 is not particularly limited as long as it is a liquid having a temperature lower than the stored liquefied ammonia 2, but is preferably liquid nitrogen or liquefied ammonia in a subcooled state, and more preferably liquefied ammonia in a subcooled state.

This makes it possible to more suitably lower the temperature in the storage tank 10, and is also advantageous from a viewpoint of cost.

[0067] Here, the subcooled state will be described with reference to the state diagram of FIG. 4.

The liquefied ammonia in the storage tank 10 is usually in a state indicated by a black circle in FIG. 4, that is, in a state of a saturation temperature at a pressure in the storage tank 10, and in this case, a gas phase in the storage tank 10 is saturated with a vaporized gas. When the liquefied ammonia in such a state is further cooled, the liquefied ammonia moves from the black circle to a white circle on a left side, and enters a subcooled state. The liquefied ammonia in such a subcooled state is in a state where generation of the boil-off gas is suppressed.

[0068] The subcooling degree of the stored liquefied ammonia 2, that is, a difference between the saturation temperature of ammonia at the pressure in the storage tank 10 and the temperature of the stored liquefied ammonia 2 is preferably -2°C or more and -12°C or less. In other words, the temperature of the liquefied ammonia in a subcooled state is preferably -45°C or higher and -35°C or lower.

As a result, the above-described effect can be made more remarkable.

[0069] Latent heat of vaporization of the liquefied ammonia at a saturation temperature of

atmospheric pressure is 1372 kJ/kg, and latent heat of vaporization of liquid nitrogen is 204 kJ/kg.

The saturation temperature of ammonia at atmospheric pressure is higher than -196°C, which is the saturation temperature of nitrogen, while the latent heat of vaporization of the liquefied ammonia is much larger than that of liquid nitrogen. In other words, the liquefied ammonia has a very small temperature rise range when a predetermined amount of heat is absorbed as compared with a case where liquid nitrogen having the same mass is used. Therefore, by using the liquefied ammonia in a subcooled state as the low-temperature liquid 3, the use amount thereof can be reduced as compared with the case of using liquid nitrogen.

[0070] When the liquefied ammonia in a subcooled state is used as the low-temperature liquid 3, the liquefied ammonia in a subcooled state may be obtained by once taking out and cooling the stored liquefied ammonia 2 in the storage tank 10, or may be obtained by cooling liquefied ammonia supplied from another storage tank.

[0071] A method for cooling the liquefied ammonia is not particularly limited as long as the liquefied ammonia can be cooled to a subcooled state, and examples thereof include a method using a refrigerator of a reverse Brayton cycle of a non-fluorocarbon refrigerant. By cooling, for example, saturated liquefied ammonia at -33°C, the refrigerator can set the temperature of the liquefied ammonia to -45°C or higher and -35°C or lower.

[0072] When liquefied ammonia obtained by taking out and cooling the stored liquefied ammonia 2 in the storage tank 10 to bring the stored liquefied ammonia 2 into a subcooled state is used as the low-temperature liquid 3, the low-temperature liquid supply unit 30 may include a pump for taking out the stored liquefied ammonia 2 in the storage tank 10 and a refrigerator for cooling the taken out liquefied ammonia to bring the liquefied ammonia into a subcooled state, instead of the storage unit 31 of the low-temperature liquid 3.

[0073] In the storage tank 10, the low-temperature liquid 3 may be supplied to any part, but in the present embodiment, the low-temperature liquid 3 is supplied into a liquid phase in the storage tank 10.

As a result, the temperature of the liquid phase itself in the storage tank 10 can be directly lowered, generation of the boil-off gas can be more efficiently suppressed, and leakage of an ammonia gas to the outside of the storage tank 10 can be more efficiently suppressed.

[0074] In addition, cold from the low-temperature liquid 3 can be stored in the liquid phase, and generation of the boil-off gas can be suppressed for a longer period of time.

For example, when an accident occurs in which the roof portion of the storage tank 10 is damaged and a hole H is opened, it is possible to gain a time until a large amount of ammonia gas leaks, and therefore during this time, the stored liquefied ammonia 2 in the storage tank 10 in which the accident has occurred is transferred to another storage tank, and the storage tank 10 in which the accident has occurred is emptied, whereby handling of the accident can be completed.

[0075] As illustrated in FIG. 3, when the low-temperature liquid 3 is supplied into the stored liquefied ammonia 2, the low-temperature liquid 3 is preferably supplied to a central portion of the storage tank 10 in plan view. Convection occurs in the stored liquefied ammonia 2 as indicated by an arrow C. Specifically, a series of flows is generated in which the stored liquefied ammonia 2 rises in a peripheral portion of the storage tank 10, goes from the peripheral portion toward the central portion, and falls in the central portion.

[0076] Therefore, by supplying the low-temperature liquid 3 to the central portion of the storage tank 10 in plan view, the low-temperature liquid 3 can be quickly spread throughout the stored liquefied ammonia 2 by convection, the temperature of the stored liquefied ammonia 2 can be further efficiently lowered, and generation of the boil-off gas can be further efficiently suppressed. As a result, leakage of an ammonia gas to the outside of the storage tank 10 can be further efficiently suppressed.

[0077] The supply amount of the low-temperature liquid 3 into the storage tank 10 varies depending on a desired reduction ratio of the boil-off gas generation amount, and in general, as the supply amount of the low-temperature liquid 3 increases, an effect of lowering the temperature in the storage tank 10 and an effect of suppressing generation of the boil-off gas are more

remarkable.

[0078] By supplying the low-temperature liquid 3 into the storage tank 10, at least a part of inevitable heat input from external area and heat input amount increased by opening of the storage tank 10 is offset by the cold amount of the low-temperature liquid 3, whereby the temperature in the storage tank 10 raised by the opening of the storage tank 10 only needs to be lowered. The temperature in the storage tank 10 is preferably made lower than the temperature in the storage tank 10 before the storage tank 10 is opened.

As a result, generation of the boil-off gas can be more effectively suppressed, and leakage of an ammonia gas to the outside of the storage tank 10 can be more effectively suppressed.

[0079] Note that when the low-temperature liquid 3 is supplied into the storage tank 10 as described above, the temperature in the storage tank 10 is lowered, and the ammonia gas present in the gas phase is condensed. As a result, the gas phase in the storage tank 10 has a negative pressure, and the atmosphere enters the gas phase of the storage tank 10 through an open portion, for example, a hole H opened in the roof portion, and the atmosphere and the ammonia gas in the gas phase are mixed. As a result, a combustible mixed gas in a combustion range of the ammonia gas may be generated. In addition, since the atmosphere enters the gas phase of the storage tank 10, leakage of ammonia, which is a toxic gas, to the atmosphere outside the storage tank 10 is prevented.

[0080] Therefore, it is preferable to further supply the inert gas 4 into the gas phase in the storage tank 10.

In the liquefied ammonia storage apparatus 1, by supplying the inert gas 4 from the inert gas supply unit 40 into the gas phase in the storage tank 10, the mixed gas of the ammonia gas and the atmosphere is diluted, and generation of the combustible mixed gas can be suppressed.

Furthermore, by supplying the inert gas 4 into the gas phase in the storage tank 10, it is possible to suppress the gas phase from having a negative pressure and to suppress inflow itself of the atmosphere.

[0081] Note that when the inert gas 4 is supplied into the gas phase in the storage tank 10, a mixed gas of the boil-off gas and the inert gas 4 is usually emitted into the atmosphere from an open portion of the storage tank 10 in an initial stage. Thereafter, since generation of a vaporized gas is suppressed by supply of the low-temperature liquid 3, the inert gas is mainly emitted into the atmosphere.

[0082] The supply amount of the inert gas 4 is not particularly limited as long as the above effect can be obtained.

For example, when an effect of suppressing generation of the boil-off gas by supplying the low-temperature liquid 3 into the storage tank 10 is large, the boil-off gas generation amount itself is suppressed to be small. Therefore, a possibility of generation of the combustible mixed gas within a combustion range of the ammonia gas is also reduced, and the amount of the inert gas 4 necessary for obtaining the above effect is also reduced.

[0083] The inert gas 4 is not particularly limited, but for example, a nitrogen gas, a carbon dioxide gas, or the like can be used, and a nitrogen gas is preferable.

This makes it possible to more effectively suppress generation of the combustible mixed gas, and is also advantageous from a viewpoint of cost.

[0084] When a nitrogen gas is used as the inert gas 4, examples of a method for supplying the inert gas 4 into the gas phase include a method for supplying a nitrogen gas as it is and a method for supplying a nitrogen gas into the gas phase by spraying liquid nitrogen into the gas phase in the storage tank 10.

[0085] When the liquefied ammonia storage apparatus 1 has a plurality of the inert gas supply units 40, the inert gas 4 may be simultaneously supplied from the plurality of inert gas supply units 40, or the inert gas 4 may be supplied from some of the plurality of inert gas supply units 40.

[0086] <Second Embodiment>

A second embodiment of the present invention will be described.

FIG. 5 is a diagram schematically illustrating a second embodiment of the liquefied

ammonia storage apparatus of the present invention. FIG. 6 is a diagram for explaining a second embodiment of the ammonia gas leakage suppression method of the present invention.

Note that, in the following description, portions different from those of the above-described embodiment will be mainly described, and description of similar matters will be omitted.

[0087] In the present embodiment, a low-temperature liquid 3 is supplied from a low-temperature liquid supply unit 30 into a gas phase in a storage tank 10. More specifically, when the storage tank 10 that stores stored liquefied ammonia 2 is opened, the low-temperature liquid supply unit 30 supplies the low-temperature liquid 3 into the gas phase in the storage tank 10 to suppress leakage of an ammonia gas to the outside of the storage tank 10.

[0088] That is, while the low-temperature liquid 3 is supplied into the liquid phase in the storage tank 10 in the first embodiment described above, the low-temperature liquid 3 is supplied into the gas phase in the storage tank 10 in the present embodiment.

[0089] As a result, the temperature of the gas phase in the storage tank 10 can be more quickly lowered, and an ammonia gas present in the gas phase can be condensed. As a result, generation of a boil-off gas can be suppressed in a shorter time. As a result, leakage of the ammonia gas to the outside of the storage tank 10 can be more efficiently suppressed. In addition, since it is possible to effectively suppress the temperature of the liquid phase in the storage tank 10 from being excessively lowered, it is possible to use low-temperature steel which is easily available and is relatively inexpensive as a constituent material of an inner tank 11.

[0090] Examples of a method for supplying the low-temperature liquid 3 into the gas phase in the storage tank 10 include a method for spraying the low-temperature liquid 3 into the gas phase.

The low-temperature liquid supply unit 30 includes, for example, a spraying unit (not illustrated) that sprays the low-temperature liquid 3 at a distal end of the pipe 32, and sprays the low-temperature liquid 3 toward the gas phase in the storage tank 10.

[0091] Since the boil-off gas is uniformly generated from the entire liquid surface of the stored liquefied ammonia 2 in plan view, a supply portion of the low-temperature liquid 3, in other words,

a portion where the low-temperature liquid supply unit 30 is disposed is not particularly limited, but is preferably a ceiling portion of the inner tank 11.

[0092] As a result, the low-temperature liquid 3 can be more efficiently supplied to a wider range of the gas phase in the storage tank 10, the temperature of the gas phase in the storage tank 10 can be more efficiently lowered, generation of the boil-off gas can be more effectively suppressed, and leakage of an ammonia gas to the outside of the storage tank 10 can be more effectively suppressed.

[0093] A liquefied ammonia storage apparatus 1 preferably includes a plurality of the low-temperature liquid supply units 30 (that is, units of supplying the low-temperature liquid 3 to the gas phase in the storage tank 10).

As a result, the low-temperature liquid 3 can be further efficiently supplied to a wider range of the gas phase in the storage tank 10, the temperature of the gas phase in the storage tank 10 can be further efficiently lowered, generation of the boil-off gas can be further effectively suppressed, and leakage of an ammonia gas to the outside of the storage tank 10 can be further effectively suppressed.

[0094] In addition, by supplying the low-temperature liquid 3 from a low-temperature liquid supply unit 30 disposed at a portion close to an open portion of the storage tank 10, for example, a hole H which is an open portion when the roof portion is damaged and the hole H is opened, heat input from the open portion can be effectively suppressed.

[0095] As a result, a temperature rise in the gas phase in the storage tank 10 can be effectively suppressed to effectively suppress generation of the boil-off gas, and leakage of an ammonia gas to the outside of the storage tank 10 can be effectively suppressed.

[0096] Furthermore, since the plurality of low-temperature liquid supply units 30 is disposed, even when some low-temperature liquid supply units 30 are damaged together with the roof portion when the roof portion is damaged, the low-temperature liquid 3 can be supplied from another low-temperature liquid supply unit 30 that is not damaged.

[0097] Note that, in the present invention, the first embodiment and the second embodiment described above can be applied in combination. In other words, in the liquefied ammonia storage apparatus 1, the low-temperature liquid supply unit 30 of the first embodiment may be disposed so as to supply the low-temperature liquid 3 into the liquid phase in the storage tank 10, and the low-temperature liquid supply unit 30 of the second embodiment may be disposed so as to supply the low-temperature liquid 3 into the gas phase in the storage tank 10.

[0098] When the storage tank 10 is opened, the low-temperature liquid 3 may be supplied into the liquid phase in the storage tank 10 from the low-temperature liquid supply unit 30 of the first embodiment, and furthermore, the low-temperature liquid 3 may be supplied into the gas phase in the storage tank 10 from the low-temperature liquid supply unit 30 of the second embodiment.

[0099] As a result, by simultaneously lowering the temperature of the liquid phase and the temperature of the gas phase in the storage tank 10, the temperature in the storage tank 10 can be further efficiently lowered, and generation of the boil-off gas can be further effectively suppressed.

[0100] A timing at which the low-temperature liquid 3 is supplied from the low-temperature liquid supply unit 30 of the first embodiment into the liquid phase and a timing at which the low-temperature liquid 3 is supplied from the low-temperature liquid supply unit 30 of the second embodiment into the gas phase may be the same or different. More specifically, for example, after the low-temperature liquid 3 is supplied into the liquid phase from the low-temperature liquid supply unit 30 of the first embodiment, the low-temperature liquid 3 may be supplied into the gas phase from the low-temperature liquid supply unit 30 of the second embodiment, or after the low-temperature liquid 3 is supplied into the gas phase from the low-temperature liquid supply unit 30 of the second embodiment, the low-temperature liquid 3 may be supplied into the liquid phase from the low-temperature liquid supply unit 30 of the first embodiment. In addition, supply of the low-temperature liquid 3 into the liquid phase from the low-temperature liquid supply unit 30 of the first embodiment and supply of the low-temperature liquid 3 into the gas phase from the low-temperature liquid supply unit 30 of the second embodiment may be repeatedly performed.

[0101] The timing at which the low-temperature liquid 3 is supplied from the low-temperature liquid supply unit 30 of the first embodiment into the liquid phase and a timing at which the inert gas 4 is supplied from the inert gas supply unit 40 into the gas phase may be the same or different. More specifically, for example, after the low-temperature liquid 3 is supplied into the liquid phase from the low-temperature liquid supply unit 30 of the first embodiment, the inert gas 4 may be supplied into the gas phase from the inert gas supply unit 40, or after the inert gas 4 is supplied into the gas phase from the inert gas supply unit 40, the low-temperature liquid 3 may be supplied into the liquid phase from the low-temperature liquid supply unit 30 of the first embodiment. In addition, supply of the low-temperature liquid 3 into the liquid phase from the low-temperature liquid supply unit 30 of the first embodiment and supply of the inert gas 4 into the gas phase from the inert gas supply unit 40 may be repeatedly performed.

[0102] The timing at which the low-temperature liquid 3 is supplied from the low-temperature liquid supply unit 30 of the second embodiment into the gas phase and the timing at which the inert gas 4 is supplied from the inert gas supply unit 40 into the gas phase may be the same or different. More specifically, for example, after the low-temperature liquid 3 is supplied into the gas phase from the low-temperature liquid supply unit 30 of the second embodiment, the inert gas 4 may be supplied into the gas phase from the inert gas supply unit 40, or after the inert gas 4 is supplied into the gas phase from the inert gas supply unit 40, the low-temperature liquid 3 may be supplied into the gas phase from the low-temperature liquid supply unit 30 of the second embodiment. In addition, supply of the low-temperature liquid 3 into the gas phase from the low-temperature liquid supply unit 30 of the second embodiment and supply of the inert gas 4 into the gas phase from the inert gas supply unit 40 may be repeatedly performed.

[0103] Next, an ammonia gas leakage suppression method at the time of maintenance of the storage tank 10 will be described.

[0104] In the above description, the method for suppressing leakage of an ammonia gas when the storage tank 10 is opened due to damage of the roof portion of the storage tank 10 in the

liquefied ammonia storage apparatus 1 has been described. However, the ammonia gas leakage suppression method of the present invention can also be applied to a method for suppressing leakage of an ammonia gas which is a combustible gas and a toxic gas when the storage tank 10 is opened at the time of maintenance of the storage tank 10.

[0105] FIG. 7 is a diagram for explaining an example of the ammonia gas leakage suppression method of the present invention, and more specifically, a diagram for explaining an ammonia gas leakage suppression method at the time of maintenance of a tank.

[0106] The storage tank 10 that stores liquefied ammonia includes a pump barrel 20 for receiving liquefied ammonia in the storage tank 10 and discharging the stored liquefied ammonia 2 to the outside from the storage tank 10.

[0107] The pump barrel 20 is a pipe-shaped structure that penetrates a roof 15 and a ceiling portion of the inner tank 11 and extends vertically to a bottom portion in the storage tank 10. A foot valve 24 is disposed at a lower portion of the pump barrel 20, and a pump 22 is disposed in the pump barrel 20.

[0108] In a top flange 23 at an upper end portion of the pump barrel 20, a head plate (not illustrated) is fixed by bolt fastening at a normal time, and the upper end portion of the pump barrel 20 and a periphery of the head plate are covered with a scattering preventing cover (not illustrated). A lower end portion of the pump barrel 20 is disposed in the stored liquefied ammonia 2, and the foot valve 24 is disposed in the lower end portion.

[0109] When the pump 22 fails, supply of liquefied ammonia to a consumption side of liquefied ammonia is seriously hindered. Therefore, it is necessary to perform maintenance and inspection of the pump 22 every predetermined operation time (for example, about 8000 hours). Since maintenance and inspection of the pump 22 are performed by taking out the pump 22 from the storage tank 10, a pump lifting device (not illustrated) for lifting the pump 22 and taking out the pump 22 from the storage tank 10 is disposed on the roof 15 of the storage tank 10.

[0110] In the pump barrel 20, a lifting wire 25 connected to the pump 22 is extended to the

vicinity of an upper end, and the pump 22 is lifted and taken out from an upper end of the pump barrel 20 by winding the lifting wire 25 with a winding device such as a hoist or a winch.

[0111] As described above, at the time of maintenance of the storage tank 10, specifically, at the time of taking out the pump 22 for discharging the stored liquefied ammonia 2 from the storage tank 10 for maintenance and inspection, and at the time of returning the pump 22 after completion of maintenance and inspection into the storage tank 10, operation is performed in a state where the top flange 23 of the pump barrel 20 is opened, and therefore the storage tank 10 is opened.

[0112] Also in this case, similarly to the case where the storage tank 10 is opened due to damage of the roof portion described above, the low-temperature liquid 3 is supplied into the storage tank 10, in other words, into the pump barrel 20, and the temperature in the pump barrel 20 is lowered, whereby generation of a vaporized gas from the stored liquefied ammonia 2 in the pump barrel 20 can be suppressed, and leakage of an ammonia gas from an open end of the pump barrel 20 can be suppressed.

[0113] Furthermore, by supplying the inert gas 4 into the pump barrel 20, it is possible to suppress generation of a combustible mixed gas within a combustion range of an ammonia gas due to mixing of the atmosphere flowing into the pump barrel 20 and an ammonia gas in the pump barrel 20, and it is possible to reduce an ammonia concentration of a toxic gas in a working environment to an allowable concentration or less.

In addition, it is possible to ensure safety of an operator at the time of maintenance work.

[0114] As a method and a condition for supplying the low-temperature liquid 3 and the inert gas 4 into the pump barrel 20, the supply method and the supply condition described above can be similarly applied.

[0115] [3] Simulation results

Next, a simulation performed for the ammonia gas leakage suppression method of the present invention will be described.

The simulation was performed under a condition of suppressing the boil-off gas

generation amount assuming that a hole was made in the roof portion of the storage tank due to an accident.

[0116] The simulation was performed using Sutton's equation, which is often used in prediction of contaminant diffusion.

FIG. 8 is a diagram schematically illustrating a state where a gaseous contaminant is diffused.

[0117] As illustrated in FIG. 8, a gaseous contaminant emitted from an emission source has a certain speed and a certain temperature, and therefore rises while being mixed and diffused, is carried in a leeward direction, and reaches the ground surface after a certain time elapses. A contaminant concentration on the ground surface at this time is referred to as "ground-level concentration".

[0118] The actual ground-level concentration varies depending on a distance from an emission source and has a local maximum value at a certain distance. The concentration at this time is a "maximum ground-level concentration". A distance from the emission source to a point where the "maximum ground-level concentration" appears is a "maximum ground-level concentration appearance distance".

[0119] [Math. 1]

Sutton's equation:

$$C_{max} = \frac{2Q}{\pi e u H e^2} \frac{C_z}{C_y}$$

[0120] Reference numerals in the formula are as follows.

C: Maximum ground-level concentration [-]

Q: Flow rate [m^3/s] (not normal flow rate but actual flow rate)

π: Ratio of a circumference of a circle to its diameter

e: Base of natural logarithm

u: Wind speed [m/s]

He: Atmosphere emission port height [m]

Cz: Diffusion coefficient

Cy: Diffusion coefficient

[0121] [3-1] Precondition of simulation

In the liquefied ammonia storage apparatus as described above, a precondition for performing the simulation was set to a more severe condition, and was as follows.

The type of tank was a pre-stressed concrete bund wall tank.

A tank storage capacity was 40,000 tons/tank. This numerical value is close to a maximum capacity that can be constructed according to the technical standard of the high-temperature gas safety law. The tank had an inner tank inner diameter of 53.5 m, a liquid height of 26.7 m, and a pre-stressed concrete bund wall height of 33.0 m from the ground surface.

A design boil-off gas generation rate was 0.05%/day. This numerical value is a standard design value of a low-temperature storage tank.

As estimation of a damaged portion of a roof portion, a circular hole having a diameter of 1 m was made in the roof portion at the height of the bund wall.

An increased boil-off gas generation rate at the time of the accident was 0.05%/day. This numerical value was estimated as an increase in heat input due to damage of the roof portion.

A boil-off gas generation rate at the time of the accident was 0.10%/day. This numerical value is a sum of the design boil-off gas generation rate and the increased boil-off gas generation rate at the time of the accident.

A flow rate of the generated boil-off gas at the time of the accident was 1.67 t/hour.

A wind speed was 1 m/s. This numerical value is a severe condition in which the maximum ground-level concentration is high.

A diffusion starting point height, in other words, a leakage portion was located at a

height of 33 m from the ground, which is the height of the bund wall. This height is the height of a side wall of a storage tank outer tank serving as a bund wall, and the lower the height, the more severe the condition.

[0122] [3-2] Study on reduction ratio of boil-off gas generation amount, maximum ground-level concentration of ammonia gas, and maximum ground-level concentration appearance distance

First, evaluation was performed on the assumption that a reduction ratio of a boil-off gas generation amount was 50% in a case of Suppression Example 1, 75% in a case of Suppression Example 2, and 90% in a case of Suppression Example 3 with respect to a case of no countermeasure. Then, for each of the no countermeasure and Suppression Examples 1 to 3, a boil-off gas generation amount, a maximum ground-level ammonia concentration, a maximum ground-level concentration reduction ratio, and a maximum ground-level concentration appearance distance were calculated.

[0123] The boil-off gas generation amount is a sum of the amount of boil-off gas generated by inevitable heat input from external area at a normal time and the amount of boil-off gas generated by heat input increased by occurrence of an accident.

Results thereof are illustrated in Table 1.

[0124] [Table 1]

Table 1

	No Countermeasure	Suppression Example 1	Suppression Example 2	Suppression Example 3
Boil-off gas reduction ratio (%)	0	50	75	90%
Boil-off gas generation amount (Nm^3/h)	2,162	1,061	540	216
Boil-off gas generation amount (m^3/s)	0.44	0.22	0.11	0.04
Maximum ground-level ammonia concentration (ppm)	95	47	24	9
Maximum ground-level concentration reduction ratio (%)	0	50	75	90
Maximum ground-level concentration appearance distance (m)	613	613	613	613

[0125] As is clear from Table 1, the no countermeasure and Suppression Examples 1 to 3 had

the same result for the maximum ground-level concentration appearance distance. In addition, in this simulation, in each of the cases, the reduction ratio of the boil-off gas generation amount and the maximum ground-level concentration reduction ratio basically coincided with each other.

[0126] Note that, according to "Recommendations on Allowable Concentration and the like" of the Japan Society of Industrial Health, the allowable concentration of ammonia is 25 ppm, and this numerical value is a concentration that does not adversely affect health even under a condition where a worker works for eight hours a day.

[0127] It was found that the maximum ground-level ammonia concentration could be suppressed within the allowable concentration range by reducing the boil-off gas generation amount by 75%.

[0128] [3-3] Study on reduction ratio of boil-off gas generation amount and supply amount of low-temperature liquid

Next, for Suppression Examples 1 to 3, in each of a case of using liquefied ammonia in a subcooled state as the low-temperature liquid and a case of using liquid nitrogen as the low-temperature liquid, the supply amount of the low-temperature liquid necessary for achieving a reduction ratio was calculated.

[0129] The liquefied ammonia in a subcooled state was liquefied ammonia cooled to -35°C. The temperature of the liquid nitrogen was -196°C.

Results thereof are illustrated in Table 2.

[0130] [Table 2]

Table 2

	Suppression Example 1	Suppression Example 2	Suppression Example 3
Boil-off gas reduction ratio (%)	50	75	90
Supplied cold flow rate (MJ/h)	1,056	1,584	1,901
Supplied cold flow rate (kW)	293	440	528
Subcooled liquefied ammonia flow rate (kg/h)	827	1,241	1,489
Liquid nitrogen supply flow rate (kg/h)	2,828	4,242	5,090

[0131] As is apparent from Table 2, it can be seen that the boil-off gas generation amount can be more reliably reduced by increasing the supply amount of the low-temperature liquid.

[0132] In addition, since the liquefied ammonia in a subcooled state has larger latent heat of vaporization than the liquid nitrogen, it can be seen that when the liquefied ammonia in a subcooled state is used as the low-temperature liquid, the supply amount of the liquefied ammonia required for achieving the same reduction ratio is only about 1/3 of that when the liquid nitrogen is used as the low-temperature liquid.

[0133] [3-4] Study on reduction ratio of boil-off gas generation amount and supply amount of inert gas

In Suppression Examples 1 to 3, a necessary supply flow rate in a case of further supplying a nitrogen gas as an inert gas in addition to the low-temperature liquid in order to suppress generation of a combustible gas was calculated.

[0134] Here, it was assumed that the supply flow rate of the inert gas necessary for suppressing generation of a combustible gas was the same as a generation flow rate of the boil-off gas.

Results thereof are illustrated in Table 3.

[0135] [Table 3]

Table 3

	Suppression Example 1	Suppression Example 2	Suppression Example 3
Boil-off gas reduction ratio (%)	50	75	90
Supplied cold flow rate (MJ/h)	1,056	1,584	1,901
Supplied cold flow rate (kW)	293	440	528
Nitrogen gas supply flow rate (Nm^3/h)	1,081	540	216
Nitrogen gas supply flow rate (kg/h)	1,352	676	270

[0136] As is clear from Table 3, since the boil-off gas generation amount varies depending on the reduction ratio of the boil-off gas generation amount by the low-temperature liquid, the amount of nitrogen gas required for suppressing generation of a combustible mixed gas varies.

[0137] It can be seen that when the reduction ratio of the boil-off gas generation amount by the

low-temperature liquid is large, the boil-off gas generation amount itself is also suppressed to be small, and therefore the amount of the inert gas required is also small.

[0138] Although the preferred embodiments of the present invention have been described above, the present invention is not limited thereto.

[0139] For example, the liquefied ammonia storage apparatus may include a component other than the storage tank, the low-temperature liquid supply unit, and the inert gas supply unit described above.

[0140] In addition, for example, the ammonia gas leakage suppression method may include a step other than the step of supplying a low-temperature liquid and the step of supplying an inert gas described above.

[0141] In addition, for example, the ammonia gas leakage suppression method of the present invention can also be applied to a case where "a storage tank is in an open state" due to a factor other than a case where a hole is opened in a roof portion due to an unexpected accident as described above and a case of maintenance of the storage tank.

Reference Signs List

[0142]

1:	Liquefied ammonia storage apparatus
2:	Stored liquefied ammonia
3:	Low-temperature liquid
4:	Inert gas
10:	Storage tank
11:	Inner tank
12:	Outer tank
13:	Bottom plate
14:	Side wall
15:	Roof

16: Heat insulating material

20: Pump barrel

22: Pump

23: Top flange

24: Foot valve

25: Lifting wire

30: Low-temperature liquid supply unit

31: Storage unit

32: Pipe

33: Regulating valve

40: Inert gas supply unit

41: Storage unit

42: Pipe

43: Regulating valve

T: Height

H: Hole

C: Arrow (convection)

CLAIMS

[Claim 1] An ammonia gas leakage suppression method, comprising:

supplying, into a storage tank that stores liquefied ammonia, a low-temperature liquid having a temperature lower than stored liquefied ammonia stored in the storage tank in a state where the storage tank is opened.

[Claim 2] The ammonia gas leakage suppression method according to claim 1, wherein

the temperature of the low-temperature liquid is -196°C or higher and -35°C or lower.

[Claim 3] The ammonia gas leakage suppression method according to claim 1 or 2, wherein

the low-temperature liquid is liquid nitrogen or liquefied ammonia in a subcooled state.

[Claim 4] The ammonia gas leakage suppression method according to any one of claims 1 to 3, wherein

the low-temperature liquid is supplied into a liquid phase in the storage tank.

[Claim 5] The ammonia gas leakage suppression method according to any one of claims 1 to 4, wherein

the low-temperature liquid is supplied into a gas phase in the storage tank.

[Claim 6] The ammonia gas leakage suppression method according to any one of claims 1 to 5, wherein

an inert gas is further supplied into a gas phase in the storage tank.

[Claim 7] The ammonia gas leakage suppression method according to claim 6, wherein

the inert gas is a nitrogen gas or a carbon dioxide gas.

[Claim 8] A liquefied ammonia storage apparatus, comprising:

a storage tank that stores liquefied ammonia; and

a low-temperature liquid supply unit that supplies, into the storage tank, a low-temperature liquid having a temperature lower than stored liquefied ammonia stored in the storage tank, wherein

the low-temperature liquid supply unit supplies the low-temperature liquid into the storage tank when the storage tank that stores the stored liquefied ammonia is opened.

[Claim 9] The liquefied ammonia storage apparatus according to claim 8, wherein

the low-temperature liquid supply unit is disposed so as to supply the low-temperature liquid into a liquid phase in the storage tank.

[Claim 10] The liquefied ammonia storage apparatus according to claim 8 or 9, wherein

the low-temperature liquid supply unit is disposed so as to supply the low-temperature liquid into a gas phase in the storage tank.

[Claim 11] The liquefied ammonia storage apparatus according to any one of claims 8 to 10, further comprising:

an inert gas supply unit that supplies an inert gas into a gas phase in the storage tank.

[Claim 12] The liquefied ammonia storage apparatus according to claim 11, wherein

the ammonia storage apparatus includes a plurality of the inert gas supply units.