

DESCRIPTION

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

5 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 CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed, so that the device sizes of an absorbent liquid recycling unit and an absorbent liquid circulating unit is
10 kept small and continuous operation is enabled.

[2] In addition, 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 the decrease in a concentration of an absorbent liquid, and CO₂ absorbed by taking only a part of the absorbent liquid used
15 when collecting CO₂ is removed and an unreacted absorbent liquid is continuously circulated, thereby enabling continuous operation.

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.

20 [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 decrease in absorption performance due to reduction in absorbent liquid caused by exhaust gas emission during operation and

concentration change in absorbent liquid caused by other consumptions.

[9] Moreover, the need is raised to apply, to vessels using LNG or low sulphur fuel oil as fuel so as to emit a small amount of SO_x or prevent SO_x emission, 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 decrease in absorption performance due to reduction in absorbent liquid caused by exhaust gas emission during operation and concentration change in absorbent liquid caused by other consumptions.

10 **DISCLOSURE**

TECHNICAL PROBLEM

[10] An object of the present invention provides an apparatus for reducing greenhouse gas emission in a vessel and a vessel including the same, in which CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed, so that the device sizes of an absorbent liquid recycling unit and an absorbent liquid circulating unit is kept small and continuous operation is enabled.

[11] Also, an object of the present invention provides 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 the decrease in a concentration of an absorbent liquid, and CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed and an unreacted absorbent liquid is continuously circulated, thereby enabling continuous operation.

TECHNICAL SOLUTION

[12] In order to achieve the above object, 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; an absorbent liquid recycling unit that recycles the absorbent liquid and NH₃ by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution and circulates and supplies the absorbent liquid and the NH₃ to the absorption tower for reuse as the absorbent liquid; and an absorbent liquid circulating unit that circulates the aqueous ammonium salt solution or a part of an unreacted absorbent liquid discharged from a lower end of the absorption tower through an absorbent liquid circulation line to an upper end of the absorption tower.

[13] In addition, the absorbent liquid circulating unit may include: an ammonia water circulation pump that circulates the aqueous ammonium salt solution and a part of the unreacted absorbent liquid through the absorbent liquid circulation line; and a pH sensor that measures a concentration of the absorbent liquid supplied to the upper end of the absorption tower.

[14] The absorbent liquid recycling unit may include: a storage tank that stores the aqueous divalent metal hydroxide solution; 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 NH₃(g)

and carbonate; and a filter that suctions a solution and precipitate from the mixing tank and separates the carbonate.

[15] In addition, the $\text{NH}_3(\text{g})$ generated by the mixing tank may be supplied to the absorption tower, or the absorbent liquid separated by the filter may be supplied to the absorbent liquid circulating unit.

[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 filter may be supplied to the absorbent liquid producing unit, 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 CO_2 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 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.

[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 CO_2 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.

5 [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
10 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 may be sequentially stacked.

[21] In addition, the NH₃ recycled by the absorbent liquid recycling unit may be supplied to the NO_x absorbing unit, and the NO_x absorbing unit may absorb the NO_x
15 with the NH₃ or may absorb the 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
20 to an amount of the exhaust gas.

[23] 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 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 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 absorbent liquid circulating unit.

[24] 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.

[25] 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.

[26] 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 .

[27] In addition, the CO_2 removing unit may include: an ammonia water spray nozzle that sprays the absorbent liquid downward; a packing material that contacts the CO_2 with the ammonia water, which is the absorbent liquid, to convert 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.

[28] 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.

[29] 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.

[30] 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.

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

[32] In order to achieve another object, 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; an absorbent liquid recycling unit that recycles the

absorbent liquid and NH_3 by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution and circulates and supplies the absorbent liquid and the NH_3 to the absorption tower for reuse as the absorbent liquid; and an absorbent liquid circulating unit that circulates the aqueous ammonium salt solution or a part of an unreacted absorbent liquid discharged from a lower end of the absorption tower through an absorbent liquid circulation line to an upper end of the absorption tower.

[33] In addition, the absorbent liquid circulating unit may include: an ammonia water circulation pump that circulates the aqueous ammonium salt solution and a part of the unreacted absorbent liquid through the absorbent liquid circulation line; and a pH sensor that measures a concentration of the absorbent liquid supplied to the upper end of the absorption tower.

[34] The absorbent liquid recycling unit may include: a storage tank that stores the aqueous divalent metal hydroxide solution; 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 filter that suctions a solution and precipitate from the mixing tank and separates the carbonate.

[35] The $\text{NH}_3(\text{g})$ generated by the mixing tank may be supplied to the absorption tower, or the absorbent liquid separated by the filter may be supplied to the absorbent liquid circulating unit.

[36] 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 .

[37] Fresh water or ammonia water separated by the filter may be supplied to the

absorbent liquid producing unit, 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.

5 [38] The vessel engine may use liquefied natural gas (LNG) or low sulphur marine gas oil (LSMGO) as fuel.

[39] 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.

10 [40] 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 remove 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.

[41] In addition, the NO_x absorbing unit and the CO₂ removing unit may be stacked.

[42] In addition, the NH₃ recycled by the absorbent liquid recycling unit may be supplied to the NO_x absorbing unit, and the NO_x absorbing unit may absorb the NO_x with the NH₃ or absorbs the NO_x using urea water.

20 [43] 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 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 absorbent liquid circulating unit.

5 [44] In addition, the CO₂ removing unit may include: an ammonia water spray nozzle that sprays the absorbent liquid 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
10 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.

15 [45] 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.

[46] In addition, the absorption tower may further include an exhaust gas economizer (EGE) that is formed between the NO_x absorbing unit and the CO₂ removing unit and
20 performs heat exchange between waste heat of the vessel engine and boiler water.

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

ADVANTAGEOUS EFFECTS

[48] According to the present invention, since CO₂ absorbed by taking only a part of

the absorbent liquid used when collecting CO₂ is removed, the device sizes of an absorbent liquid recycling unit and an absorbent liquid circulating unit may be kept small and continuous operation may be enabled.

[49] In addition, it is possible to flexibly cope with a CO₂ absorption rate according to a load change of a vessel engine. A high-concentration absorbent liquid may be supplied to prevent the decrease in greenhouse gas absorption performance. A pressurization system may be applied to prevent the loss of absorbent liquid due to the natural evaporation of high-concentration absorbent liquid.

[50] 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. Side reactions caused by SO_x remaining during NH₃ recycling may be removed, thereby minimizing the loss of NH₃ and preventing impurities from being included when recovering ammonia.

[51] In addition, according to the present invention exhaust gas is cooled by a heat exchange method, thereby preventing the decrease in a concentration of an absorbent liquid. Since CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed, the device sizes of an absorbent liquid recycling unit and an absorbent liquid circulating unit may be kept small and continuous operation may be enabled.

[52] In addition, it is possible to flexibly cope with a CO₂ absorption rate according to a load change of a vessel engine. A high-concentration absorbent liquid may be supplied to prevent the decrease in greenhouse gas absorption performance. A

pressurization system may be applied to prevent the loss of absorbent liquid due to the natural evaporation of high-concentration absorbent liquid.

[53] Moreover, 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 gases may be stored in the form of carbonates that exist in the natural state, and may be discharged to the sea. Side reactions caused by NO_x or 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

[54] 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.

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

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

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

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

- [59] FIG. 6 separately illustrates a SO_x absorbing unit of the absorption tower of FIG. 5.
- [60] 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.
- 5 [61] FIG. 8 illustrates various packing materials applied to the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.
- [62] FIG. 9 illustrates an ammonia water spray nozzle applied to the apparatus for reducing greenhouse gas emission in a vessel, illustrated in FIG. 2.
- [63] FIG. 10 is a schematic configuration diagram of an apparatus for reducing
10 greenhouse gas emission in a vessel, according to another embodiment of the present invention.
- [64] 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.
- 15 [65] 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.
- [66] FIG. 13 separately illustrates an absorbent liquid producing unit, an absorbent liquid recycling unit, and an absorbent liquid circulating unit of the apparatus for
20 reducing greenhouse gas emission in a vessel according to another embodiment, illustrated in FIG. 11.
- [67] 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.

[68] 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.

[69] 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

[70] 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.

[71] 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; an absorbent liquid recycling unit 140 that recycles an absorbent liquid and NH₃ by reacting the aqueous ammonium salt solution discharged from the absorption tower 130 with an aqueous divalent metal hydroxide solution and circulates and supplies the absorbent liquid and the NH₃ to

the absorption tower 130 for reuse as the absorbent liquid; and an absorbent liquid circulating unit 150 that circulates the aqueous ammonium salt solution or a part of an unreacted absorbent liquid discharged from a lower end of the absorption tower 130 through an absorbent liquid circulation line A to an upper end of the absorption tower 130. Only a part of the aqueous ammonium salt solution is converted into carbonate and the remaining unreacted absorbent liquid is circulated to the absorption tower 130, thereby maintaining a CO₂ absorption rate.

[72] 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 130 may optionally include, in addition to the CO₂ removing unit, a NO_x absorbing unit that removes nitrogen oxide or a SO_x absorbing unit, or may include both the NO_x absorbing unit and the SO_x absorbing unit.

[73] 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.

[74] 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 130 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 optionally included according to the vessel engine specification and the fuel type.

[75] Hereinafter, the apparatus for reducing greenhouse gas emission in the vessel will

be described in detail with reference to FIGS. 1 to 9.

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

5 [77] 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
10 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.

[78] 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
15 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.

[79] Here, the seawater control valve 112 may be a manually operated diaphragm
20 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 of the SO_x absorbing unit 132 can be controlled according to the amount of exhaust gas.

[80] Next, in order to supply a high-concentration absorbent liquid for maintaining

the concentration of the absorbent liquid, 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 ($\text{NH}_4\text{OH}(\text{aq})$) through the absorbent liquid circulating unit 150 to the CO_2 removing unit 131 formed at the upper end of the absorption tower 130.

[Chemical Formula 1]



[81] 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 ; the 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 an absorbent liquid circulation line A of the absorbent liquid circulating unit 150.

[82] The concentration of the ammonia water that is the absorbent liquid circulating through the absorption tower 130 and the absorbent liquid recycling unit 140 along the absorbent liquid circulation line A 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 to the atmosphere 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 A of the absorbent liquid circulating unit 150 to compensate for the reduced concentration of the ammonia water so that the ammonia water is constantly maintained at a designed concentration.

[83] 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.

[84] 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 effectively preventing the evaporation loss of NH_3 .

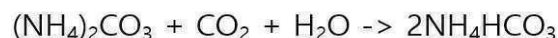
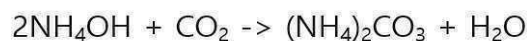
[85] For example, since NH_3 may be stored in a liquid state at -34°C and 8.5 bar, 50% concentration of ammonia water may be stored in the ammonia water tank 123 by maintaining the inside of the ammonia water tank 123 at a constant pressure by using compressed air of 7 bar available in the vessel.

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

[87] Next, the absorption tower 130 includes a CO_2 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 supplied from the absorbent liquid producing unit 120 or ammonia water circulating through the absorbent liquid circulation line A, and
5 converts CO₂ into a high-concentration aqueous ammonium salt solution (NH₄HCO₃(aq)) to remove CO₂ as shown in [Chemical Formula 2] below.

[Chemical Formula 2]



[88] Specifically, as illustrated in FIG. 3, the CO₂ removing unit 131 may include: an

10 ammonia water spray nozzle 131a that sprays the ammonia water supplied from the absorbent liquid circulating unit 150 downward; a packing material 131b that contacts CO₂ of the exhaust gas with the ammonia water and converts CO₂ into high-concentration 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
15 131b and cools heat generated by the CO₂ 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
20 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.

[89] Here, the cooling jacket may cool heat to 30°C to 50°C at which the material

transfer is smoothest, so that NH_3 is not evaporated and lost while maintaining a CO_2 absorption rate at a certain level.

[90] On the other hand, the CO_2 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_3 . 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.

[91] 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.

[92] 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.

[93] 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.

[94] 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.

[95] 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.

[96] 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.

[97] 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.

[98] 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.

[99] 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.

[100] 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.

[101] 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 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.

[102] 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 to sequentially absorb and remove the NO_x , the SO_x , and the CO_2 .

[103] 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.

[104] 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.

[105] 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 the absorbent liquid 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 .

[106] On the other hand, since NH_3 and CO_2 are generated when the urea water is

decomposed, it may be preferable that NH₃ is directly supplied to reduce the amount of CO₂ generated.

[107] 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.

[108] Next, the absorbent liquid recycling unit 140 may recycle NH₃ from the aqueous ammonium salt solution and return NH₃ back to the CO₂ removing unit 131 of the absorption tower 130 through the absorbent liquid circulating unit 150 for reuse as a CO₂ absorbent liquid, may store CO₂ in the form of CaCO₃(s) or MgCO₃(s) or discharge CO₂ to the outside of the vessel, or may supply NH₃ to the NO_x absorbing unit 133 so as to absorb NO_x.

[109] Specifically, as illustrated in FIG. 4, the absorbent liquid recycling unit 140 may include: a storage tank 141 that stores an aqueous divalent metal hydroxide solution; 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 NH₃(g) and carbonate as shown in [Chemical Formula 3] below; and a filter 143 that suctions a solution and precipitate from the mixing tank 142 and separates the carbonate.

[Chemical Formula 3]



[110] In addition, the aqueous divalent metal hydroxide solution stored in the storage tank 141 may be Ca(OH)₂ or Mg(OH)₂ produced by reacting the fresh water with CaO or MgO.

[111] 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 2] 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 so that the CO_2 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.

[112] In addition, a separate storage tank (not illustrated) that stores carbonate ($\text{CaCO}_3(\text{s})$ or $\text{MgCO}_3(\text{s})$) separated by the filter 143 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 filter 143, a membrane filter suitable for precipitate separation by high-pressure fluid transfer may be applied.

[113] On the other hand, the fresh water or the ammonia water separated by the filter 143 is supplied to the absorbent liquid circulating unit 150, 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.

[114] In this manner, since only the relatively inexpensive metal oxide (CaO or MgO)

or aqueous divalent metal hydroxide solution (Ca(OH)_2 or Mg(OH)_2) is added, no additional addition of water is required, there is no decrease in the concentration of ammonia water, the capacity size of the filter 143 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.

[115] In addition, ammonia gas generated in the mixing tank 142 may be supplied to the CO_2 removing unit 131 of the absorption tower 130, or may be supplied to the NO_x absorbing unit 133.

10 [116] Next, in order to maximize the absorption of CO_2 by continuously circulating the absorbent liquid to the absorption tower 130, the absorbent liquid circulating unit 150 circulates the high-concentration aqueous ammonium salt solution discharged from the CO_2 removing unit 131 of the absorption tower 130 and a part of the absorbent liquid that has not reacted with CO_2 to the ammonia water spray nozzle 131a of the CO_2 removing unit 131, so that only a part of the aqueous ammonium salt solution is converted into carbonate by the absorbent liquid recycling unit 140, and maintains the CO_2 absorption rate by circulating the remaining unreacted absorbent liquid to the absorption tower 130.

[117] Specifically, as illustrated in FIG. 4, the absorbent liquid circulating unit 150 may include: a centrifugal pump-type ammonia water circulation pump 151 that circulates the aqueous ammonium salt solution and a part of the unreacted absorbent liquid through the absorbent liquid circulation line A; and a pH sensor 152 that measures the concentration of the absorbent liquid supplied to the upper end of the CO_2 removing unit 131.

[118] Here, when the concentration of HCO_3^- in the absorbent liquid is high, the amount of CO_2 absorbed decreases, resulting in an increase in the amount of CO_2 emitted. When the concentration of HCO_3^- is low, the amount of carbonate produced increases more than necessary due to excessive CO_2 absorption. Therefore, by continuously monitoring the concentration of the absorbent liquid through the pH sensor 152, the concentration of HCO_3^- or OH^- in the absorbent liquid, that is, pH, may be maintained at an appropriate level.

[119] In this manner, a part of the aqueous ammonium salt solution flowing through the absorbent liquid circulation line A may be transferred to the mixing tank 142 of the absorbent liquid recycling unit 140 and converted into carbonate so that only a part of CO_2 is removed. By supplying the ammonia water recycled by the filter 143 to the absorbent liquid circulation line A, the absorbent liquid having a high concentration of OH^- and a low concentration of HCO_3^- may be supplied to maintain the CO_2 absorption rate.

[120] Therefore, since CO_2 absorbed by taking only a part of the absorbent liquid used when collecting CO_2 is removed, the device sizes of the absorbent liquid recycling unit 140 and the absorbent liquid circulating unit 150 may be kept small, continuous operation may be enabled, and it is possible to flexibly cope with the CO_2 absorption rate according to the load change of the vessel engine 10.

[121] 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.

5 The steam generating unit 160 generates and supplies steam required for heating devices in the vessel.

[122] 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
10 auxiliary boiler 161 itself may burn fuel to produce necessary steam.

[123] 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
15 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,
20 such as soot, which do not satisfy the outboard discharge conditions, in the sludge storage tank 174.

[124] 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.

[125] 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.

5 [126] Therefore, the apparatus for reducing greenhouse gas emission in the vessel has the following effects. Since CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed, the device sizes of the absorbent liquid recycling unit 140 and the absorbent liquid circulating unit 150 may be kept small, continuous operation may be enabled, and it is possible to flexibly cope with the CO₂ absorption rate according to the load change of the vessel engine 10. The high-
10 concentration absorbent liquid may be supplied to prevent the decrease in greenhouse gas absorption performance. 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
15 then separately discharged or may be converted into useful materials and then stored. NH₃ may be recycled to minimize consumption of relatively expensive NH₃. The capacity size of the rear end of a filter may be reduced. Side reactions caused by SO_x remaining during NH₃ recycling may be removed, thereby minimizing the loss of NH₃ and preventing impurities from being included when recovering ammonia.
20

[127] 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 and supplies a high-

concentration CO₂ absorbent liquid; an 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; 5 an absorbent liquid recycling unit 140` that recycles the absorbent liquid and NH<sub>3</sub> by reacting the aqueous ammonium salt solution discharged from the absorption tower 130` with an aqueous divalent metal hydroxide solution, and circulates and supplies the absorbent liquid and NH₃ to the absorption tower 130` for reuse as the absorbent liquid; and an absorbent liquid circulating unit 150` that circulates the aqueous ammonium salt solution or a part of the unreacted absorbent liquid discharged from 10 the lower end of the absorption tower 130` through an absorbent liquid circulation line L to the upper end of the absorption tower 130`. Therefore, the high-temperature and high-pressure exhaust gas is cooled by a heat exchange method, thereby preventing the decrease in the concentration of the absorbent liquid, and only 15 a part of the aqueous ammonium salt solution is converted into carbonate and the remaining unreacted absorbent liquid is circulated to the absorption tower 130`, thereby maintaining a CO₂ absorption rate.

[128] 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 20 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.

5 [129] 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
10 according to the types of vessel engine and fuel.

[130] Hereinafter, the apparatus for reducing greenhouse gas emission in the vessel will be described in detail with reference to FIGS. 10 to 16.

[131] 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
15 absorption of CO₂ by a greenhouse gas absorbent liquid.

[132] For example, as illustrated in FIG. 12, 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 high-temperature and high-pressure exhaust gas may be cooled by the heat exchange with the fresh water to a temperature of 27°C to
20 33°C, which is required by the CO₂ removing unit 131`, by circulating the fresh water supplied from an onboard cooling system 20` to a heat exchange pipe 111` surrounding an exhaust gas discharge pipe 11` through which the exhaust gas flows.

[133] 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 a deterioration in the greenhouse gas absorption performance. By improving the water cooling method, the high-temperature and high-pressure 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.

[134] 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.

[135] Next, in order to supply the high-concentration absorbent liquid for maintaining the concentration of the absorbent liquid circulating through the absorbent liquid circulation line L, 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 circulating unit 150` to the CO<sub>2</sub> removing unit 131` formed at the upper end of the absorption tower 130`.

[Chemical Formula 4]



[136] 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`; a NH<sub>3</sub> storage 122` that stores high-pressure NH₃; 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 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 absorbent liquid circulation line L of the absorbent liquid circulating unit 150`.

[137] The concentration of the ammonia water that is the absorbent liquid circulating through the absorption tower 130` and the absorbent liquid recycling unit 140` along the absorbent liquid circulation line L 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 132` and used to absorb and remove  $\text{NO}_x$ , or when  $\text{NH}_3$  passes through the absorption tower 130` and is exhausted to the atmosphere 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 L of the absorbent liquid circulating unit 150` to compensate for the reduced concentration of the ammonia water so that the ammonia water is constantly maintained at a concentration designed as the absorbent liquid.

[138] That is, the absorbent liquid producing unit 120` compensates for the reduced concentration of the ammonia water by supplying the ammonia water to the  $\text{CO}_2$  removing unit 131` during initial operation of the absorption tower 130`, and replenishing the high-concentration ammonia water to the absorbent liquid circulation line L when the concentration of the ammonia water decreases during repeated operations of the absorption tower 130`.

[139] 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 of $\text{NH}_3(\text{g})$ and reducing the vapor pressure of $\text{NH}_3(\text{g})$ 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.

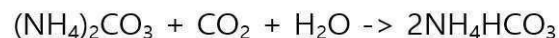
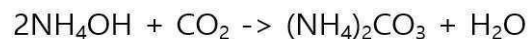
[141] For example, since NH_3 may be stored in a liquid state at -34°C and 8.5 bar, 50% concentration of ammonia water may be stored in the ammonia water tank 123` by maintaining the inside of the ammonia water tank 123` at a constant pressure by using compressed air of 7 bar available in the vessel.

[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 supplied from the absorbent liquid producing unit 120` or the ammonia water circulating along the absorbent liquid circulation line L to convert

CO₂ into an aqueous ammonium salt solution as shown in [Chemical Formula 5] below.

[Chemical Formula 5]



- 5 [144] Specifically, as illustrated in FIG. 12, the CO₂ removing unit 131` may include:
an ammonia water spray nozzle 131a` that sprays the ammonia water supplied from
the absorbent liquid circulating unit 150` downward toward a packing material 131b`;
the packing material 131b` that contacts CO₂ of the exhaust gas with the ammonia
water to convert CO₂ into NH₄HCO₃(aq); a cooling jacket (not illustrated) that is
10 formed in multi-stages for each section of an absorption apparatus filled with the
packing material 131b` and cools heat generated by a CO₂ 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
15 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 to the NO_x 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`.
- 20 [145] Here, the cooling jacket may cool heat to 30°C to 50°C at which the material
shear 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_3 . 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,  $\text{SO}_x$  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  $\text{CO}_2$  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<sub>x</sub> has been removed may be cooled by the exhaust gas cooling unit 110`, and CO₂ 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 absorbent liquid recycling unit 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 NH<sub>3</sub> spray nozzle 132e` through a urea water supply pump 132d` so as to compensate for the loss or lack of NH₃.

10 [156] On the other hand, since NH₃ and CO₂ are generated when the urea water is decomposed, it may be preferable that NH₃ is directly supplied to reduce the amount of CO₂ generated.

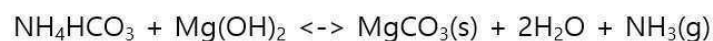
[157] In addition, the absorption tower 130` may further include an EGE 133` that is formed between the NO_x absorbing unit 132` and the exhaust gas cooling unit 110` and performs heat exchange between waste heat of the vessel engine 10` and boiler water.

15 [158] Next, the absorbent liquid recycling unit 140` may recycle NH<sub>3</sub> from the aqueous ammonium salt solution and return NH<sub>3</sub> back to the CO<sub>2</sub> removing unit 131` of the absorption tower 130` through the absorbent liquid circulating unit 150` for reuse as a CO₂ absorbent liquid, may store CO₂ in the form of CaCO₃(s) or MgCO₃(s) or discharge CO₂ to the outside of the vessel, or may supply NH₃ to the NO_x absorbing unit 132` so as to absorb NO_x.

20 [159] Specifically, as illustrated in FIG. 13, the absorbent liquid recycling unit 140` may include: a storage tank 141` that stores an aqueous divalent metal hydroxide

solution; 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 6] below; and a filter 143` that suctions a solution and precipitate from the mixing tank 142` and separates carbonate.

[Chemical Formula 6]



[160] 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 .

[161] For example, when the concentration of the ammonia water circulating through the absorbent liquid circulation line L 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 so that the CO_2 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.

[162] In addition, a separate storage tank (not illustrated) that stores carbonate ($\text{CaCO}_3(\text{s})$ or $\text{MgCO}_3(\text{s})$) separated by the filter 143` 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 directly discharged to the outside of the vessel without being stored. Here, as an example of the filter 143`, a membrane filter suitable for precipitate separation by high-pressure fluid transfer may be applied.

5 [163] On the other hand, the fresh water or the ammonia water separated by the filter 143` is supplied to the absorbent liquid circulating unit 150`, 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
10 saving the fresh water.

[164] 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 size of the filter 143` may be reduced, and the NH_3
15 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.

[165] In addition, ammonia gas generated in the mixing tank 142` may be supplied to the  $\text{CO}_2$  removing unit 131` of the absorption tower 130`, or may be supplied to the
20 NO_x absorbing unit 132`.

[166] Next, in order to maximize the absorption of CO_2 by continuously circulating the absorbent liquid to the absorption tower 130`, the absorbent liquid circulating unit 150` circulates the high-concentration aqueous ammonium salt solution discharged from the CO_2 removing unit 131` of the absorption tower 130` and a part of the

absorbent liquid that has not reacted with CO_2 to the ammonia water spray nozzle 131a` of the  $\text{CO}_2$  removing unit 131`, so that only a part of the aqueous ammonium salt solution is converted into carbonate by the absorbent liquid recycling unit 140`, and maintains the  $\text{CO}_2$  absorption rate by circulating the remaining unreacted absorbent liquid to the absorption tower 130`.

[167] Specifically, as illustrated in FIGS. 10 and 13, the absorbent liquid circulating unit 150` may include: a centrifugal pump-type ammonia water circulation pump 151` that circulates the high-concentration aqueous ammonium salt solution and a part of the unreacted absorbent liquid through the absorbent liquid circulation line L; and a pH sensor 152` that measures the concentration of the absorbent liquid supplied to the upper end of the  $\text{CO}_2$  removing unit 131`.

[168] Here, when the concentration of HCO_3^- in the absorbent liquid is high, the amount of CO_2 absorbed decreases, resulting in an increase in the amount of CO_2 emitted. When the concentration of HCO_3^- is low, the amount of carbonate produced increases more than necessary due to excessive CO_2 absorption. Therefore, by continuously monitoring the concentration of the absorbent liquid through the pH sensor 152`, the concentration of HCO_3^- or OH^- in the absorbent liquid, that is, pH, may be maintained at an appropriate level.

[169] In this manner, a part of the aqueous ammonium salt solution flowing through the absorbent liquid circulation line L may be transferred to the mixing tank 142` of the absorbent liquid recycling unit 140` and converted into carbonate so that only a part of CO_2 is removed. By supplying the ammonia water recycled by the filter 143` to the absorbent liquid circulation line L, the absorbent liquid having a high concentration of OH^- and a low concentration of HCO_3^- may be supplied to maintain

the CO₂ absorption rate.

[170] Therefore, since CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed, the device sizes of the absorbent liquid recycling unit 140` and the absorbent liquid circulating unit 150` may be kept small, continuous operation may be enabled, and it is possible to flexibly cope with the CO₂ absorption rate according to the load change of the vessel engine 10`.

[171] 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 with exhaust gas 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 circulation 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.

[172] 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.

[173] 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.

[174] Therefore, the apparatus for reducing greenhouse gas emission in the vessel and the vessel including the same have the following effects. The high-temperature and high-pressure exhaust gas may be cooled by the heat exchange method, thereby preventing the decrease in the concentration of the absorbent liquid. Since CO₂ absorbed by taking only a part of the absorbent liquid used when collecting CO₂ is removed, the device sizes of the absorbent liquid recycling unit and the absorbent liquid circulating unit may be kept small, continuous operation may be enabled, and the recovery rate of the absorbent liquid may be increased, thereby preventing the deterioration in the greenhouse gas absorption performance. It is possible to flexibly cope with the CO₂ absorption rate according to the load change of the vessel engine. A pressurization system may be applied to prevent the loss of absorbent liquid due to the natural evaporation of NH₃ 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. NH₃ may be recycled to minimize consumption of relatively expensive NH₃. The capacity size of the rear end of a filter may be reduced. Greenhouse gases may be stored in the form of carbonates that exist in the natural state, and may be discharged to the sea. Side reactions caused by NO_x or SO_x remaining during NH₃ recycling may be removed, thereby minimizing the loss of NH₃ and preventing impurities from being included when recovering ammonia.

[175] 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;

5 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
10 the absorbent liquid supplied from the absorbent liquid producing unit to convert CO₂ into an aqueous ammonium salt solution;

an absorbent liquid recycling unit that recycles the absorbent liquid and NH₃ by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution and circulates and supplies the absorbent
15 liquid and the NH₃ to the absorption tower for reuse as the absorbent liquid; and

an absorbent liquid circulating unit that circulates the aqueous ammonium salt solution or a part of an unreacted absorbent liquid discharged from a lower end of the absorption tower through an absorbent liquid circulation line to an upper end of the absorption tower.

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

an ammonia water circulation pump that circulates the aqueous ammonium salt solution and a part of the unreacted absorbent liquid through the absorbent liquid circulation line; and

a pH sensor that measures a concentration of the absorbent liquid supplied to the upper end of the absorption tower.

[CLAIM 3] The apparatus according to claim 1, wherein the absorbent liquid recycling unit comprises:

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

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 filter that suctions a solution and precipitate from the mixing tank and separates the carbonate.

[CLAIM 4] The apparatus according to claim 3, wherein the $\text{NH}_3(\text{g})$ generated by the mixing tank is supplied to the absorption tower, or the absorbent liquid separated by the filter is supplied to the absorbent liquid circulating unit.

[CLAIM 5] The apparatus according to claim 3, 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 3, wherein fresh water or ammonia water separated by the filter is supplied to the absorbent liquid producing unit, 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 CO₂ 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 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 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 CO₂ 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 CO_2 removing unit that removes CO_2 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 are sequentially stacked.

[CLAIM 10] The apparatus according to claim 8 or 9, wherein the NH_3 recycled by the absorbent liquid recycling unit is supplied to the NO_x absorbing unit, and the NO_x absorbing unit absorbs the NO_x with the NH_3 or absorbs the 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 1, 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 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

- 5 an ammonia water supply pump that supplies the ammonia water from the ammonia water tank to the absorbent liquid circulating unit.

[CLAIM 13] The apparatus according to claim 7 or 9, wherein the SO_x absorbing unit comprises:

- 10 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.

- 15 [CLAIM 14] The apparatus according to claim 13, 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.

- 20 [CLAIM 15] The apparatus according to claim 13, 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 16] The apparatus according to claim 1, wherein the CO₂ removing unit comprises:

an ammonia water spray nozzle that sprays the absorbent liquid downward;

a packing material that contacts the CO₂ with the ammonia water, which is the
5 absorbent liquid, to convert 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
10 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 flow back; and
an umbrella-shaped blocking plate that covers an exhaust gas inlet hole surrounded by
15 the partition wall.

[CLAIM 17] The apparatus according to claim 16, wherein the packing material includes multi-stage distilling column packings designed to increase a contact area per unit volume, and

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

[CLAIM 18] 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 19] The apparatus according to claim 1, further comprising a discharge unit comprising:

5 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;

10 and

 a sludge storage tank that separates and stores solid emissions.

[CLAIM 20] A vessel comprising the apparatus according to claims 1.

15 [CLAIM 21] 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-
20 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;

an absorbent liquid recycling unit that recycles the absorbent liquid and NH_3 by reacting the aqueous ammonium salt solution discharged from the absorption tower with an aqueous divalent metal hydroxide solution and circulates and supplies the absorbent liquid and the NH_3 to the absorption tower for reuse as the absorbent liquid; and

- 5 an absorbent liquid circulating unit that circulates the aqueous ammonium salt solution or a part of an unreacted absorbent liquid discharged from a lower end of the absorption tower through an absorbent liquid circulation line to an upper end of the absorption tower.

[CLAIM 22] . The apparatus according to claim 21, wherein the absorbent liquid
10 circulating unit comprises:

an ammonia water circulation pump that circulates the aqueous ammonium salt solution and a part of the unreacted absorbent liquid through the absorbent liquid circulation line; and

- a pH sensor that measures a concentration of the absorbent liquid supplied to the upper
15 end of the absorption tower.

[CLAIM 23] The apparatus according to claim 21, wherein the absorbent liquid recycling unit comprises:

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

- 20 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 filter that suctions a solution and precipitate from the mixing tank and separates the carbonate.

[CLAIM 24] The apparatus according to claim 23, wherein the $\text{NH}_3(\text{g})$ generated by the mixing tank is supplied to the absorption tower, or the absorbent liquid separated by the filter is supplied to the absorbent liquid circulating unit.

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[CLAIM 25] The apparatus according to claim 23, 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 .

10 [CLAIM 26] The apparatus according to claim 23, wherein fresh water or ammonia water separated by the filter is supplied to the absorbent liquid producing unit, 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.

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[CLAIM 27] The apparatus according to claim 21, wherein the vessel engine uses liquefied natural gas (LNG) or low sulphur marine gas oil (LSMGO) as fuel.

[CLAIM 28] The apparatus according to claim 21, wherein the exhaust gas cooling unit
20 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 29] The apparatus according to claim 21, 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 30] The apparatus according to claim 29, wherein the NO_x absorbing unit and the CO₂ removing unit are stacked.

[CLAIM 31] The apparatus according to claim 29, wherein the NH₃ recycled by the absorbent liquid recycling unit is supplied to the NO_x absorbing unit, and

the NO_x absorbing unit absorbs the NO_x with the NH₃ or absorbs the NO_x using urea water.

[CLAIM 32] The apparatus according to claim 21, 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 absorbent liquid circulating unit.

5 [CLAIM 33] The apparatus according to claim 21, wherein the CO₂ removing unit comprises:

an ammonia water spray nozzle that sprays the absorbent liquid downward;

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

10 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;

15 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.

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[CLAIM 34] The apparatus according to claim 33, 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 35] The apparatus according to claim 29, wherein the absorption tower further comprises an exhaust gas economizer (EGE) that is formed between the NO_x absorbing
5 unit and the CO₂ removing unit and performs heat exchange between waste heat of the vessel engine and boiler water.

[CLAIM 36] A vessel comprising the apparatus according to claims 21.

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