

DESCRIPTION

INVENTION TITLE : APPARATUS FOR REDUCING GREENHOUSE GAS EMISSION IN VESSEL AND VESSEL INCLUDING THE SAME

TECHNICAL FIELD

- [1] The present invention relates to an apparatus for reducing greenhouse gas emission in a vessel and a vessel including the same, in which an absorbent liquid recycling unit is provided in two or more stages so that an unreacted aqueous ammonium salt solution remaining in ammonia water is removed to maintain a concentration of ammonia water at a certain level, thereby increasing a recovery rate of an absorbent liquid and preventing a deterioration in greenhouse gas absorption performance.
- [2] The present invention relates to an apparatus for reducing greenhouse gas emission in a vessel and a vessel including the same, in which exhaust gas is cooled by a heat exchange method, thereby preventing a decrease in a concentration of an absorbent liquid, and an absorbent liquid recycling unit is provided in two or more stages so that an unreacted aqueous ammonium salt solution remaining in ammonia water is removed, thereby increasing a recovery rate of the absorbent liquid and preventing a deterioration in greenhouse gas absorption performance.

BACKGROUND ART

- [3] Recently, global warming and related environmental disasters have occurred due to the influence of greenhouse gas emission caused by indiscriminate use of fossil fuels.
- [4] In this regard, a series of technologies related to capture and storage of carbon dioxide, which is the representative greenhouse gas, without carbon dioxide emission are

called carbon dioxide capture and storage (CCS) technologies. In recent years, CCS technologies have attracted much attention. Among CCS technologies, chemical absorption is the most commercialized technology in terms of enabling large-scale treatment.

- [5] In addition, carbon dioxide emission is regulated through the IMO's EEDI. The IMO is targeting a reduction of 50% or more in emissions by 2050 compared to 2008 and a reduction of 40% in emissions by 2030 compared to 2008. Therefore, technologies that do not emit CO₂ or capture emitted CO₂ are attracting attention.
- [6] For reference, among the carbon dioxide capture and storage (CCS) technologies for directly capturing and storing carbon dioxide, a CO₂ capture technology may be approached in various ways according to CO₂ generation conditions of target processes. Current representative technologies are an absorption method, an adsorption method, and a membrane separation method. Among them, the wet absorption method has high technological maturity in onshore plants and may easily process CO₂ in large quantities. Therefore, the wet absorption method may be said to be the closest capture technology to commercialization of CCS technology. As an absorbent agent, amines and ammonia are mainly used.
- [7] On the other hand, the above-described technologies for reducing carbon dioxide emission or capturing generated carbon dioxide are not currently commercialized in vessels, and methods of using hydrogen or ammonia as fuel are currently under development and have not reached the level of commercialization.
- [8] Furthermore, the need is raised to apply, to vessels, a technology for absorbing CO₂, which is greenhouse gas among exhaust gases emitted from a vessel engine, with an absorbent liquid, converting CO₂ into materials that do not affect environments,

discharging the materials, or converting CO₂ into useful materials and storing the useful materials, and preventing the deterioration in absorption performance due to the change in concentration of absorbent liquid.

- [9] Furthermore, the need is raised to apply, to vessels using LNG or low sulphur fuel oil so as to emit a small amount of SO_x or prevent SO_x emission, a technology for absorbing CO₂, which is one of exhaust gases emitted from a vessel engine, with an absorbent liquid, converting CO₂ into materials that do not affect environments, discharging the materials, or converting CO₂ into useful materials and storing the useful materials, preventing the decrease in concentration of absorbent liquid due to cooling of exhaust gas by seawater, and preventing the decrease in absorption performance due to concentration change caused by repeated circulation of absorbent liquid.

DISCLOSURE

TECHNICAL PROBLEM

- [10] An object of the present invention is to provide an apparatus for reducing greenhouse gas emission in a vessel and a vessel including the same, in which an absorbent liquid recycling unit is provided in two or more stages so that an unreacted aqueous ammonium salt solution remaining in ammonia water is removed to maintain a concentration of ammonia water at a certain level, thereby increasing a recovery rate of an absorbent liquid and preventing a deterioration in greenhouse gas absorption performance.
- [11] Also, an object of the present invention is to provide an apparatus for reducing greenhouse gas emission in a vessel and a vessel including the same, in which exhaust gas is cooled by a heat exchange method, thereby preventing a decrease in a

concentration of an absorbent liquid, and an absorbent liquid recycling unit is provided in two or more stages so that an unreacted aqueous ammonium salt solution remaining in ammonia water is removed, thereby increasing a recovery rate of the absorbent liquid and preventing a deterioration in greenhouse gas absorption performance.

TECHNICAL SOLUTION

- [12] In order to achieve the object described above, the present invention provides an apparatus for reducing greenhouse gas emission in a vessel, the apparatus including: a seawater supply unit that supplies seawater; an absorbent liquid producing unit that produces and supplies a high-concentration CO₂ absorbent liquid; an absorption tower including a CO₂ removing unit that cools exhaust gas discharged from a vessel engine by reacting the exhaust gas with the seawater supplied from the seawater supply unit, and removes CO₂ by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into an aqueous ammonium salt solution; and an absorbent liquid recycling unit including a primary recycling unit that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution, and a secondary recycling unit that secondarily recycles the high-concentration absorbent liquid by additionally reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling unit and circulates and supplies the recycled absorbent liquid to the absorption tower for reuse as the absorbent liquid.
- [13] In addition, the absorbent liquid recycling unit may include: a storage tank that stores the aqueous divalent metal hydroxide solution; the primary recycling unit

including a mixing tank in which the aqueous divalent metal hydroxide solution and the aqueous ammonium salt solution discharged from the absorption tower are stirred by an agitator to generate $\text{NH}_3(\text{g})$ and carbonate, and a primary filter that suctions a solution and precipitate from the mixing tank and separates the carbonate; and a secondary recycling unit including a primary absorbent liquid storage tank that stores the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter and re-reacts the unreacted aqueous ammonium salt solution with the aqueous divalent metal hydroxide solution supplied from the storage tank, a secondary filter that suctions the solution and precipitate from the primary absorbent liquid storage tank to separate carbonate and high-concentration ammonia water, and a secondary absorbent liquid storage tank that stores the high-concentration ammonia water separated by the secondary filter.

- [14] In addition, the storage capacity of the primary absorbent liquid storage tank may be at least three times the capacity of the absorbent liquid circulating through the absorption tower and the absorbent liquid recycling unit.
- [15] In addition, the primary absorbent liquid storage tank may include: an agitator that stirs and reacts the aqueous divalent metal hydroxide solution and the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter; and a pH sensor that measures the degree of reaction by the agitator.
- [16] In addition, the aqueous divalent metal hydroxide solution stored in the storage tank may be $\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$ produced by reacting fresh water with CaO or MgO .
- [17] In addition, fresh water or ammonia water separated by the secondary filter may be supplied to the secondary absorbent liquid storage tank, or surplus fresh water

additionally generated by the mixing tank relative to a total circulating fresh water may be stored in a fresh water tank and reused when the aqueous divalent metal hydroxide solution is generated in the storage tank.

[18] In addition, the absorption tower may further include a SO_x absorbing unit that dissolves and removes SO_x while cooling the exhaust gas discharged from the vessel engine by reacting the exhaust gas with the seawater supplied from the seawater supply unit, and the CO₂ removing unit may cool the exhaust gas, from which the SO_x has been removed, by reacting the exhaust gas with the seawater supplied from the seawater supply unit and may remove CO₂ by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into the aqueous ammonium salt solution.

[19] In addition, the absorption tower may further include a NO_x absorbing unit that absorbs and removes NO_x from the exhaust gas emitted from the vessel engine, and the CO₂ removing unit may cool the exhaust gas, from which the NO_x has been removed, by reacting the exhaust gas with the seawater supplied from the seawater supply unit and may remove CO₂ by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into the aqueous ammonium salt solution.

[20] In addition, in the absorption tower, a NO_x absorbing unit that absorbs and removes NO_x from the exhaust gas discharged from the vessel engine, a SO_x absorbing unit that dissolves and removes SO_x while cooling the exhaust gas, from which the NO_x has been removed, through reaction with the seawater supplied from the seawater supply unit, and the CO₂ removing unit that removes CO₂ by reacting the exhaust gas, from which the SO_x has been removed, with the absorbent liquid

supplied from the absorbent liquid producing unit to convert CO_2 into the aqueous ammonium salt solution may be sequentially stacked.

[21] In addition, NH_3 recycled by the absorbent liquid recycling unit may be returned back to the absorption tower and converted into the absorbent liquid for reuse as the absorbent liquid, and the NO_x absorbing unit may receive the NH_3 recycled by the absorbent liquid recycling unit to absorb NO_x with the NH_3 , or may absorb NO_x using urea water.

[22] In addition, the seawater supply unit may include: a seawater pump that receives seawater from the outside of the vessel through a sea chest and pumps the seawater to the SO_x absorbing unit; and a seawater control valve that controls a spray amount of the seawater supplied from the seawater pump to the SO_x absorbing unit according to an amount of the exhaust gas.

[23] In addition, the absorbent liquid producing unit may include: a fresh water tank that stores fresh water; a fresh water control valve that supplies the fresh water from the fresh water tank; a NH_3 storage that stores high-pressure NH_3 ; an ammonia water tank that produces and stores high-concentration ammonia water, which is the absorbent liquid, by spraying the NH_3 supplied from the NH_3 storage to the fresh water supplied by the fresh water control valve; a pH sensor that measures a concentration of the ammonia water in the ammonia water tank; and an ammonia water supply pump that supplies the ammonia water from the ammonia water tank to the secondary absorbent liquid storage tank.

[24] In addition, the apparatus may further include an ammonia water circulation pump that circulates the ammonia water from the secondary absorbent liquid storage tank to the absorption tower.

- [25] In addition, the SO_x absorbing unit may include: a multi-stage seawater spray nozzle that sprays the seawater supplied from the seawater supply unit downward; and a partition wall-shaped exhaust gas inlet pipe that prevents cleaning water from flowing back, or an umbrella-shaped blocking plate that covers the exhaust gas inlet pipe.
- [26] In addition, porous upper plates having a passage through which the exhaust gas passes may be respectively formed in multi-stages under the seawater spray nozzle, so that the seawater and the exhaust gas come into contact with each other.
- [27] In addition, an absorption apparatus filled with a packing material for allowing the seawater and the exhaust gas to come into contact with each other may be formed under the seawater spray nozzle, so that the seawater dissolves the SO_x .
- [28] In addition, the CO_2 removing unit may include: an ammonia water spray nozzle that sprays the absorbent liquid supplied from the absorbent liquid recycling unit downward; a packing material that contacts the CO_2 with the ammonia water, which is the absorbent liquid, to convert the CO_2 into $\text{NH}_4\text{HCO}_3(\text{aq})$; a cooling jacket that is formed in multi-stages for each section of an absorption apparatus filled with the packing material and cools heat generated by a CO_2 absorption reaction; a water spray that collects NH_3 discharged to the outside without reacting with CO_2 ; a mist removal plate that is formed in a curved multi-plate shape and returns the ammonia water toward the packing material; a partition wall that is formed so that the ammonia water does not flow back; and an umbrella-shaped blocking plate that covers an exhaust gas inlet hole surrounded by the partition wall.
- [29] In addition, the packing material may include multi-stage distilling column packings designed to increase a contact area per unit volume, and a solution

redistributor may be formed between the multi-stage distilling column packings.

[30] In addition, the absorption tower may further include an exhaust gas economizer (EGE) that is formed between the NO_x absorbing unit and the SO_x absorbing unit and performs heat exchange between waste heat of the vessel engine and boiler water.

[31] In addition, the apparatus may further include a discharge unit including: a cleaning water tank that stores cleaning water discharged from the absorption tower; a water treatment device including a filtering unit that controls turbidity to satisfy an outboard discharge condition of the cleaning water transferred to the cleaning water tank by a transfer pump, and a neutralizing agent injecting unit that controls pH; and a sludge storage tank that separates and stores solid emissions.

[32] On the other hand, the present invention may provide a vessel including the above-described apparatus.

[33] In order to achieve another object described above, the present invention provides an apparatus for reducing greenhouse gas emission in a vessel, the apparatus including: an exhaust gas cooling unit that cools exhaust gas discharged from a vessel engine; an absorbent liquid producing unit that produces and supplies a high-concentration CO₂ absorbent liquid; an absorption tower including a CO₂ removing unit that removes CO₂ by reacting the exhaust gas cooled by the exhaust gas cooling unit with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into an aqueous ammonium salt solution; and an absorbent liquid recycling unit including a primary recycling stage that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution, and a secondary recycling stage that secondarily recycles the high-concentration absorbent

liquid by additionally reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling stage and circulates and supplies the recycled absorbent liquid to the absorption tower for reuse as the absorbent liquid.

[34] In addition, the vessel engine may use liquefied natural gas (LNG) or low sulphur marine gas oil (LSMGO) as fuel.

[35] In addition, the exhaust gas cooling unit may cool the exhaust gas to a temperature of 27°C to 33°C by circulating fresh water supplied from an onboard cooling system through a heat exchange pipe surrounding an exhaust gas discharge pipe.

[36] In addition, the absorbent liquid recycling unit may include: a storage tank that stores the aqueous divalent metal hydroxide solution; the primary recycling stage including a mixing tank in which the aqueous ammonium salt solution discharged from the absorption tower and the aqueous divalent metal hydroxide solution supplied from the storage tank are stirred by an agitator to generate $\text{NH}_3(\text{g})$ and carbonate, and a primary filter that suctions a solution and precipitate from the mixing tank and separates the carbonate; and the secondary recycling stage including: a primary absorbent liquid storage tank that stores the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter and re-reacts the unreacted aqueous ammonium salt solution with the aqueous divalent metal hydroxide solution supplied from the storage tank; a secondary filter that suctions the solution and precipitate from the primary absorbent liquid storage tank to separate carbonate and high-concentration ammonia water; and a secondary absorbent liquid storage tank that stores the high-concentration ammonia water separated by the

secondary filter.

- [37] In addition, the storage capacity of the primary absorbent liquid storage tank is at least three times the capacity of the absorbent liquid circulating through the absorption tower and the absorbent liquid recycling unit along an absorbent liquid circulation line.
- [38] In addition, the primary absorbent liquid storage tank may include: an agitator that stirs and reacts the aqueous divalent metal hydroxide solution supplied from the storage tank and the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter; and a pH sensor that measures the degree of reaction by the agitator.
- [39] In addition, the aqueous divalent metal hydroxide solution stored in the storage tank may be $\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$ produced by reacting fresh water with CaO or MgO .
- [40] In addition, fresh water or ammonia water separated by the secondary filter may be supplied to the secondary absorbent liquid storage tank, or surplus fresh water additionally generated by the mixing tank relative to a total circulating fresh water may be stored in a fresh water tank and reused when the aqueous divalent metal hydroxide solution is generated in the storage tank.
- [41] In addition, the absorption tower may further include a NO_x absorbing unit that absorbs and removes NO_x from the exhaust gas emitted from the vessel engine, and the CO_2 removing unit may remove CO_2 by reacting the exhaust gas, from which the NO_x has been removed and which is cooled by the exhaust gas cooling unit, with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO_2 into the aqueous ammonium salt solution.

- [42] In addition, the absorbent liquid recycling unit may recycle NH_3 and return the NH_3 back to the absorption tower for reuse as the absorbent liquid, and the NO_x absorbing unit may absorb NO_x with the NH_3 supplied from the absorbent liquid recycling unit, or may absorb NO_x using urea water.
- [43] In addition, the absorbent liquid producing unit may include: a fresh water tank that stores fresh water; a fresh water control valve that controls an amount of the fresh water supplied from the fresh water tank; a NH_3 storage that stores high-pressure NH_3 ; an ammonia water tank that produces and stores high-concentration ammonia water, which is the absorbent liquid, by spraying the NH_3 supplied from the NH_3 storage to the fresh water supplied by the fresh water control valve; a pH sensor that measures a concentration of the ammonia water in the ammonia water tank; and an ammonia water supply pump that supplies the ammonia water from the ammonia water tank to the secondary absorbent liquid storage tank.
- [44] In addition, the apparatus may further include an ammonia water circulation pump that circulates the ammonia water from the secondary absorbent liquid storage tank to the absorption tower.
- [45] In addition, the CO_2 removing unit may include: an ammonia water spray nozzle that sprays the absorbent liquid supplied from the absorbent liquid recycling unit downward; a packing material that contacts the CO_2 with the ammonia water, which is the absorbent liquid, to convert the CO_2 into $\text{NH}_4\text{HCO}_3(\text{aq})$; a cooling jacket that is formed in multi-stages for each section of an absorption apparatus filled with the packing material and cools heat generated by a CO_2 absorption reaction; a water spray that collects NH_3 discharged to the outside without reacting with CO_2 ; a mist removal plate that is formed in a curved multi-plate shape and returns the ammonia water

toward the packing material; a partition wall that is formed so that the ammonia water does not leak out; and an umbrella-shaped blocking plate that covers an exhaust gas inlet hole surrounded by the partition wall.

[46] In addition, the packing material may include multi-stage distilling column packings designed to increase a contact area per unit volume, and a solution redistributor is formed between the multi-stage distilling column packings.

[47] In addition, the absorption tower may further include an exhaust gas economizer (EGE) that is formed between the NO_x absorbing unit and the exhaust gas cooling unit and performs heat exchange between waste heat of the exhaust gas from the vessel engine and boiler water.

[48] On the other hand, the present invention may provide a vessel including the above-described apparatus.

ADVANTAGEOUS EFFECTS

[49] According to the present invention, an absorbent liquid recycling unit is provided in two or more stages so that an unreacted aqueous ammonium salt solution remaining in ammonia water is removed to maintain a concentration of ammonia water at a certain level, thereby increasing a recovery rate of an absorbent liquid and preventing the deterioration in greenhouse gas absorption performance.

[50] In addition, a pressurization system may be applied to prevent the loss of absorbent liquid due to the natural evaporation of high-concentration absorbent liquid.

[51] Furthermore, in order to satisfy the IMO greenhouse gas emission regulations, greenhouse gas may be converted into materials that do not affect environments and then separately discharged or may be converted into useful materials and then stored. NH₃ may be recycled to minimize consumption of relatively expensive NH₃. A

capacity size of a rear end of a filter may be reduced. Greenhouse gas may be stored in the form of carbonate that exists in a natural state so that greenhouse gas may be discharged to the sea. Side reactions caused by SO_x remaining during NH_3 recycling may be removed, thereby minimizing the loss of NH_3 and preventing impurities from being included when recovering ammonia.

[52] In addition, according to the present invention, exhaust gas may be cooled by a heat exchange method, thereby preventing a decrease in a concentration of an absorbent liquid and preventing a deterioration in greenhouse gas absorption performance.

[53] In addition, according to the present invention, exhaust gas may be cooled by a heat exchange method, thereby preventing a decrease in a concentration of an absorbent liquid and preventing a deterioration in greenhouse gas absorption performance.

[54] Furthermore, in order to satisfy the IMO greenhouse gas emission regulations, greenhouse gas may be converted into materials that do not affect environments and then separately discharged or may be converted into useful materials and then stored. NH_3 may be recycled to minimize consumption of relatively expensive NH_3 . A capacity size of a rear end of a filter may be reduced. Greenhouse gas may be stored in the form of carbonate that exists in a natural state so that greenhouse gas may be discharged to the sea. Side reactions caused by SO_x remaining during NH_3 recycling may be removed, thereby minimizing the loss of NH_3 and preventing impurities from being included when recovering ammonia.

DESCRIPTION OF DRAWINGS

[55] FIG. 1 is a schematic configuration diagram of an apparatus for reducing

greenhouse gas emission in a vessel, according to an embodiment of the present invention.

[56] FIG. 2 is a circuit diagram of a system implementing the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 1.

[57] FIG. 3 separately illustrates a seawater supply unit of the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.

[58] FIG. 4 separately illustrates an absorbent liquid producing unit and an absorbent liquid recycling unit of the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.

[59] FIG. 5 separately illustrates an absorption tower of the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.

[60] FIG. 6 separately illustrates a SO_x absorbing unit of the absorption tower of FIG. 5.

[61] FIG. 7 separately illustrates a steam generating unit and a discharge unit of the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.

[62] FIG. 8 illustrates various packing materials applied to the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.

[63] FIG. 9 illustrates an ammonia water spray nozzle applied to the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.

[64] FIG. 10 is a schematic configuration diagram of an apparatus for reducing greenhouse gas emission in a vessel, according to another embodiment of the present invention.

[65] FIG. 11 is a circuit diagram of a system implementing the apparatus for reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in

FIG. 10.

[66] FIG. 12 separately illustrates an exhaust gas cooling unit and an absorption tower of the apparatus for reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in FIG. 11.

[67] FIG. 13 separately illustrates an absorbent liquid producing unit and an absorbent liquid recycling unit of the apparatus for reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in FIG. 11.

[68] FIG. 14 separately illustrates a steam generating unit of the apparatus for reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in FIG. 11.

[69] FIG. 15 illustrates various packing materials applied to the apparatus for reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in FIG. 11.

[70] FIG. 16 illustrates an ammonia water spray nozzle applied to the apparatus for reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in FIG. 11.

BEST MODE

[71] Hereinafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings so that the present invention can be easily carried out by those of ordinary skill in the art. The present invention may be embodied in many different forms and is not limited to embodiments of the present invention described herein.

[72] Referring to FIG. 1, an apparatus for reducing greenhouse gas emission in a vessel according to an embodiment of the present invention includes: a seawater

supply unit 110 that supplies seawater; an absorbent liquid producing unit 120 that produces and supplies a high-concentration CO₂ absorbent liquid; an absorption tower 130 including a CO₂ removing unit 131 that cools exhaust gas discharged from a vessel engine 10 by reacting the exhaust gas with the seawater supplied from the seawater supply unit 110, and removes CO₂ by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit 120 to convert CO₂ into an aqueous ammonium salt solution; and an absorbent liquid recycling unit including a primary recycling unit 140 that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower 130 with an aqueous divalent metal hydroxide solution, and a secondary recycling unit 150 that secondarily recycles the high-concentration absorbent liquid by additionally reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling unit 140 and circulates and supplies the recycled absorbent liquid to the absorption tower 130 for reuse as the absorbent liquid. A recovery rate of the absorbent liquid is increased and maintained at a certain concentration, thereby preventing a deterioration in absorption performance.

[73] Here, according to the type and specification of the vessel engine (low-pressure engine or high-pressure engine) used in a main engine or power generation engine and the type of fuel supplied to the vessel engine (HFO, MDO, LNG, MGO, LSMGO, ammonia, etc.), the absorption tower may optionally include, in addition to the CO₂ removing unit, a NO_x absorbing unit or a SO_x absorbing unit, or may include both the NO_x absorbing unit and the SO_x absorbing unit.

[74] In particular, when low sulphur marine gas oil (LSMGO) is used as the fuel of

the vessel engine, a SO_x absorbing unit capable of simultaneously performing cooling of exhaust gas and absorption and removal by dissolution of SO_x may be additionally provided.

[75] Hereinafter, an embodiment in which the NO_x absorbing unit, the SO_x absorbing unit, and the CO₂ removing unit are sequentially stacked on the absorption tower will be described, but the present invention is not limited thereto. As described above, the NO_x absorbing unit and/or the SO_x absorbing unit may or may not be included according to the types of vessel engine and fuel.

[76] Hereinafter, the apparatus for reducing greenhouse gas emission in the vessel will be described in detail with reference to FIGS. 1 to 9.

[77] First, a seawater supply unit 110 supplies seawater to an absorption tower 130 so that temperature of exhaust gas is lowered to facilitate absorption of CO₂ by an absorbent liquid.

[78] Specifically, as illustrated in FIGS. 2 and 3, the seawater supply unit 110 may include: a seawater pump 111 that suctions seawater from the outside of the vessel through a sea chest (not illustrated) and pumps the seawater to a SO_x absorbing unit 132 of the absorption tower 130; and a seawater control valve 112 that controls the spray amount of the seawater supplied to the SO_x absorbing unit 132 according to the amount of exhaust gas. Here, the seawater pump 111 may separately include a suction pump that suctions the seawater from the outside of the vessel and a seawater transfer pump that pumps and transfers the seawater to the SO_x absorbing unit 132.

[79] For reference, when the vessel is berthing or sailing, seawater may be selectively supplied to the seawater pump 111 from a high sea chest that suctions upper seawater or a low sea chest that suctions lower seawater according to the depth of water. That

is, when the vessel is berthing, the high sea chest may be used because the upper seawater is cleaner than the lower seawater, and when the vessel is sailing, the low sea chest may be used because the lower seawater is cleaner than the upper seawater.

[80] Here, the seawater control valve 112 may be a manually operated diaphragm valve or a solenoid type valve that controls the flow rate of seawater, but the present invention is not limited thereto. Any type of valve may be applied as long as the amount of seawater sprayed through a seawater spray nozzle 132a can be controlled according to the amount of exhaust gas.

[81] Next, the absorbent liquid producing unit 120 reacts fresh water with NH_3 as shown in [Chemical Formula 1] below to produce high-concentration ammonia water ($\text{NH}_4\text{OH}(\text{aq})$), which is a high-concentration CO_2 absorbent liquid, and supplies the high-concentration ammonia water ($\text{NH}_4\text{OH}(\text{aq})$) to the absorption tower 130 through an absorbent liquid storage tank 153.

[Chemical Formula 1]



[82] Specifically, as illustrated in FIGS. 2 and 4, the absorbent liquid producing unit 120 may include: a fresh water tank (not illustrated) that stores fresh water; a fresh water control valve 121 that supplies the fresh water from the fresh water tank to an ammonia water tank 123; a NH_3 storage 122 that stores high-pressure NH_3 ; an ammonia water tank 123 that produces and stores high-concentration ammonia water by spraying NH_3 supplied from the NH_3 storage 122 to the fresh water supplied by the fresh water control valve 121; a pH sensor 124 that measures a concentration of the ammonia water in the ammonia water tank 123; and an ammonia water supply pump 125 that supplies the high-concentration ammonia water from the ammonia

water tank 123 to a secondary absorbent liquid storage tank 153.

[83] The concentration of the ammonia water circulating through the absorption tower 130 and an absorbent liquid recycling unit changes as the operation is repeated. For example, the concentration of the ammonia water is reduced when NH_3 is supplied to the NO_x absorbing unit 133 and used to absorb and remove NO_x , or when NH_3 passes through the absorption tower 130 and is exhausted together with the exhaust gas. When the concentration of the ammonia water is reduced, the absorbent liquid producing unit 120 supplies the high-concentration ammonia water to an absorbent liquid circulation line (see A in FIG. 1) to compensate for the reduced concentration of the ammonia water so that the ammonia water is constantly maintained at a designed concentration.

[84] On the other hand, since the high-concentration ammonia water has a higher partial pressure of $\text{NH}_3(\text{g})$ than that of the low-concentration ammonia water at the same temperature, NH_3 is relatively more evaporated in an atmospheric pressure state, resulting in an increase in loss. Therefore, in order to store the high-concentration ammonia water, it is necessary to lower temperature in order for increasing the solubility and reducing the vapor pressure of $\text{NH}_3(\text{g})$ and to operate under a pressurization system.

[85] That is, in order to prevent a phenomenon that $\text{NH}_3(\text{g})$ is evaporated and lost to the atmosphere, compressed air of a constant pressure may be injected into the ammonia water tank 123 so that the pressure in the ammonia water tank 123 is maintained to be high, thereby preventing the evaporation loss of NH_3 .

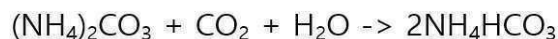
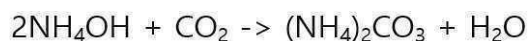
[86] For example, since NH_3 may be stored in a liquid state at -34°C and 8.5 bar, 50% concentration of ammonia water may be stored in the ammonia water tank 123 by

maintaining the inside of the ammonia water tank 123 at a constant pressure by using compressed air of 7 bar available in the vessel.

[87] In addition, a safety valve 123a for preventing overpressure of the ammonia water tank 123 may be installed.

[88] Next, the absorption tower 130 includes a CO₂ removing unit 131 that cools exhaust gas discharged from the vessel engine 10 by reacting the exhaust gas with the seawater supplied from the seawater supply unit 110, reacts CO₂ of the cooled exhaust gas with ammonia water, which is the absorbent liquid supplied from the absorbent liquid producing unit 120, and converts CO₂ into an aqueous ammonium salt solution (NH₄HCO₃(aq)) to remove CO₂ as shown in [Chemical Formula 2] below.

[Chemical Formula 2]



[89] Specifically, as illustrated in FIG. 3, the CO₂ removing unit 131 may include: an ammonia water spray nozzle 131a that sprays the ammonia water supplied from the secondary absorbent liquid storage tank 153 downward; a packing material 131b that contacts CO₂ of the exhaust gas with the ammonia water, which is the absorbent liquid, and converts CO₂ into NH₄HCO₃(aq); a cooling jacket (not illustrated) that is formed in multi-stages for each section of an absorption apparatus filled with the packing material 131b and cools heat generated by the CO₂ absorption reaction; a water spray 131c that collects NH₃ discharged to the outside without reacting with CO₂; a mist removal plate 131d that is formed in a curved multi-plate shape and returns the ammonia water scattered when sprayed by the ammonia water spray

nozzle 131a toward the packing material 131b; a partition wall 131e that is formed so that the ammonia water passing through the packing material 131b does not flow back to the SO_x absorbing unit 132, and an umbrella-shaped blocking plate 131f that covers an exhaust gas inlet hole surrounded by the partition wall 131e.

[90] Here, the cooling jacket may cool heat to 30°C to 50°C at which the material transfer is smoothest, so that NH₃ is not evaporated and lost while maintaining a CO₂ absorption rate at a certain level.

[91] On the other hand, the CO₂ removing unit 131 may be considered in various forms so as to operate within an allowable pressure drop of an exhaust pipe required by an engine specification while increasing a contact area between the exhaust gas and NH₃. For example, the packing material 131b may include multi-stage distilling column packings designed to increase a contact area per unit volume. As illustrated in FIG. 8, a distilling column packing suitable for an absorption process may be selected considering the contact area per unit area, the pressure drop of gas, and the flooding velocity. As illustrated in FIG. 9, the ammonia water spray nozzle 131a may be provided in a ladder pipe form FIG. 9A or a spray form FIG. 9B.

[92] In addition, a solution redistributor (not illustrated) may be formed between the distilling column packings so as to prevent channeling when the ammonia water passes downward through the packing material 131b, the exhaust gas passes upward through the packing material 131b, and the ammonia water and the exhaust gas contact each other.

[93] In addition, the mist removal plate 131d allows the scattered ammonia water to adhere to the curved multi-plate, so that droplets become large, and drains the ammonia water toward the packing material 131b by the own weight thereof.

- [94] On the other hand, when the vessel engine 10 uses LNG as fuel, SO_x may not be generated, but when the vessel engine 10 uses LSMGO as fuel, the absorption tower 130 may further include the SO_x absorbing unit 132.
- [95] That is, the SO_x absorbing unit 132 may dissolve and remove SO_x while cooling the exhaust gas discharged from the vessel engine 10 by reacting the exhaust gas with the seawater supplied from the seawater supply unit 110, and the CO₂ removing unit 131 may cool the exhaust gas, from which the SO_x is removed, through reaction with the seawater supplied from the seawater supply unit 110, react the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit 120 to convert CO₂ into an aqueous ammonium salt solution, and absorb and remove CO₂.
- [96] Specifically, the SO_x absorbing unit 132 is a section that is in primary contact with seawater. As illustrated in FIGS. 3 and 6, the SO_x absorbing unit 132 may include: a multi-stage seawater spray nozzle 132a that dissolves SO_x by spraying the seawater supplied from the seawater supply unit 110 downward and removes dusts such as soot; and a partition wall-shaped exhaust gas inlet pipe 132b that prevents cleaning water from flowing back, or an umbrella-shaped blocking plate 132c that covers the exhaust gas inlet pipe 132b.
- [97] On the other hand, the SO_x absorbing unit 132 may cool the temperature of the exhaust gas to 27°C to 33°C, preferably about 30°C, which is required by the CO₂ removing unit 131, through the seawater spray nozzle 132a or a separate cooling jacket (not illustrated). As illustrated in FIG. 6A, porous upper plates 132d having a passage through which the exhaust gas passes may be respectively formed in multi-stages under the seawater spray nozzle 132a, so that the seawater and the exhaust gas come into smooth contact with each other. As illustrated in FIG. 6B, an absorption

apparatus 132e filled with a packing material for allowing the seawater and the exhaust gas to come into contact with each other may be formed under the seawater spray nozzle 132a, so that the seawater dissolves SO_x.

[98] On the other hand, a closed loop system may be applied to add a compound forming alkali ions, for example, a basic chemical of NaOH or MgO, to the seawater supplied to the SO_x absorbing unit 132 in order to further increase the solubility of SO_x.

[99] For reference, the closed loop system involves additional consumption of basic chemicals, but has an advantage that the amount of circulating seawater is small, and the open loop system that discharges SO_x dissolved by spraying only seawater to the outside of the vessel has no additional consumption of basic chemicals and is simple. In order to maximize these advantages, a hybrid system in which the open loop system and the closed loop system are combined may be applied.

[100] In this regard, by removing SO_x through the SO_x absorbing unit 132 and then removing CO₂ through the CO₂ removing unit 131, it is possible to solve the problem that it is difficult to remove CO₂ until SO_x is completely dissolved because the solubility of SO_x is high and thus SO_x is first changed to a compound such as NaSO₃, thereby improving the solubility of CO₂ and the removal efficiency of CO₂.

[101] Here, cleaning water drained to a discharge unit 170 after SO_x is absorbed by the SO_x absorbing unit 132 contains SO₃⁻, SO₄²⁻, soot, NaSO₃, Na₂SO₄, MgCO₃, MgSO₄, and other ionic compounds together.

[102] On the other hand, as described above, the absorption tower 130 may further include a NO_x absorbing unit 133 that absorbs and removes NO_x from the exhaust gas discharged from the vessel engine 10. The absorption tower 130 may cool the

exhaust gas, from which the NO_x has been removed, through reaction with the seawater supplied from the seawater supply unit 110 and may remove CO_2 by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit 120 to convert CO_2 into an aqueous ammonium salt solution.

[103] That is, in the absorption tower 130, the NO_x absorbing unit 133 that absorbs and removes NO_x from the exhaust gas discharged from the vessel engine 10, the SO_x absorbing unit 132 that dissolves and removes SO_x while cooling the exhaust gas, from which the NO_x has been removed, through reaction with the seawater, and the CO_2 removing unit 131 that removes CO_2 by reacting the exhaust gas, from which the SO_x has been removed, with the ammonia water supplied from the absorbent liquid producing unit 120 to convert CO_2 into $\text{NH}_4\text{HCO}_3(\text{aq})$ are stacked in the vertical direction to sequentially absorb and remove the NO_x , the SO_x , and the CO_2 .

[104] Therefore, since the CO_2 removing unit 131 removes NO_x and SO_x by reacting the ammonia water with the exhaust gas from which the NO_x and the SO_x have been removed, side reactions caused by NO_x and SO_x do not occur during the CO_2 removal process, thereby minimizing the generation of impurities and obtaining NH_4HCO_3 with less impurities in a subsequent process.

[105] Here, the absorption tower 130 may include the CO_2 removing unit 131, the SO_x absorbing unit 132, the NO_x absorbing unit 133, and an exhaust gas economizer (EGE) 134 to be described later, may be modularized and combined with individual modules, and may be integrated in a single tower form, and the absorption tower 130 itself may include a single tower or a group of a plurality of towers.

[106] Specifically, the NO_x absorbing unit 133 is a selective catalyst reactor (SCR). As illustrated in FIG. 5, the NO_x absorbing unit 133 may directly supply NH_3 from a

primary recycling unit 140 to a first NH_3 spray nozzle 133b through a blower 133a or a compressor, or when NH_3 is insufficient, may receive urea water of a urea water storage tank 133c from a second NH_3 spray nozzle 133e through a urea water supply pump 133d so as to compensate for the lack of NH_3 .

[107] On the other hand, since NH_3 and CO_2 are generated when the urea water is decomposed, it may be preferable that NH_3 is directly supplied to reduce the amount of CO_2 generated.

[108] In addition, the absorption tower 130 may further include an EGE 134 that is formed between the NO_x absorbing unit 133 and the SO_x absorbing unit 132 and performs heat exchange between waste heat of the vessel engine 10 and boiler water.

[109] Next, the absorbent liquid recycling unit may recycle NH_3 and return NH_3 back to the absorption tower 130 for reuse as a CO_2 absorbent liquid, may store CO_2 in the form of $\text{CaCO}_3(\text{s})$ or $\text{MgCO}_3(\text{s})$ or discharge CO_2 to the outside of the vessel, or may supply NH_3 to the NO_x absorbing unit 133 so as to absorb NO_x with NH_3 .

[110] That is, the absorbent liquid recycling unit may include: a primary recycling unit 140 that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower 130 with an aqueous divalent metal hydroxide solution; and a secondary recycling unit 150 that secondarily recycles the high-concentration absorbent liquid by reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling unit 140 and circulates and supplies the recycled absorbent liquid to the absorption tower 130 for reuse as the absorbent liquid. A recovery rate of the absorbent liquid may be increased and maintained at a certain concentration. As described above, NH_3 is supplied to the NO_x absorbing unit 133

and used to absorb and remove NO_x . NH_3 is discharged together with exhaust gas through the absorption tower 130, so that the concentration of the ammonia water is lowered. Therefore, it is possible to effectively prevent the deterioration in absorption performance.

[111] Specifically, as illustrated in FIG. 4, the absorbent liquid recycling unit may include: a storage tank 141 that stores an aqueous divalent metal hydroxide solution; a primary recycling unit 140 including a mixing tank 142 in which the aqueous divalent metal hydroxide solution and the aqueous ammonium salt solution discharged from the absorption tower 130 are stirred by an agitator to generate $\text{NH}_3(\text{g})$ and carbonate as shown in [Chemical Formula 3] below, and a primary filter 143 that suctions a solution and precipitate from the mixing tank 142 and separates the carbonate and ammonia water (or fresh water); and a secondary recycling unit 150 including a primary absorbent liquid storage tank 151 that stores an unreacted aqueous ammonium salt solution remaining without reacting with the ammonia water and the aqueous divalent metal hydroxide separated by the primary filter 143 and re-reacting the unreacted aqueous ammonium salt solution with the aqueous divalent metal hydroxide solution supplied from the storage tank 141, a secondary filter 152 that suctions the solution and precipitate from the primary absorbent liquid storage tank 151 to separate carbonate and high-concentration ammonia water and is designed corresponding to the capacity of the primary absorbent liquid storage tank 151, a secondary absorbent liquid storage tank 153 that stores the high-concentration ammonia water separated by the secondary filter 152, and an ammonia water circulation pump 154 that pumps and circulates the ammonia water from the secondary absorbent liquid storage tank 153 to the CO_2 removing unit 131.

[Chemical Formula 3]



[112] Here, the storage capacity of the primary absorbent liquid storage tank 151 is designed to be at least three times the capacity of the absorbent liquid circulating through the absorption tower 130 and the absorbent liquid recycling unit, and thus has a relatively large capacity compared to the capacity of the circulating absorbent liquid. The stay time of the unreacted aqueous ammonium salt solution in the primary absorbent liquid storage tank 151 is increased to sufficiently secure the reaction time. Therefore, the unreacted aqueous ammonium salt solution may be converted into carbonate.

[113] Accordingly, the unreacted aqueous ammonium salt solution remaining in the ammonia water may be removed to maintain the concentration of the ammonia water at a certain level.

[114] That is, in the mixing tank 142, the aqueous divalent metal hydroxide solution frequently changes while passing through the filter due to the influence of the reaction rate, the evaporation of ammonia, and the like. When the generation of carbonate is not completed, a considerable amount of the unreacted aqueous ammonium salt solution remains in the ammonia water, resulting in a reduction in the absorption rate. Therefore, by designing a large-capacity primary absorbent liquid storage tank 151, the recovery rate of the ammonia water is increased by allowing reaction for a sufficient time and passing through the secondary filter 152 again. The concentration of the ammonia water may be maintained at a certain level at which the ammonia water can function as an effective absorbing liquid.

- [115] In addition, ammonia gas generated in the mixing tank 142 may be supplied to the CO₂ removing unit 131 of the absorption tower 130, or may be supplied to the NO_x absorbing unit 133.
- [116] On the other hand, the primary absorbent liquid storage tank 151 may include: an agitator 151a that stirs and reacts the aqueous divalent metal hydroxide solution and the unreacted aqueous ammonium salt solution; and a pH sensor 151b that measures the degree of reaction by the agitator 151a.
- [117] In addition, the aqueous divalent metal hydroxide solution stored in the storage tank may be Ca(OH)₂ or Mg(OH)₂ produced by reacting fresh water with CaO or MgO.
- [118] For example, when the concentration of the ammonia water circulating through the ammonia water circulation line A is low, the amount of (NH₄)₂CO₃ produced in [Chemical Formula 2] decreases, resulting in an increase in the amount of CO₂ emitted. When the concentration of the ammonia water is high, the amount of carbonate produced increases more than necessary due to excessive CO₂ absorption. Thus, it is necessary to constantly maintain the concentration of the ammonia water so that the CO₂ absorption performance of the absorption tower 130 is kept. In order to achieve this purpose, the concentration of the ammonia water may be designed to be adjusted to 12% by mass, but the present invention is not limited thereto and the concentration of the ammonia water may be changed according to the conditions of use.
- [119] In addition, a separate storage tank (not illustrated) that stores carbonate (CaCO₃(s) or MgCO₃(s)) separated by the primary filter 143 and the secondary filter 152 in a slurry state or a solid state transferred to a dryer (not illustrated) and solidified

may be provided, and carbonate ($\text{CaCO}_3(\text{s})$ or $\text{MgCO}_3(\text{s})$) may be discharged to the outside of the vessel. Here, as an example of the primary filter 143 and the secondary filter 152, a membrane filter suitable for precipitate separation by high-pressure fluid transfer may be applied.

[120] In addition, the ammonia water circulation pump 154 may be provided as a centrifugal pump-type pump so that a large amount of ammonia water circulates through the ammonia water circulation line A.

[121] On the other hand, the fresh water or the ammonia water separated by the primary filter 143 and the secondary filter 152 is supplied to the secondary absorbent liquid storage tank 153, or surplus fresh water additionally generated by the mixing tank 142 relative to the total circulating fresh water is stored in a fresh water tank (not illustrated) and reused when the aqueous divalent metal hydroxide solution is generated in the storage tank 141, thereby saving the fresh water.

[122] In this manner, since only the relatively inexpensive metal oxide (CaO or MgO) or aqueous divalent metal hydroxide solution ($\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$) is added, no additional addition of water is required, there is no decrease in the concentration of ammonia water, the capacity sizes of the primary filter 143 and the secondary filter 152 may be reduced, and the NH_3 recycling cost may be reduced. That is, in theory, only the metal oxide is consumed and NH_3 and fresh water are reused, thereby significantly reducing the CO_2 removal cost.

[123] Next, as illustrated in FIG. 7, the steam generating unit 160 may include: an auxiliary boiler 161 that receives a mixture in the form of saturated water and steam heat-exchanged through the EGE 134, separates the steam by a steam drum (not illustrated), and supplies the separated steam to a steam consumer; a boiler water

circulation pump 162 that circulates and supplies boiler water from the auxiliary boiler 161 to the EGE 134; a cascade tank 163 that recovers condensed water condensed and phase-changed after being consumed from the steam consumer; and a supply pump 164 and a control valve 165 that supply boiler water from the cascade tank 163 to the auxiliary boiler 161 while controlling the amount of boiler water. The steam generating unit 160 generates and supplies steam required for heating devices in the vessel.

[124] Here, when the load of the vessel engine 10 is large, the amount of heat that may be provided from the exhaust gas is large, and thus the amount of steam required in the vessel may be sufficiently produced through the EGE 134; otherwise, the auxiliary boiler 161 itself may burn fuel to produce necessary steam.

[125] Next, as illustrated in FIG. 7, the discharge unit 170 may include: a cleaning water tank 171 that stores cleaning water discharged from the absorption tower 130; a water treatment device 173 including a filtering unit that controls turbidity to satisfy the outboard discharge condition of the cleaning water transferred from the cleaning water tank 171 by the transfer pump 172, and a neutralizing agent injecting unit that controls pH; and a sludge storage tank 174 that separates and stores solid emissions such as soot. The discharge unit 170 may discharge the cleaning water, which passes through the water treatment device 173 and satisfies the outboard discharge condition, to the outside of the vessel, and may separately store the solid emissions, such as soot, which do not satisfy the outboard discharge conditions, in the sludge storage tank 174.

[126] On the other hand, NaOH may be used as the neutralizing agent for satisfying the outboard discharge condition. However, assuming that the materials discharged

from the absorption tower 130 are acidic and basic, a neutralizing agent capable of neutralizing each of the acidic material and the basic material may be selected and used as necessary.

[127] On the other hand, according to another embodiment of the present invention, a vessel including the apparatus for reducing greenhouse gas emission may be provided.

[128] Therefore, the apparatus for reducing greenhouse gas emission in the vessel has the following effects. The absorbent liquid recycling unit may be provided in two or more stages so that the unreacted aqueous ammonium salt solution remaining in the ammonia water is removed to maintain the concentration of the ammonia water at a certain level, thereby increasing the recovery rate of the absorbent liquid. The deterioration in greenhouse gas absorption performance may be prevented. A pressurization system may be applied to prevent the loss of absorbent liquid due to the natural evaporation of high-concentration absorbent liquid. In order to satisfy the IMO greenhouse gas emission regulations, greenhouse gas may be converted into materials that do not affect environments and then separately discharged or may be converted into useful materials and then stored. NH_3 may be recycled to minimize consumption of relatively expensive NH_3 . A capacity size of a rear end of a filter may be reduced. Greenhouse gas may be stored in the form of carbonate that exists in a natural state so that greenhouse gas may be discharged to the sea. Side reactions caused by SO_x remaining during NH_3 recycling may be removed, thereby minimizing the loss of NH_3 and preventing impurities from being included when recovering ammonia.

[129] Referring to FIG. 10, an apparatus for reducing greenhouse gas emission in a vessel according to still another embodiment of the present invention may include:

an exhaust gas cooling unit 110` that cools exhaust gas discharged from a vessel engine 10`; an absorbent liquid producing unit 120` that produces a high-concentration CO<sub>2</sub> absorbent liquid and supplies the high-concentration CO<sub>2</sub> absorbent liquid to an absorption tower 130`; the absorption tower 130` including a CO<sub>2</sub> removing unit 131` that removes CO₂ by reacting the exhaust gas cooled by the exhaust gas cooling unit 110` with the absorbent liquid supplied from the absorbent liquid producing unit 120` to convert CO₂ into an aqueous ammonium salt solution; and an absorbent liquid recycling unit including a primary recycling stage 140` that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower 130` with an aqueous divalent metal hydroxide solution, and a secondary recycling stage 150` that secondarily recycles the high-concentration absorbent liquid by additionally reacting the unreacted aqueous ammonium salt solution supplied from the primary recycling stage 140` with an aqueous divalent metal hydroxide solution and circulates and supplies the high-concentration absorbent liquid to the absorption tower 130` for reuse as the absorbent liquid. Therefore, the exhaust gas is cooled by a heat exchange method, thereby preventing the decrease in the concentration of the absorbent liquid, and the absorbent liquid recycling unit is provided in two or more stages so that the unreacted aqueous ammonium salt solution remaining in the ammonia water is removed to increase the recovery rate of the absorbent liquid, thereby preventing the deterioration in greenhouse gas absorption performance.

[130] Here, according to the type and specification of the vessel engine 10` (low-pressure engine or high-pressure engine) used in a main engine or power generation engine and the type of fuel supplied to the vessel engine 10` (HFO, MDO, LNG,

MGO, LSMGO, ammonia, etc.), the absorption tower may optionally include, in addition to the CO₂ removing unit, a NO_x absorbing unit or a SO_x absorbing unit, or may include both the NO_x absorbing unit and the SO_x absorbing unit. In particular, when LNG is used as the fuel of the vessel engine 10`, SO_x is not generated, and thus a separate SO_x absorbing unit need not be installed. However, when LSMGO is used, a small amount of SO_x may be generated, and thus a SO_x absorbing unit capable of simultaneously performing cooling of exhaust gas and absorption by dissolution of SO_x may be additionally provided.

[131] Hereinafter, an embodiment in which, when LNG or LSMGO is used as the fuel of the vessel engine 10`, the NO_x absorbing unit, the exhaust gas cooling unit, and the CO₂ removing unit are sequentially stacked on the absorption tower will be described, but the present invention is not limited thereto. As described above, the NO_x absorbing unit and/or the SO_x absorbing unit may or may not be included according to the types of vessel engine and fuel.

[132] First, the exhaust gas cooling unit 110` cools exhaust gas discharged from the vessel engine 10` so that temperature of the exhaust gas is lowered to facilitate absorption of CO₂ by a greenhouse gas absorbent liquid.

[133] For example, the exhaust gas cooling unit 110` may cool the exhaust gas discharged from the vessel engine 10` by a heat exchange method of the fresh water. Specifically, the exhaust gas may be cooled with the fresh water by the heat exchange method to a temperature of 27°C to 33°C, which is required by the CO₂ removing unit 131`, by circulating the fresh water provided from an onboard cooling system 20` through a heat exchange pipe 111` surrounding an exhaust gas discharge pipe through which the exhaust gas flows.

[134] That is, in a water cooling method in which the exhaust gas is directly cooled by the fresh water, the concentration of the absorbent liquid is lowered due to the addition of the fresh water, resulting in the deterioration in the greenhouse gas absorption performance. By improving the water cooling method, the exhaust gas is cooled by a heat exchange method without direct contact with the fresh water, thereby preventing the decrease in the concentration of the absorbent liquid and preventing the deterioration in greenhouse gas absorption performance.

[135] On the other hand, an example in which the exhaust gas cooling unit 110` performs cooling by the heat exchange method using the fresh water has been described, but various cooling media and cooling methods may be applied.

[136] Next, the absorbent liquid producing unit 120` produces a high-concentration CO<sub>2</sub> absorbent liquid and supplies the high-concentration CO<sub>2</sub> absorbent liquid to the absorption tower 130`. The absorbent liquid producing unit 120` reacts fresh water with NH₃ as shown in [Chemical Formula 4] below to produce high-concentration ammonia water (NH₄OH(aq)), which is a high-concentration CO₂ absorbent liquid, and supplies the high-concentration ammonia water (NH₄OH(aq)) through the absorbent liquid storage tank 153` to the CO<sub>2</sub> removing unit 131` of the absorption tower 130` along the absorbent liquid circulation line (see A` in FIG. 10).

[Chemical Formula 4]



[137] Specifically, as illustrated in FIGS. 11 and 13, the absorbent liquid producing unit 120` may include: a fresh water tank (not illustrated) that stores fresh water; a fresh water control valve 121` that supplies the fresh water from the fresh water tank to an ammonia water tank 123` by controlling a supply amount of the fresh water; a

NH₃ storage 122` that stores high-pressure NH<sub>3</sub>; an ammonia water tank 123` that produces and stores high-concentration ammonia water by spraying NH₃ supplied from the NH₃ storage 122` to the fresh water supplied by the fresh water control valve 121`; a pH sensor 124` that measures and monitors the concentration of the ammonia water in the ammonia water tank 123`; and an ammonia water supply pump 125` that supplies the high-concentration ammonia water from the ammonia water tank 123` to the secondary absorbent liquid storage tank 153`.

[138] The concentration of the ammonia water circulating through the absorption tower 130` and the absorbent liquid recycling unit along the absorbent liquid circulation line A` changes as the operation is repeated. For example, the concentration of the ammonia water is reduced when NH₃ is supplied to the NO_x absorbing unit 132` and used to absorb and remove NO<sub>x</sub>, or when NH<sub>3</sub> passes through the absorption tower 130` and is exhausted together with the exhaust gas. When the concentration of the ammonia water is reduced, the absorbent liquid producing unit 120` supplies the high-concentration ammonia water to the absorbent liquid circulation line (see A` in FIG. 10) to compensate for the reduced concentration of the ammonia water so that the ammonia water is constantly maintained at a concentration designed as a preset absorption performance.

[139] On the other hand, since the high-concentration ammonia water has a higher partial pressure of NH₃(g) than that of the low-concentration ammonia water at the same temperature, NH₃ is relatively more evaporated in an atmospheric pressure state, resulting in an increase in loss. Therefore, in order to store the high-concentration ammonia water without loss, it is necessary to lower temperature in order for increasing the solubility of NH₃(g) and reducing the vapor pressure of NH₃(g) and to

operate under a pressurization system.

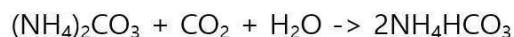
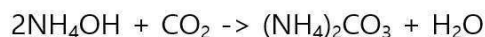
[140] That is, in order to prevent a phenomenon that $\text{NH}_3(\text{g})$ is evaporated and lost, compressed air of a certain pressure may be injected into the upper portion of the ammonia water in the ammonia water tank 123` so that the pressure in the ammonia water tank 123` is maintained to be high, thereby constantly maintaining the concentration of the ammonia water with NH_3 of a high concentration, for example, 50 %wt.

[141] For example, since NH_3 may be stored in a liquid state at -34°C and 8.5 bar, 50% concentration of ammonia water may be stored in the ammonia water tank 123` by maintaining the inside of the ammonia water tank 123` at a constant pressure by using compressed air of 7 bar available in the vessel.

[142] In addition, a safety valve 123a` for reducing the pressure by exhausting air to a safety area so as to prevent overpressure of the ammonia water tank 123` may be installed.

[143] Next, the absorption tower 130` includes a  $\text{CO}_2$  removing unit 131` that removes CO_2 by reacting the exhaust gas cooled by the exhaust gas cooling unit 110` with the ammonia water, which is the absorbent liquid initially supplied from the absorbent liquid producing unit 120` and circulating along the absorbent liquid circulation line A`, to convert CO_2 into an aqueous ammonium salt solution ($\text{NH}_4\text{HCO}_3(\text{aq})$) as shown in [Chemical Formula 5] below.

[Chemical Formula 5]



[144] Specifically, as illustrated in FIG. 12, the CO_2 removing unit 131` may include:

an ammonia water spray nozzle 131a` that sprays the ammonia water supplied from the secondary absorbent liquid storage tank 153` downward toward a packing material 131b`; the packing material 131b` that contacts CO₂ of the exhaust gas with the ammonia water, which is the absorbent liquid, to convert CO₂ into NH₄HCO₃(aq); a cooling jacket (not illustrated) that is formed in multi-stages for each section of an absorption apparatus filled with the packing material 131b` and cools heat generated by a CO<sub>2</sub> absorption reaction; a water spray 131c` that collects NH₃ discharged to the atmosphere without reacting with CO₂; a mist removal plate 131d` that is formed in a curved multi-plate shape and returns the ammonia water scattered when sprayed by the ammonia water spray nozzle 131a` toward the packing material 131b`; a partition wall 131e` that is formed so that the ammonia water passing through the packing material 131b` does not leak out and flow back toward the NO<sub>x</sub> absorbing unit 132`; and an umbrella-shaped blocking plate 131f` that covers an upper end of an exhaust gas inlet hole surrounded by the partition wall 131e`.

[145] Here, the cooling jacket may cool heat to 30°C to 50°C at which the material transfer is smoothest, so that NH₃ is not evaporated and lost while maintaining a CO₂ absorption rate at a certain level.

[146] On the other hand, the CO₂ removing unit 131` may be considered in various forms so as to operate within an allowable pressure drop of an exhaust pipe required by an engine specification while increasing a contact area between the exhaust gas and NH<sub>3</sub>. For example, the packing material 131b` may include multi-stage distilling column packings designed to increase a contact area per unit volume. As illustrated in FIG. 15, a distilling column packing suitable for an absorption process may be selected considering the contact area per unit area, the pressure drop of gas,

and the flooding velocity. As illustrated in FIG. 16, the ammonia water spray nozzle 131a` may be provided in a ladder pipe form FIG. 16A or a spray form FIG. 16B.

[147] In addition, a solution redistributor (not illustrated) may be formed between the distilling column packings so as to prevent channeling when the ammonia water passes downward through the packing material 131b`, the exhaust gas passes upward through the packing material 131b`, and the ammonia water and the exhaust gas contact each other.

[148] In addition, the mist removal plate 131d` allows the scattered ammonia water to adhere to the curved multi-plate, so that droplets become large, and drains the ammonia water toward the packing material 131b` by the own weight thereof.

[149] On the other hand, as described above, the vessel engine 10` is based on the premise of using LNG or LSMGO as fuel. When the vessel engine 10` uses LNG as fuel, SO_x may not be generated, but when the vessel engine 10` uses LSMGO as fuel, SO<sub>x</sub> may be included in the exhaust gas, and thus the absorption tower 130` may include the SO_x absorbing unit.

[150] For example, although not separately illustrated, the SO_x absorbing unit may dissolve and remove SO_x while cooling the exhaust gas discharged from the vessel engine 10` through reaction with the seawater, and the CO<sub>2</sub> removing unit 131` may absorb and remove CO₂ by reacting the cooled exhaust gas, from which the SO_x is removed, with the absorbent liquid supplied from the absorbent liquid producing unit 120` to convert CO₂ into an aqueous ammonium salt solution.

[151] In addition, as described above, the absorption tower 130` may further include a NO<sub>x</sub> absorbing unit 132` that absorbs and removes NO_x from the exhaust gas discharged from the vessel engine 10`. The exhaust gas from which the NO_x has

been removed may be cooled by the exhaust gas cooling unit 110`, and CO<sub>2</sub> may be removed by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit 120` to convert CO₂ into an aqueous ammonium salt solution.

[152] That is, in the absorption tower 130`, the NO<sub>x</sub> absorbing unit 132` that absorbs and removes NO_x from the exhaust gas discharged from the vessel engine 10`, and the CO<sub>2</sub> removing unit 131` that removes CO₂ by reacting the cooled exhaust gas, from which the NO_x has been removed, with the ammonia water supplied from the absorbent liquid producing unit 120` to convert CO₂ into NH₄HCO₃(aq) are stacked to sequentially absorb and remove the NO_x and the CO₂ from the exhaust gas.

[153] Therefore, since the CO₂ removing unit 131` reacts the ammonia water with the exhaust gas from which the NO<sub>x</sub> has been removed by the NO<sub>x</sub> absorbing unit 132`, side reactions caused by NO_x do not occur during the CO₂ removal process, thereby minimizing the generation of impurities and obtaining NH₄HCO₃(aq) with less impurities in a subsequent process.

[154] Here, the absorption tower 130` may include the CO<sub>2</sub> removing unit 131`, the NO_x absorbing unit 132`, and an EGE 133` to be described later, may be modularized and combined with individual modules, and may be integrated in a single tower form, and the absorption tower 130` itself may include a single tower or a group of a plurality of towers.

[155] Specifically, the NO_x absorbing unit 132` is an SCR. As illustrated in FIG. 12, the NO<sub>x</sub> absorbing unit 132` may absorb NO_x by directly supplying the recycled NH₃ from the primary recycling stage 140` to a NH<sub>3</sub> spray nozzle 132b` through a blower 132a` or a compressor, or when NH<sub>3</sub> supplied to the NH<sub>3</sub> spray nozzle 132b` is

insufficient, may receive urea water of a urea water storage tank 132c` from a  $\text{NH}_3$  spray nozzle 132e` through a urea water supply pump 132d` so as to compensate for the loss or lack of NH_3 .

[156] On the other hand, since NH_3 and CO_2 are generated when the urea water is decomposed, it may be preferable that NH_3 is directly supplied to reduce the amount of CO_2 generated.

[157] In addition, the absorption tower 130` may further include an EGE 133` that is formed between the NO_x absorbing unit 132` and the exhaust gas cooling unit 110` and performs heat exchange between waste heat of the exhaust gas from the vessel engine 10` and boiler water.

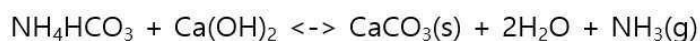
[158] Next, the absorbent liquid recycling unit may recycle NH_3 and return NH_3 back to the absorption tower 130` for reuse as a  $\text{CO}_2$  absorbent liquid, may store  $\text{CO}_2$  in the form of  $\text{CaCO}_3(\text{s})$  or  $\text{MgCO}_3(\text{s})$  or discharge  $\text{CO}_2$  to the outside of the vessel, or may supply the recycled  $\text{NH}_3$  to the  $\text{NO}_x$  absorbing unit 132` so as to absorb NO_x .

[159] That is, the absorbent liquid recycling unit may include: a primary recycling stage 140` that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution, which is discharged from the absorption tower 130` after the absorption of CO_2 , with an aqueous divalent metal hydroxide solution; and a secondary recycling stage 150` that secondarily recycles the high-concentration absorbent liquid by additionally reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling stage 140` and circulates and supplies the secondarily recycled absorbent liquid to the absorption tower 130` for reuse as the absorbent liquid. A recovery rate of the absorbent liquid may be increased and maintained at a certain concentration, thereby effectively

preventing the deterioration in absorption performance.

[160] Specifically, as illustrated in FIG. 13, the absorbent liquid recycling unit may include: a storage tank 141` that stores an aqueous divalent metal hydroxide solution; a primary recycling stage 140` including a mixing tank 142` in which the aqueous ammonium salt solution discharged from the absorption tower 130` and the aqueous divalent metal hydroxide solution supplied from the storage tank 141` are stirred by an agitator to generate  $\text{NH}_3(\text{g})$  and carbonate as shown in [Chemical Formula 6] below, and a primary filter 143` that suctions a solution and precipitate from the mixing tank 142` and separates the carbonate and ammonia water (or fresh water); and a secondary recycling stage 150` including a primary absorbent liquid storage tank 151` that stores an unreacted aqueous ammonium salt solution remaining without reacting with the ammonia water and the aqueous divalent metal hydroxide solution separated by the primary filter 143` and re-reacting the unreacted aqueous ammonium salt solution with the aqueous divalent metal hydroxide solution supplied from the storage tank 141`, a secondary filter 152` that suctions the solution and precipitate from the primary absorbent liquid storage tank 151` to separate carbonate and high-concentration ammonia water and is designed corresponding to the capacity of the primary absorbent liquid storage tank 151`, a secondary absorbent liquid storage tank 153` that stores the high-concentration ammonia water separated by the secondary filter 152`, and an ammonia water circulation pump 154` that pumps and circulates the ammonia water from the secondary absorbent liquid storage tank 153` to the CO_2 removing unit 131` of the absorption tower 130`.

[Chemical Formula 6]



[161] Here, the storage capacity of the primary absorbent liquid storage tank 151` is designed to be at least three times the capacity of the absorbent liquid circulating through the absorption tower 130` and the absorbent liquid recycling unit along the absorbent liquid circulation line A`, and thus has a relatively large capacity compared to the capacity of the circulating absorbent liquid. The stay time of the unreacted aqueous ammonium salt solution in the primary absorbent liquid storage tank 151` is increased to sufficiently secure the reaction time. Therefore, the unreacted aqueous ammonium salt solution may be converted into carbonate as much as possible.

[162] Accordingly, the unreacted aqueous ammonium salt solution remaining in ammonia water is re-reacted in the primary absorbent liquid storage tank 151` to additionally generate ammonia water, thereby maintaining the concentration of the ammonia water at a certain level.

[163] That is, in the mixing tank 142`, the aqueous divalent metal hydroxide solution frequently changes while passing through the filter due to the influence of the reaction rate, the evaporation of ammonia, and the like. When the generation of carbonate is not completed, a considerable amount of the unreacted aqueous ammonium salt solution remains in the ammonia water, resulting in the reduction in the CO₂ absorption rate. Therefore, by designing a large-capacity primary absorbent liquid storage tank 151`, the ammonia water recovery rate is increased by allowing reaction for a sufficient time and passing through the secondary filter 152` again. The concentration of the ammonia water may be maintained at a certain level at which the ammonia water can function as an effective absorbing liquid.

- [164] In addition, $\text{NH}_3(\text{g})$ generated in the mixing tank 142` may be supplied to the  $\text{CO}_2$  removing unit 131` of the absorption tower 130` and used to remove  $\text{CO}_2$ , or may be supplied to the  $\text{NO}_x$  absorbing unit 132` and used to remove NO_x .
- [165] On the other hand, the primary absorbent liquid storage tank 151` may include: an agitator 151a` that stirs and reacts the aqueous divalent metal hydroxide solution and the unreacted aqueous ammonium salt solution; and a pH sensor 151b` that measures the degree of reaction by the agitator 151a`.
- [166] In addition, the aqueous divalent metal hydroxide solution stored in the storage tank 141` may be $\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$ produced by reacting the fresh water with CaO or MgO .
- [167] For example, when the concentration of the ammonia water circulating through the absorbent liquid circulation line A` is low, the amount of $(\text{NH}_4)_2\text{CO}_3$ produced in [Chemical Formula 5] decreases, resulting in an increase in the amount of CO_2 emitted. When the concentration of the ammonia water is high, the amount of carbonate produced increases more than necessary due to excessive CO_2 absorption. Thus, it is necessary to constantly maintain the concentration of the ammonia water at an appropriate level so that the CO_2 absorption performance of the absorption tower 130` is not deteriorated. In order to achieve this purpose, the concentration of the ammonia water may be designed to be adjusted to 12% by mass, but the present invention is not limited thereto and the concentration of the ammonia water may be changed according to the conditions of use.
- [168] In addition, a separate storage tank (not illustrated) that stores carbonate ($\text{CaCO}_3(\text{s})$ or $\text{MgCO}_3(\text{s})$), which is separated by the primary filter 143` and the secondary filter 152` and can be discharged to the sea, in a slurry state or a solid state

transferred to a dryer (not illustrated) and solidified may be provided, and carbonate ($\text{CaCO}_3(\text{s})$ or $\text{MgCO}_3(\text{s})$) may be discharged to the outside of the vessel without being stored. Here, as an example of the primary filter 143` and the secondary filter 152`, a membrane filter suitable for precipitate separation by high-pressure fluid transfer may be applied.

[169] In addition, the ammonia water circulation pump 154` may be provided as a centrifugal pump-type pump so that a large amount of ammonia water circulates through the absorbent liquid circulation line A`.

[170] On the other hand, the fresh water or the ammonia water separated by the primary filter 143` and the secondary filter 152` is supplied to the secondary absorbent liquid storage tank 153`, or surplus fresh water additionally generated by the mixing tank 142` relative to the total circulating fresh water is stored in a fresh water tank (not illustrated) and reused when the aqueous divalent metal hydroxide solution is generated in the storage tank 141`, thereby saving the fresh water.

[171] In this manner, since only the relatively inexpensive metal oxide (CaO or MgO) or aqueous divalent metal hydroxide solution ($\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$) is added, no additional addition of water is required, there is no decrease in the concentration of ammonia water, the capacity sizes of the primary filter 143` and the secondary filter 152` may be reduced, and the NH_3 recycling cost may be reduced. That is, in theory, only the metal oxide is consumed and NH_3 and fresh water are reused, thereby significantly reducing the CO_2 removal cost.

[172] Next, as illustrated in FIG. 14, the steam generating unit 160` may include: an auxiliary boiler 161` that receives a mixture in the form of saturated water and steam heat-exchanged through the EGE 133`, separates the steam by a steam drum (not

illustrated), and supplies the separated steam to a steam consumer; a boiler water circulating pump 162` that circulates and supplies boiler water from the auxiliary boiler 161` to the EGE 133`; a cascade tank 163` that recovers condensed water condensed and phase-changed after being consumed from the steam consumer; and a supply pump 164` and a control valve 165` that supply boiler water from the cascade tank 163` to the auxiliary boiler 161` while controlling the amount of boiler water. The steam generating unit 160` generates and supplies steam required for heating devices in the vessel.

[173] Here, when the load of the vessel engine 10` is large, the amount of heat that may be provided from the exhaust gas is large, and thus the amount of steam required in the vessel may be sufficiently produced through the EGE 133`; otherwise, the auxiliary boiler 161` itself may burn fuel to produce necessary steam.

[174] On the other hand, according to still another embodiment of the present invention, a vessel including the apparatus for reducing greenhouse gas emission may be provided.

[175] Therefore, the apparatus for reducing greenhouse gas emission in the vessel has the following effects. The exhaust gas may be cooled by a heat exchange method, thereby preventing the decrease in the concentration of the absorbent liquid. A pressurization system may be applied to prevent the loss of absorbent liquid due to the natural evaporation of high-concentration absorbent liquid. The absorbent liquid recycling unit may be provided in two or more stages so that the unreacted aqueous ammonium salt solution remaining in the ammonia water is removed to maintain the concentration of the ammonia water at a certain level, thereby increasing the recovery rate of the absorbent liquid and preventing the deterioration in

greenhouse gas absorption performance. In order to satisfy the IMO greenhouse gas emission regulations, greenhouse gas may be converted into materials that do not affect environments and then separately discharged or may be converted into useful materials and then stored. NH_3 may be recycled to minimize consumption of relatively expensive NH_3 . The capacity size of the rear end of the filter may be reduced. Greenhouse gas may be stored in the form of carbonate that exists in a natural state so that greenhouse gas may be discharged to the sea. Side reactions caused by SO_x remaining during NH_3 recycling may be removed, thereby minimizing the loss of NH_3 and preventing impurities from being included when recovering ammonia.

[176] The present invention has been described above with reference to the embodiments illustrated in the drawings. However, the present invention is not limited thereto, and various modifications or other embodiments falling within the scope equivalent to the present invention can be made by those of ordinary skill in the art. Therefore, the true scope of protection of the present invention should be determined by the appended claims.

CLAIMS

[CLAIM 1] An apparatus for reducing greenhouse gas emission in a vessel, the apparatus comprising:

a seawater supply unit that supplies seawater;

an absorbent liquid producing unit that produces and supplies a high-concentration CO₂ absorbent liquid;

an absorption tower comprising a CO₂ removing unit that cools exhaust gas discharged from a vessel engine by reacting the exhaust gas with the seawater supplied from the seawater supply unit, and removes CO₂ by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into an aqueous ammonium salt solution; and

an absorbent liquid recycling unit comprising a primary recycling unit that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution, and a secondary recycling unit that secondarily recycles the high-concentration absorbent liquid by additionally reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling unit and circulates and supplies the recycled absorbent liquid to the absorption tower for reuse as the absorbent liquid.

[CLAIM 2] The apparatus according to claim 1, wherein the absorbent liquid recycling unit comprises:

a storage tank that stores the aqueous divalent metal hydroxide solution;

the primary recycling unit comprising a mixing tank in which the aqueous

divalent metal hydroxide solution and the aqueous ammonium salt solution discharged from the absorption tower are stirred by an agitator to generate $\text{NH}_3(\text{g})$ and carbonate, and a primary filter that suctions a solution and precipitate from the mixing tank and separates the carbonate; and

a secondary recycling unit comprising a primary absorbent liquid storage tank that stores the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter and re-reacts the unreacted aqueous ammonium salt solution with the aqueous divalent metal hydroxide solution supplied from the storage tank, a secondary filter that suctions the solution and precipitate from the primary absorbent liquid storage tank to separate carbonate and high-concentration ammonia water, and a secondary absorbent liquid storage tank that stores the high-concentration ammonia water separated by the secondary filter.

[CLAIM 3] The apparatus according to claim 2, wherein the storage capacity of the primary absorbent liquid storage tank is at least three times the capacity of the absorbent liquid circulating through the absorption tower and the absorbent liquid recycling unit.

[CLAIM 4] The apparatus according to claim 2, wherein the primary absorbent liquid storage tank comprises:

an agitator that stirs and reacts the aqueous divalent metal hydroxide solution and the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter; and

a pH sensor that measures the degree of reaction by the agitator.

[CLAIM 5] The apparatus according to claim 2, wherein the aqueous divalent metal hydroxide solution stored in the storage tank is $\text{Ca}(\text{OH})_2$ or $\text{Mg}(\text{OH})_2$ produced by reacting fresh water with CaO or MgO .

[CLAIM 6] The apparatus according to claim 2, wherein fresh water or ammonia water separated by the secondary filter is supplied to the secondary absorbent liquid storage tank, or surplus fresh water additionally generated by the mixing tank relative to a total circulating fresh water is stored in a fresh water tank and reused when the aqueous divalent metal hydroxide solution is generated in the storage tank.

[CLAIM 7] The apparatus according to claim 1, wherein the absorption tower further comprises a SO_x absorbing unit that dissolves and removes SO_x while cooling the exhaust gas discharged from the vessel engine by reacting the exhaust gas with the seawater supplied from the seawater supply unit, and the CO_2 removing unit cools the exhaust gas, from which the SO_x has been removed, by reacting the exhaust gas with the seawater supplied from the seawater supply unit and removes CO_2 by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO_2 into the aqueous ammonium salt solution.

[CLAIM 8] The apparatus according to claim 1, wherein the absorption tower further comprises a NO_x absorbing unit that absorbs and removes NO_x from the exhaust gas emitted from the vessel engine, and

the CO_2 removing unit cools the exhaust gas, from which the NO_x has been

removed, by reacting the exhaust gas with the seawater supplied from the seawater supply unit and removes CO₂ by reacting the cooled exhaust gas with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into the aqueous ammonium salt solution.

[CLAIM 9] The apparatus according to claim 1, wherein, in the absorption tower, a NO_x absorbing unit that absorbs and removes NO_x from the exhaust gas discharged from the vessel engine, a SO_x absorbing unit that dissolves and removes SO_x while cooling the exhaust gas, from which the NO_x has been removed, through reaction with the seawater supplied from the seawater supply unit, and the CO₂ removing unit that removes CO₂ by reacting the exhaust gas, from which the SO_x has been removed, with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into the aqueous ammonium salt solution are sequentially stacked.

[CLAIM 10] The apparatus according to claim 8 or 9, wherein NH₃ recycled by the absorbent liquid recycling unit is returned back to the absorption tower and converted into the absorbent liquid for reuse as the absorbent liquid, and

the NO_x absorbing unit receives the NH₃ recycled by the absorbent liquid recycling unit to absorb NO_x with the NH₃, or absorbs NO_x using urea water.

[CLAIM 11] The apparatus according to claim 7 or 9, wherein the seawater supply unit comprises:

a seawater pump that receives seawater from the outside of the vessel through a sea chest and pumps the seawater to the SO_x absorbing unit; and

a seawater control valve that controls a spray amount of the seawater supplied from the seawater pump to the SO_x absorbing unit according to an amount of the exhaust gas.

[CLAIM 12] The apparatus according to claim 2, wherein the absorbent liquid producing unit comprises:

a fresh water tank that stores fresh water;

a fresh water control valve that supplies the fresh water from the fresh water tank;

a NH₃ storage that stores high-pressure NH₃;

an ammonia water tank that produces and stores high-concentration ammonia water, which is the absorbent liquid, by spraying the NH₃ supplied from the NH₃ storage to the fresh water supplied by the fresh water control valve;

a pH sensor that measures a concentration of the ammonia water in the ammonia water tank; and

an ammonia water supply pump that supplies the ammonia water from the ammonia water tank to the secondary absorbent liquid storage tank.

[CLAIM 13] The apparatus according to claim 12, further comprising an ammonia water circulation pump that circulates the ammonia water from the secondary absorbent liquid storage tank to the absorption tower.

[CLAIM 14] The apparatus according to claim 7 or 9, wherein the SO_x absorbing unit comprises:

a multi-stage seawater spray nozzle that sprays the seawater supplied from the seawater supply unit downward; and

a partition wall-shaped exhaust gas inlet pipe that prevents cleaning water from flowing back, or an umbrella-shaped blocking plate that covers the exhaust gas inlet pipe.

[CLAIM 15] The apparatus according to claim 14, wherein porous upper plates having a passage through which the exhaust gas passes are respectively formed in multi-stages under the seawater spray nozzle, so that the seawater and the exhaust gas come into contact with each other.

[CLAIM 16] The apparatus according to claim 14, wherein an absorption apparatus filled with a packing material for allowing the seawater and the exhaust gas to come into contact with each other is formed under the seawater spray nozzle, so that the seawater dissolves the SO_x .

[CLAIM 17] The apparatus according to claim 1, wherein the CO_2 removing unit comprises:

- an ammonia water spray nozzle that sprays the absorbent liquid supplied from the absorbent liquid recycling unit downward;

- a packing material that contacts the CO_2 with the ammonia water, which is the absorbent liquid, to convert the CO_2 into $\text{NH}_4\text{HCO}_3(\text{aq})$;

- a cooling jacket that is formed in multi-stages for each section of an absorption apparatus filled with the packing material and cools heat generated by a CO_2 absorption reaction;

- a water spray that collects NH_3 discharged to the outside without reacting with CO_2 ;

a mist removal plate that is formed in a curved multi-plate shape and returns the ammonia water toward the packing material;

a partition wall that is formed so that the ammonia water does not flow back; and

an umbrella-shaped blocking plate that covers an exhaust gas inlet hole surrounded by the partition wall.

[CLAIM 18] The apparatus according to claim 17, wherein the packing material includes multi-stage distilling column packings designed to increase a contact area per unit volume, and

a solution redistributor is formed between the multi-stage distilling column packings.

[CLAIM 19] The apparatus according to claim 9, wherein the absorption tower further comprises an exhaust gas economizer (EGE) that is formed between the NO_x absorbing unit and the SO_x absorbing unit and performs heat exchange between waste heat of the vessel engine and boiler water.

[CLAIM 20] The apparatus according to claim 1, further comprising a discharge unit comprising:

a cleaning water tank that stores cleaning water discharged from the absorption tower;

a water treatment device comprising a filtering unit that controls turbidity to satisfy an outboard discharge condition of the cleaning water transferred to the cleaning water tank by a transfer pump, and a neutralizing agent injecting unit that controls pH; and

a sludge storage tank that separates and stores solid emissions.

[CLAIM 21] A vessel comprising the apparatus according to claims 1.

[CLAIM 22] An apparatus for reducing greenhouse gas emission in a vessel, the apparatus comprising:

- an exhaust gas cooling unit that cools exhaust gas discharged from a vessel engine;

- an absorbent liquid producing unit that produces and supplies a high-concentration CO₂ absorbent liquid;

- an absorption tower comprising a CO₂ removing unit that removes CO₂ by reacting the exhaust gas cooled by the exhaust gas cooling unit with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into an aqueous ammonium salt solution; and

- an absorbent liquid recycling unit comprising a primary recycling stage that primarily recycles the absorbent liquid by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution, and a secondary recycling stage that secondarily recycles the high-concentration absorbent liquid by additionally reacting the aqueous divalent metal hydroxide solution with an unreacted aqueous ammonium salt solution supplied from the primary recycling stage and circulates and supplies the recycled absorbent liquid to the absorption tower for reuse as the absorbent liquid.

[CLAIM 23] The apparatus according to claim 22, wherein the vessel engine uses

liquefied natural gas (LNG) or low sulphur marine gas oil (LSMGO) as fuel.

[CLAIM 24] The apparatus according to claim 22, wherein the exhaust gas cooling unit cools the exhaust gas to a temperature of 27°C to 33°C by circulating fresh water supplied from an onboard cooling system through a heat exchange pipe surrounding an exhaust gas discharge pipe.

[CLAIM 25] The apparatus according to claim 22, wherein the absorbent liquid recycling unit comprises:

a storage tank that stores the aqueous divalent metal hydroxide solution;

the primary recycling stage comprising a mixing tank in which the aqueous ammonium salt solution discharged from the absorption tower and the aqueous divalent metal hydroxide solution supplied from the storage tank are stirred by an agitator to generate $\text{NH}_3(\text{g})$ and carbonate, and a primary filter that suctions a solution and precipitate from the mixing tank and separates the carbonate; and

the secondary recycling stage comprising a primary absorbent liquid storage tank that stores the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter and re-reacts the unreacted aqueous ammonium salt solution with the aqueous divalent metal hydroxide solution supplied from the storage tank, a secondary filter that suctions the solution and precipitate from the primary absorbent liquid storage tank to separate carbonate and high-concentration ammonia water, and a secondary absorbent liquid storage tank that stores the high-concentration ammonia water separated by the secondary filter.

[CLAIM 26] The apparatus according to claim 25, wherein the storage capacity of the primary absorbent liquid storage tank is at least three times the capacity of the absorbent liquid circulating through the absorption tower and the absorbent liquid recycling unit along an absorbent liquid circulation line.

[CLAIM 27] The apparatus according to claim 25, wherein the primary absorbent liquid storage tank comprises:

an agitator that stirs and reacts the aqueous divalent metal hydroxide solution supplied from the storage tank and the unreacted aqueous ammonium salt solution or the ammonia water separated by the primary filter; and

a pH sensor that measures the degree of reaction by the agitator.

[CLAIM 28] The apparatus according to claim 25, wherein the aqueous divalent metal hydroxide solution stored in the storage tank is Ca(OH)_2 or Mg(OH)_2 produced by reacting fresh water with CaO or MgO .

[CLAIM 29] The apparatus according to claim 25, wherein fresh water or ammonia water separated by the secondary filter is supplied to the secondary absorbent liquid storage tank, or surplus fresh water additionally generated by the mixing tank relative to a total circulating fresh water is stored in a fresh water tank and reused when the aqueous divalent metal hydroxide solution is generated in the storage tank.

[CLAIM 30] The apparatus according to claim 22, wherein the absorption tower further comprises a NO_x absorbing unit that absorbs and removes NO_x from the exhaust gas

emitted from the vessel engine, and

the CO₂ removing unit removes CO₂ by reacting the exhaust gas, from which the NO_x has been removed and which is cooled by the exhaust gas cooling unit, with the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into the aqueous ammonium salt solution.

[CLAIM 31] The apparatus according to claim 30, wherein the absorbent liquid recycling unit recycles NH₃ and returns the NH₃ back to the absorption tower for reuse as the absorbent liquid, and
the NO_x absorbing unit absorbs NO_x with the NH₃ supplied from the absorbent liquid recycling unit, or absorbs NO_x using urea water.

[CLAIM 32] The apparatus according to claim 25, wherein the absorbent liquid producing unit comprises:

a fresh water tank that stores fresh water;

a fresh water control valve that controls an amount of the fresh water supplied from the fresh water tank;

a NH₃ storage that stores high-pressure NH₃;

an ammonia water tank that produces and stores high-concentration ammonia water, which is the absorbent liquid, by spraying the NH₃ supplied from the NH₃ storage to the fresh water supplied by the fresh water control valve;

a pH sensor that measures a concentration of the ammonia water in the ammonia water tank; and

an ammonia water supply pump that supplies the ammonia water from the

ammonia water tank to the secondary absorbent liquid storage tank.

[CLAIM 33] The apparatus according to claim 32, further comprising an ammonia water circulation pump that circulates the ammonia water from the secondary absorbent liquid storage tank to the absorption tower.

[CLAIM 34] The apparatus according to claim 22, wherein the CO₂ removing unit comprises:

- an ammonia water spray nozzle that sprays the absorbent liquid supplied from the absorbent liquid recycling unit downward;

- a packing material that contacts the CO₂ with the ammonia water, which is the absorbent liquid, to convert the CO₂ into NH₄HCO₃(aq);

- a cooling jacket that is formed in multi-stages for each section of an absorption apparatus filled with the packing material and cools heat generated by a CO₂ absorption reaction;

- a water spray that collects NH₃ discharged to the outside without reacting with CO₂;

- a mist removal plate that is formed in a curved multi-plate shape and returns the ammonia water toward the packing material;

- a partition wall that is formed so that the ammonia water does not leak out; and
- an umbrella-shaped blocking plate that covers an exhaust gas inlet hole surrounded by the partition wall.

[CLAIM 35] The apparatus according to claim 34, wherein the packing material includes

multi-stage distilling column packings designed to increase a contact area per unit volume,
and
a solution redistributor is formed between the multi-stage distilling column packings.

[CLAIM 36] The apparatus according to claim 30, wherein the absorption tower further comprises an exhaust gas economizer (EGE) that is formed between the NO_x absorbing unit and the exhaust gas cooling unit and performs heat exchange between waste heat of the exhaust gas from the vessel engine and boiler water.

[CLAIM 37] A vessel comprising the apparatus according to claims 22.