SHIP DESULFURIZATION DEVICE, HULL INTEGRATED DESULFURIZATION DEVICE, SHIP, AND METHOD FOR ASSEMBLING HULL INTEGRATED DESULFURIZATION DEVICE TO SHIP

TECHNICAL FIELD

[0001] This invention relates to a ship desulfurization device, a ship equipped with the ship desulfurization device, a hull integrated desulfurization device, a ship in which a part of a hull structure is formed by the hull integrated desulfurization device, and a method for assembling the hull integrated desulfurization device to the ship.

BACKGROUND

[0002] With the recent tightening of the exhaust gas regulations for ships, in the emission control area (ECA), it is required to use fuel oil containing 0.1% or less of sulfur, or to take an alternative measure that has an effect similar thereto. Furthermore, from 2020, also in a normal sea area, it is going to be required to use fuel oil containing 0.5% or less of sulfur, or to take an alternative measure that has an effect similar thereto. Typically, for super-large size ships such as an ultra large container ship (ULCS), a low-sulfur fuel oil containing a small amount of sulfur has been used to comply with such regulations. In future, a demand for provision of desulfurization devices is expected to increase also for these super-large size ships.

[0003] The amount of exhaust gas discharged from a main engine of a super-large size ship (exhaust gas amount at the time of 100% load) reaches as much as 200,000 Nm^3/h, or even more. Further, to meet various demands for electricity in the vessel, a super-large size ship is equipped with a plurality of power generation engines and boilers. Thus, a desulfurization device to be mounted to a super-large size ship needs to have an absorber having a broad area for passage, to desulfurize a large volume of exhaust gas discharged from the main engine and the plurality of power generation engines and boilers. However, if a typical desulfurization device for a main engine mounted to a relatively small ship such as a

bulk carrier is diverted for a super-large size ship, a plurality of absorbers would be needed, which causes limitations and changes in terms of design such as reducing the load capacity and increasing the vessel-body dimensions.

[0004] Further, a typical desulfurization device for a relatively small main engine is equipped with a round (circular) absorber. One may consider increasing the size of this round absorber for a super-large size ship. However, a round absorber tends to involve dead space when placed in a ship, as compared to a rectangular absorber, and thus may deteriorate the layout efficiency in a ship.

[0005] Thus, to solve the above problems, as an absorber of a desulfurization device for a super-large size ship, a rectangular absorber may be provided, which is a proven absorber that has been used in onshore desulfurization devices for plant facilities, factories, and the like. For instance, Patent Document 1 discloses an example of cleaning device provided with a rectangular cleaning tank (absorber), which is a wet-type cleaning device for removing pollutants such as particulate matters, harmful gases, acidic compounds, and foul odor, from a production process, an industrial process, a commercial process, or the like.

Citation List

Patent Literature

[0006]

Patent Document 1: JP5631985B

Patent Document 2: JPH9-239233A

SUMMARY

Problems to be Solved

[0007] Meanwhile, most of the rectangular absorbers used in onshore desulfurization devices have a length L in the exhaust gas introducing direction in the interior space of the absorber and a length W in a direction orthogonal to the exhaust gas introducing direction, which satisfy a ratio (W: L) of from 1:0.2 to 1:1.0. In other words, in a planar view, the

absorber has a rectangular shape with a lateral (shorter) direction along the exhaust gas introducing direction, and a longitudinal (longer) direction along a direction orthogonal to the exhaust gas introducing direction. This is because, if the shape has a longitudinal direction along the exhaust gas introducing direction, the gas flow velocity varies considerably between the front side (the side of exhaust gas inlet) and the back side (opposite side to the exhaust gas inlet) in the longitudinal direction, which makes it difficult to let exhaust gas flow uniformly through the absorber. If the flow of exhaust gas in the absorber becomes uneven, the desulfurization process in the absorber becomes also uneven, which may deteriorate the desulfurization performance.

[0008] To address the above problem, the cleaning device of the Patent Document 1 described above has an exhaust gas inlet on an upper end portion of the absorber, and is configured to introduce exhaust gas introduced from the exhaust gas inlet into a gas distribution chamber disposed on a lower part of the absorber via an exhaust gas duct extending vertically in the absorber, so as to let exhaust gas flow uniformly through the absorber.

[0009] However, diverting such an absorber as disclosed in Patent Document 1 to an absorber for a super-large size ship raises several problems in terms of layout limitations, as described below.

[0010] Firstly, while the absorber disclosed in Patent Document 1 has a substantially square shape in a planar view (W: L = 1:1), in a certain type of super-large size ship such as ULCS, an absorber having a longitudinal direction along the exhaust gas introducing direction in a planar view may have a higher arrangement performance.

[0011] Secondly, as described above, the cleaning tank disclosed in Patent Document 1 includes an exhaust gas duct extending vertically in the absorber, and a gas distribution chamber disposed on a lower part of the cleaning tank. Thus, the volume of the absorber is increased as much as the space required to provide the exhaust gas duct and the gas distribution chamber.

[0012] Thirdly, while the absorber for a ship is normally disposed protruding upward from the upper deck, the main engine, which is a main source that discharges exhaust gas, is disposed in an engine room in a lower section inside the ship body. That is, the absorber is normally disposed above the main engine in the ship. Thus, with the absorber in Patent Document 1, it is necessary to guide exhaust gas discharged from the main engine not to the lateral end portion of the absorber but to the upper end portion via the lateral end portion, which leads to an increase in the length of the exhaust gas introducing line.

[0013] Further, Patent Document 2 discloses a desulfurization device having a rectangular absorber mounted to a ship (FIGs. 3 and 4). However, the absorber of Patent Document 2 is mounted to a barge towed by a tanker (main ship), not to the main ship itself, and there is no disclosure of the problem related to layout limitations in arranging a desulfurization device on a vessel (main ship), or solution thereto.

[0014] The present invention was made under the above described background art, and the object thereof is to provide a ship desulfurization device which has a high arrangement performance in a ship such as a super-large size ship.

Solution to Problem

[0015] (1) A ship desulfurization device according to one embodiment of the present invention is a desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device including:

an absorber including an absorber body unit defining an interior space having a longitudinal direction and having an exhaust gas inlet formed on an end portion of the absorber body unit with respect to the longitudinal direction, the exhaust gas inlet being in communication with the interior space, and an exhaust gas introducing device for introducing exhaust gas discharged from the exhaust gas generation device to the absorber body unit,

wherein, when L is a maximum length of the interior space of the absorber body unit with respect to the longitudinal direction, and W is a maximum width of the interior space of

the absorber body unit with respect to a lateral direction that is orthogonal to the longitudinal direction,

a ratio (W: L) of the maximum width W to the maximum length L is within a range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0016] The desulfurization device according to the embodiment described in (1) includes the absorber including the absorber body unit defining the interior space having a longitudinal direction and having the exhaust gas inlet formed on the end portion of the absorber body unit with respect to the longitudinal direction, the exhaust gas inlet being in communication with the interior space. In other words, the interior space of the absorber body unit is configured to have a longitudinal direction along the exhaust gas introducing direction. Thus, compared to conventional round (circular) absorbers, the absorber according to the embodiment is less likely to form a dead space and is thus easily arranged in the ship. Furthermore, a ship desulfurization device that is easily arranged can be provided for certain types of ultra large ships, for example, ULCSs (in which an absorber planarly shaped to have a longitudinal direction along the exhaust gas introducing direction is more easily arranged). Furthermore, compared to a case where the interior space of the absorber body unit has a longitudinal direction along the direction orthogonal to the exhaust gas introducing direction, the embodiment can make the exhaust gas less likely to be discharged to the outside of the absorber without being desulfurized.

[0017] Furthermore, according to the embodiment described in (1), the ratio (W: L) of the maximum width W to the maximum length L of the interior space is within the range of 1: over 1.1 and 1: 6.0 or under 6.0. The upper limit of the ratio (W: L) of the maximum width W to the maximum length L of the interior space is thus set to 1 : 6.0, allowing non-uniformity of an exhaust gas flow in the absorber to be limited to within a practical allowable range examined by the present inventor.

[0018] (2) In certain embodiments, in the ship desulfurization device described in (1), the ratio (W: L) of the maximum width W to the maximum length L is within a range of 1: over 1.5 and 1: 2.0 or under 2.0.

[0019] The results of the present inventors' examinations indicate that the upper limit of the ratio (W: L) of the maximum width W to the maximum length L that allows the uniformity of exhaust gas flow in the absorber to be kept preferable is 1: 2.0. On the other hand, given the advantage of arrangement of the desulfurization device in the ship, the ratio (W: L) of the maximum width W to the maximum length L should be increased to some degree, and the lower limit of the ratio (W: L) of the maximum width W to the maximum length L may be 1: 1.5. Therefore, according to the embodiment described in (2), a well-balanced ship desulfurization device can be provided that is advantageous both in arrangement and desulfurization performance.

[0020] (3) In certain embodiments, in the ship desulfurization device described in (1) or (2), the absorber is mounted to the ship such that the longitudinal direction of the interior space of the absorber body unit extends along a width direction of the ship.

[0021] In certain types of ultra large ships, for example, ULCSs, an absorber may be more easily arranged that has a longitudinal direction, not along a bow-stern direction, but along a starboard-port direction (width direction) that is orthogonal to the bow-stern direction. For example, in the above-described ULCS, the hull is divided in the bow-stern direction into a plurality of areas for which a base unit is a length over which a 40-feet container can be housed along a longitudinal direction thereof, and the absorber may need to be arranged in one of the areas. Accordingly, the embodiment described in (3) is easily arranged in such a ship.

[0022] Furthermore, according to the embodiments described in (3), the absorber body unit may be configured to have a longitudinal direction along the width direction of the ship. Thus, compared to an absorber having a longitudinal direction along the bow-stern direction of the ship, the absorber according to the embodiment enables a reduction in bending stress acting on the absorber during rolling of the ship. The absorber according to the embodiment is highly resistant to rolling.

[0023] (4) In certain embodiments, in the ship desulfurization device described in (3), the ship includes a steel plate structure for emitting exhaust gas discharged from the exhaust gas

generation device, the steel plate structure being formed like a long tube having a longitudinal direction along the width direction of the ship. The absorber is arranged inside the steel plate structure.

[0024] According to the embodiments described in (4), the absorber is arranged inside the steel plate structure shaped like a long tube and having a longitudinal direction along the width direction of the ship, allowing minimization of adverse effects on a layout planning of other facilities and the like mounted to the ship. This facilitates retrofitting to the existing ship. Furthermore, compared to a case where the absorber is arranged inside the ship, for example, inside the engine room, the arrangement of the absorber inside the steel plate structure is also excellent in installation workability and maintainability.

[0025] (5) In certain embodiments, in the ship desulfurization device described in (4), a waste heat recovery device is arranged inside the steel plate structure to recover thermal energy from exhaust gas discharged from the exhaust gas generation device. The absorber is arranged side by side with the waste heat recovery device along the width direction of the ship.

[0026] According to the embodiments described in (5), the absorber and the waste heat recovery device are arranged side by side inside the steel plate structure along the width direction of the ship. Thus, compared to a case where the waste heat recovery device and the absorber are arranged away from each other, the exhaust gas introducing device may be simply configured.

[0027] (6) In certain embodiments, in the ship desulfurization device described in (5), the absorber has one end connected to the exhaust gas inlet of the absorber body unit and further includes an exhaust gas introducing unit extending upward from the one end toward the other end.

[0028] According to the embodiments described in (6), the absorber further includes the exhaust gas introducing unit extending upward from the exhaust gas inlet of the absorber body unit. An exhaust gas introducing line is connected to the other end of exhaust gas introducing unit to allow exhaust gas to be introduced into the absorber arranged in a small and narrow space inside the steel plate structure.

[0029] (7) In certain embodiments, in the ship desulfurization device described in (6), the exhaust gas generation device includes a main engine and an auxiliary engine. The exhaust gas introducing unit includes an exhaust gas introducing pipe extending from the waste heat recovery device side toward the other end of exhaust gas introducing unit along the width direction of the ship, and an auxiliary-engine exhaust gas introducing pipe connected to the exhaust gas introducing pipe to guide exhaust gas discharged from the auxiliary engine to the absorber body unit via the exhaust gas introducing pipe.

[0030] According to the embodiments described in (7), exhaust gas discharged from the main engine and the auxiliary engine can be guided to the absorber arranged in the small and narrow space inside the steel plate structure.

[0031] (8) In certain embodiments, in the ship desulfurization device in any one of (1) to (7), the absorber body unit includes a pair of longitudinal wall surfaces extending parallel to each other along the longitudinal direction of the interior space and a pair of lateral wall surfaces extending parallel to each other along the lateral direction of the interior space.

[0032] According to the embodiments described in (8), the interior space of the absorber body unit is planarly shaped like a rectangle defined by the pair of longitudinal wall surfaces and the pair of lateral wall surfaces. The absorber body unit having such a rectangular interior space is less likely to form a dead space when arranged in the ship, and is thus efficiently arranged in the ship.

[0033] (9) In certain embodiments, in the ship desulfurization device described in (8), a storage space is formed in the absorber body unit to store a sprayed cleaning liquid sprayed over exhaust gas guided to the interior space. The absorber body unit has a transverse member to which the pair of longitudinal wall surfaces is connected and which transverses the storage space along the lateral direction of the interior space.

[0034] According to the embodiments described in (9), if rolling of the ship or the like causes sloshing in which a surface of the cleaning liquid stored in the storage space significantly swells, the transverse member allows the swinging of the fluid surface to be suppressed. Furthermore, provision of the transverse member to which the pair of

longitudinal wall surfaces is connected enables an increase in the strength of the absorber body unit having the rectangular interior space.

[0035] (10) In certain embodiments, in the ship desulfurization device described in (9), the transverse member is a transverse beam member having an elongate shape.

[0036] According to the embodiments described in (10), the transverse beam member having an elongate shape allows exertion of a suppression effect against the above-described sloshing and a reinforcement effect for the absorber body unit.

[0037] (11) In certain embodiments, in the ship desulfurization device described in (9), the transverse member is a sheeting member having a flat plate shape.

[0038] According to the embodiments described in (11), the sheeting member having a flat plate shape allows exertion of the suppression effect against the above-described sloshing and the reinforcement effect for the absorber body unit.

[0039] (12) In certain embodiments, the ship desulfurization device in any one of (8) to (11) further includes a spraying device for spraying the cleaning liquid over exhaust gas guided to the interior space of the absorber body unit. The spraying device has a longitudinal spray pipe extending through the interior space of the absorber body unit parallel to each longitudinal wall surface of the pair of longitudinal wall surfaces and a plurality of spray nozzles provided in the longitudinal spray pipe.

[0040] According to the embodiments described in (12), a distance from each of the plurality of spray nozzles provided in the longitudinal spray pipe to the longitudinal wall surfaces may be made constant. This enables the cleaning liquid to be uniformly sprayed in the interior space, thus allowing suppression of the adverse effect of defects in which the cleaning liquid is non-uniformly sprayed as a result of shaking (rolling, pitching, yawing, or the like) of the ship.

[0041] (13) In certain embodiments, the ship desulfurization device in any one of (8) to (11) further includes a spraying device for spraying the cleaning liquid over exhaust gas guided to the interior space of the absorber body unit. The spraying device has a plurality of lateral spray pipes extending through the interior space of the absorber body unit parallel to

each lateral wall surface of the pair of lateral wall surfaces and at least one spray nozzle provided on each of the plurality of lateral spray pipes.

[0042] According to the embodiments described in (13), an equal spraying area may be set for the spray nozzles provided in each of the plurality of lateral spray pipes. This enables the cleaning liquid to be uniformly sprayed in the interior space, thus allowing suppression of the adverse effect of defects in which the cleaning liquid is non-uniformly sprayed as a result of shaking (rolling, pitching, yawing, or the like) of the ship.

[0043] (14) In certain embodiments, in the ship desulfurization device in any one of (1) to (13), the exhaust gas generation device includes the main engine. The main engine has an exhaust gas amount (the amount of exhaust gas under a 100% load) of 200,000 Nm^3/h or more.

[0044] The ship desulfurization device described in (1) to (13) is suitably used as a desulfurization device for such ultra large ships as include a main engine having an exhaust gas amount of 200,000 Nm^3/h or more. The upper limit of exhaust gas amount of the main engine is not particularly limited but is, in practical terms, 500,000 Nm^3/h or less.

[0045] (15) In certain embodiments, in the ship desulfurization device in any one of (1) to (14), the ship is a container ship having a container load of 10,000 TEU or more.

[0046] The ship desulfurization device described in (1) to (14) is suitably used as a desulfurization device for ultra large container ships (ULCSs) having a container load capacity of 10,000 TEU or more. The upper limit of the container load capacity is not particularly limited but is, practical terms, 20,000 TEU or less.

[0047] (16) Furthermore, the ship according to one embodiment of the present invention is equipped with the ship desulfurization device in any one of (1) to (15).

[0048] (17) A ship desulfurization device according to one embodiment of the present invention is a ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device including:

an absorber including an absorber body unit defining an interior space;

a spraying device capable of spraying a cleaning liquid over exhaust gas flowing

through the interior space; and

packing materials packed in a packed layer provided in the interior space and configured to bring the cleaning liquid into gas-liquid contact with the exhaust gas passing through the packed layer.

[0049] The ship desulfurization device according to the embodiment described in (17) is capable of bring the cleaning liquid having an increased contact area with a surface of the packing materials into gas-liquid contact with exhaust gas having a flow thereof disturbed by the packing materials packed in the packed layer, when the exhaust gas flows through the packing materials. Such a ship desulfurization device allows the efficiency of gas-liquid contact between the cleaning liquid and the exhaust gas to be improved using the packing materials. Thus, compared to a case where no packing materials are provided, the ship desulfurization device allows effective removal of sulfurs contained in exhaust gas.

[0050] (18) In certain embodiments, in the ship desulfurization device described in (17), an anticorrosion layer is formed on at least a part of a wall surface defining the interior space of the absorber body unit, the part being other than a part of the wall surface partitioning the packed layer. The anticorrosion layer is not formed on the part of the wall surface partitioning the packed layer of the absorber body unit.

[0051] In the ship desulfurization device, hot exhaust gas flows inside the absorber body unit, and thus, for example, the wall surface (inner wall surface) defining the interior space of the absorber body unit may be corroded with, for example, sulfurs contained in exhaust gas. Furthermore, if seawater is used as the cleaning liquid, the seawater may corrode the above-described wall surface and the like. Typically, to protect the above-described wall surface, the anticorrosion layer may be provided all over the above-described wall surface. However, shaking of the ship may move the packing materials, which may collide against the anticorrosion layer protecting the wall surface partitioning the packed layer to peel off or damage the anticorrosion layer. Peel-off of the anticorrosion layer or damage thereto may contribute to corrosion of the wall surface protected by the anticorrosion layer.

[0052] In the ship desulfurization device according to the embodiments described in (18),

the anticorrosion layer is formed on a part of the wall surface (inner wall surface) defining the interior space of the absorber body unit, the part being other than a part of the wall surface partitioning the packed layer. When the anticorrosion layer is formed on the part of the wall surface partitioning the packed layer, shaking of the ship may move the packing materials, which may collide against the anticorrosion layer to peel off or damage the anticorrosion layer. The anticorrosion layer is thus not formed on the part of the wall surface partitioning the packed layer, and instead, a layered portion of the absorber body unit surrounding the packed layer is formed of an anticorrosive material, for example, stainless steel to suppress corrosion of the wall surface. Such a ship desulfurization device is capable of suppressing corrosion of the wall surface defining the interior space while preventing the packing materials from damaging the anticorrosion layer.

[0053] (19) In certain embodiments, in the ship desulfurization device described in (17) or (18), the packing materials are regular packing materials.

In the ship desulfurization device according to the embodiments described in (19), the packing materials are the regular packing materials. Thus, compared to a case where the packing materials are irregular packing materials, the embodiment enables a reduction in pressure drop of exhaust gas and an increase in exhaust gas throughput. Compared to a ship desulfurization device using the irregular packing materials as the packing materials, the ship desulfurization device using the regular packing materials as the packing materials thus enables a reduction in the size of the absorber. Furthermore, compared to the irregular packing materials, the regular packing materials are less likely to move or lead to non-uniform arrangement in spite of shaking of the ship. Compared to a ship desulfurization device using the irregular packing materials as the packing materials, the ship desulfurization device using the regular packing materials as the packing materials is thus capable of reducing the risk that exhaust gas is discharged to the outside of the absorber without being desulfurized.

[0054] (20) In certain embodiments, in the ship desulfurization device described in (17) to (19), the absorber body unit is configured such that the exhaust gas flows from a lower side toward an upper side in a vertical direction. The spraying device is configured to inject the

cleaning liquid upward.

The spraying device according to the embodiments described in (20) is configured to inject the cleaning liquid upward. The cleaning liquid injected upward disperses at an upper end (top) and is then micronized and falls down. The cleaning liquid is thus dispersively present, for example, on surfaces of the packing materials in the interior space. When flowing from the lower side toward the upper side in the vertical direction, exhaust gas comes into gas-liquid contact with the cleaning liquid adhering to the surfaces of the packing materials or the falling cleaning liquid, thus removing sulfurs contained in exhaust gas.

[0055] (21) A ship desulfurization device according to one embodiment is a ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device including an absorber including an absorber body unit defining an interior space and configured such that the exhaust gas flows through the interior space, and a light-transmissive visual confirmation window enabling the interior space to be viewed from outside of the absorber body unit.

[0056] The absorber described in (21) includes the absorber body unit configured such that exhaust gas flows through the interior space and the light-transmissive visual confirmation window enabling the interior space to be viewed from outside of the absorber body unit. In the ship desulfurization device including the absorber, the operator or the like can check, via the visual confirmation window, for example, the flow of exhaust gas flowing through the interior space.

[0057] (22) In certain embodiments, in the ship desulfurization device described in (21), the interior space has a longitudinal direction. The absorber body unit has an exhaust gas inlet on an end portion of the absorber body unit with respect to the longitudinal direction. Moreover, the visual confirmation window is provided on the other end portion with respect to the longitudinal direction.

[0058] When the interior space has a longitudinal direction, the gas flow rate may vary significantly between the exhaust gas inlet side and the opposite side, leading to a non-uniform flow of exhaust gas in the absorber. The absorber body unit according to the

embodiments described in (22) has the exhaust gas inlet on an end portion of the interior space with respect to the longitudinal direction and in communication with the interior space. The visual confirmation window is provided on the other end portion of the interior space with respect to the longitudinal direction. An operator or the like may check the flow of exhaust gas on the side opposite to the exhaust gas inlet, which is difficult to check through a visual confirmation window provided on the exhaust gas inlet side.

[0059] (23) In certain embodiments, the ship desulfurization device described in (21) or (22) further includes a spraying device capable of spraying a cleaning liquid over exhaust gas flowing through the interior space. The spraying device has a spray nozzle capable of injecting the cleaning liquid into the interior space. The visual confirmation window is arranged at a position where a visual check of a state of spraying of the cleaning liquid from the spray nozzle is enabled.

[0060] The visual confirmation window according to the embodiments described in (23) is arranged at the position where the visual check of the state of spraying of the cleaning liquid from the spray nozzle is enabled. The operator or the like may check, via the visual confirmation window, the state of spraying of the cleaning liquid by the spraying device such as the state of spraying of the cleaning liquid using the spray nozzle. If the state of spraying of the cleaning liquid by the spraying device is inappropriate, the state of spraying by the spraying device can be improved by, for example, cleaning the spray nozzle.

[0061] (24) In certain embodiments, in the ship desulfurization device described in (23), the absorber body unit is configured such that the exhaust gas flows from a lower side toward an upper side in a vertical direction, the absorber body unit having a mist eliminator provided above the spray nozzle in the interior space. The visual confirmation window is arranged above the spray nozzle and below the mist eliminator.

[0062] The absorber body unit according to the embodiments described in (24) is configured such that the exhaust gas flows from the lower side toward the upper side in the vertical direction. The visual confirmation window is arranged above the spray nozzle and below the mist eliminator. Exhaust gas comes into gas-liquid contact with the cleaning

liquid below the eliminator, thus precluding check of the state of spraying of the cleaning liquid by the spraying device if the visual confirmation window is provided above the mist eliminator. The visual confirmation window arranged as described above allows the operator to check, via the visual confirmation window, the state of spraying of the cleaning liquid by the spraying device. In particular, if the spray nozzle is configured to be capable of injecting the cleaning liquid upward, the operator may check whether the state of spraying of the cleaning liquid is appropriate by checking an upper end of the cleaning liquid sprayed by the spraying device.

[0063] (25) A ship desulfurization device according to one embodiment of the present invention is a ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device including an absorber including an absorber body unit defining an interior space, and

a spraying device capable of spraying a cleaning liquid over exhaust gas flowing through the interior space, wherein

the spraying device has a spray pipe extending through the interior space of the absorber body unit, and a plurality of spray nozzles arranged on the spray pipe at predetermined intervals.

[0064] The ship desulfurization device according to the embodiment described in (25) causes the cleaning liquid flowing through the spray pipe to be injected from each of the plurality of spray nozzles arranged on the spray pipe at the predetermined intervals, allowing the cleaning liquid to be uniformly sprayed through the interior space. The ship desulfurization device is therefore capable of suppressing the adverse effect of defects in which the cleaning liquid is non-uniformly sprayed as a result of shaking (rolling, pitching, yawing, or the like) of the ship.

[0065] (26) A ship desulfurization device according to one embodiment of the present invention is a ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device including:

an absorber including an absorber body unit that defines an interior space and includes

an exhaust gas inlet communicating with the interior space, the absorber including an exhaust gas introducing unit connected to the exhaust gas inlet; and

an exhaust gas cooling device capable of spraying cooling water over the exhaust gas before being introduced into the interior space after being introduced into the exhaust gas introducing unit, wherein

the exhaust gas cooling device has a cooling water nozzle configured to inject the cooling water toward an upstream side in a flow direction of exhaust gas.

[0066] The ship desulfurization device according to the embodiment described in (26) uses the exhaust gas cooling device to spray cooling water over the exhaust gas that is to be introduced into the interior space after being introduced into the exhaust gas inlet. This enables a reduction in the temperature of exhaust gas guided into the exhaust gas introducing unit to allow suppression of a rise in the temperature in exhaust gas introducing unit. Furthermore, the exhaust gas cooling device is used to spray the cooling water, enabling a reduction in the volume of exhaust gas guided into the exhaust gas introducing unit to allow a large amount of exhaust gas to be treated in the absorber. Furthermore, the cooling water nozzle of exhaust gas cooling device injects the cooling water toward the upstream side in the flow direction of exhaust gas. This enables a reduction in the temperature of exhaust gas introduced into the exhaust gas introducing unit before reaching the cooling water nozzle, enabling suppression of damage to the cooling water nozzle resulting from the heat of exhaust gas.

[0067] (27) In certain embodiments, in the ship desulfurization device described in (26), the cooling water is seawater introduced into the ship.

The ship desulfurization device according to the embodiments described in (27) uses, as the cooling water, the seawater introduced into the ship to allow suppression of an increase in the consumption of water such as industrial water which is needed during navigation of the ship.

[0068] (28) In certain embodiments, in the ship desulfurization device described in (26) or (27), the exhaust gas introducing unit is configured such that the exhaust gas flows from an

upper side toward a lower side in a vertical direction. The cooling water nozzle is configured to inject the cooling water upward.

[0069] When the exhaust gas cooling device is used to spray the cooling water over the exhaust gas introduced into the exhaust gas introducing unit to reduce the temperature of exhaust gas, sulfurous acids may be generated. Furthermore, if the seawater is used as the cooling water, the temperature may increase to precipitate salt from the seawater. Sulfuric acids and salts adhering to the cooling water nozzle may degrade spraying performance.

The cooling water nozzle according to the embodiments described in (28) is configured to inject the cooling water upward, that is, in a direction opposite to the flow direction of the exhaust gas. The cooling water injected upward comes into contact with the exhaust gas above the cooling water nozzle to reduce the temperature of exhaust gas, and falls onto the cooling water nozzle and the like. The cleaning liquid having fallen onto the cooling water nozzle allows the sulfurous acids and salts adhering to the cooling water nozzle to be washed away. Furthermore, the cooling water nozzle is kept wet with the cleaning liquid having fallen onto the cooling water nozzle, allowing sulfurous acids and salts to be restrained from adhering to the cooling water nozzle and also allowing suppression of an increase in the temperature of the cooling water nozzle.

[0070] (29) In certain embodiments, in the ship desulfurization device described in any one of (26) to (28), the exhaust gas cooling device has the cooling water nozzle for spraying the cooling water, a cooling water conduit for feeding the cooling water to the cooling water nozzle, and a cooling water control valve provided in the cooling water conduit and capable of controlling an amount of the cooling water sprayed through the cooling water nozzle.

[0071] The pressure of the cooling water on a primary side of the cooling water conduit, which is on an upstream side of the cooling water control valve, fluctuates significantly according to fluctuation factors such as the number of pumps operated. If no cooling water control valve is provided, the amount of cooling water sprayed through the cooling water nozzle fluctuates significantly according to the above-described fluctuation factors. The exhaust gas introduced into the exhaust gas introducing unit may thus be insufficiently cooled.

In contrast, the exhaust gas cooling device according to the embodiments described in (29) allows the cooling water control valve to control the amount of cooling water sprayed through the cooling water nozzle to sufficiently cool the exhaust gas introduced into the exhaust gas introducing unit.

[0072] (30) In certain embodiments, the ship desulfurization device described in (29) includes a pressure gauge provided on a wake flow side of the cooling water control valve in the cooling water conduit. The cooling water control valve is configured to adjust a degree of opening thereof such that a pressure of the cooling water detected by the pressure gauge is kept constant.

[0073] The cooling water control valve keeps the pressure of the cooling water on the wake flow side of the cooling water control valve constant to also keep the pressure of the cooling water as injected through the cooling water nozzle constant. At least a constant amount of cooling water is thus sprayed to a constant height through the cooling water nozzle. The exhaust gas cooling device according to the embodiments described in (30) is capable of constantly spraying at least a constant amount of cooling water through the cooling water nozzle, thus continuously cooling exhaust gas guided into the exhaust gas introducing unit.

[0074] (31) A ship desulfurization device according to one embodiment of the present invention is a ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device including:

an absorber including an absorber body unit defining an interior space;

a spraying device capable of spraying a cleaning liquid over exhaust gas flowing through the interior space; and

a cleaning liquid feeding device capable of feeding the cleaning liquid to the spraying device, wherein

the cleaning liquid feeding device has:

a cleaning liquid feeding line for feeding the cleaning liquid to the spraying device;

a bypass line which branches off from the cleaning liquid feeding line and through which the cleaning liquid is fed to a storage space where the sprayed cleaning liquid sprayed

over exhaust gas guided to the interior space is stored; and

a control valve provided in the bypass line and capable of controlling a feeding amount of the cleaning liquid flowing through the bypass line.

[0075] For example, between emission control areas and general waters, required desulfurization performance varies, and thus, the needed amount of cleaning liquid fed to the spraying device also varies. If the amount of cleaning liquid fed to the spraying device is smaller than the needed amount of cleaning liquid, a needed desulfurization effect may fail to be produced. Furthermore, if the amount of cleaning liquid fed to the spraying device is greater than the needed amount of cleaning liquid, the pressure drop of exhaust gas may increase. To allow an appropriate amount of cleaning liquid to be fed to the spraying device, a control valve may be provided in the cleaning liquid feeding line for feeding the cleaning liquid to the spraying device to control the feeding amount of cleaning liquid flowing through the cleaning liquid feeding line. However, the conduit constituting the cleaning liquid feeding line has a large diameter, and thus, the size and cost of the control valve provided in the cleaning liquid feeding line may be increased. Furthermore, there is difficulty in controlling the feeding amount of cleaning liquid in the cleaning liquid feeding line including the conduit with a large diameter.

[0076] The cleaning liquid feeding device according to the embodiment described in (31) uses the control valve provided in the bypass line to control the feeding amount of cleaning liquid flowing through the bypass line to allow indirect control of the feeding amount of cleaning liquid flowing through the cleaning liquid feeding line. In this case, the conduit constituting the bypass line may have a smaller diameter than the conduit constituting the cleaning liquid feeding line, and thus, the control valve provided in the bypass line has a smaller size and a lower cost than the control valve provided in the cleaning liquid feeding line. Furthermore, the bypass line allows the feeding amount of cleaning liquid to be more easily controlled than the cleaning liquid feeding line.

[0077] (32) Furthermore, a ship according to one embodiment of the present invention includes the ship desulfurization device in any one of (1) and (17) to (31) mounted therein.

[0078] (33) A hull integrated desulfurization device according to one embodiment includes a casing forming a part of a hull structure of a ship, and an absorber supported by the casing to desulfurize exhaust gas discharged from an exhaust gas generation device mounted to the ship.

The "hull structure" means a structure main body forming a framework and a contour of the ship and excluding rigging, an engine and the like. An engine casing described below also corresponds to the "hull structure".

The conventional ship desulfurization device is a piece of machinery mounted to the ship independently from the hull structure.

For the hull integrated desulfurization device having the configuration described in (33), before the hull integrated desulfurization device is mounted to the ship, the absorber is already supported by the casing forming a part of the hull structure. The casing of the hull integrated desulfurization device is connected to another hull structure of the ship on the ship.

[0079] According to the configuration described in (33), the casing supporting the absorber forms a part of the hull structure. This eliminates a need to provide, around the absorber, an excess clearance or a reinforcing member intended to prevent vibration and shaking of the absorber. An attachment structure for the absorber may thus be compactified, and the weight of the hull structure may be reduced.

[0080] (34) In one embodiment, in the configuration described in (33), the absorber is connected by welding to the casing surrounding an outer periphery of the absorber and is formed integrally with the casing.

According to the configuration described in (34), the absorber is connected by welding to the casing surrounding the outer periphery of the absorber, and thus, a force applied from the absorber to the casing is distributed over the periphery of the casing. The load of the absorber, which otherwise concentrates on a base of the absorber, is therefore distributed over the casing, allowing a support structure for the absorber to be compactified.

[0081] (35) In one embodiment, in the configuration described in (33) or (34), in a state where the hull integrated desulfurization device is mounted to the ship, a gap is formed

between the absorber and an engine casing of the ship positioned below the absorber, and the absorber is peripherally supported by the casing.

According to the configuration described in (35), the absorber is peripherally supported by the casing, eliminating a need for a support unit supporting the absorber from below. This allows a gap to be formed between the absorber and the engine casing of the ship positioned below the absorber. This allows piping to be arranged in the gap; the piping includes liquid piping through which an absorbing liquid flows (seawater feeding pipe and seawater discharge pipe), exhaust gas piping through which exhaust gas discharged from the exhaust gas generation device such as the main engine is introduced into the absorber, and the like.

[0082] (36) In one embodiment, in the configuration in any one of (33) to (35), a length of the casing along a width direction of the ship is larger than a length of the casing along a front-back direction of the ship.

According to the configuration described in (36), the longitudinal direction of the casing is arranged along the width direction of the ship. Compared to an absorber having a longitudinal direction along the bow-stern direction of the ship, the absorber supported by the casing has the longitudinal direction arranged along the width direction of the ship, enabling a reduction in bending stress acting on the absorber body during rolling of the ship. The absorber according to this embodiment may be highly resistant to rolling.

[0083] (37) In one embodiment, in the configuration in any one of (33) to (36), in a state where the hull integrated desulfurization device is mounted to the ship, the absorber is positioned above exhaust gas piping of exhaust gas generation device.

According to the configuration described in (37), the absorber is positioned above the exhaust gas piping of exhaust gas introducing unit, enabling a reduction in the length of exhaust gas piping through which exhaust gas discharged from the exhaust gas generation device is introduced into the absorber.

Here, the “position above the exhaust gas piping” means the “position where the exhaust gas piping and the absorber at least partly overlap each other in a plan view”.

[0084] (38) In one embodiment, the configuration in any one of (33) to (37) further includes piping supported by the casing and including at least one of: gas piping connecting the exhaust gas piping of exhaust gas generation device to an exhaust gas inlet of the absorber; and liquid piping through which an absorbing liquid to be used in the absorber flows.

According to the configuration described in (38), the piping is supported by the casing forming a part of the hull structure of the ship, allowing compactification of the support structure for the absorber including the piping.

[0085] (39) A ship according to one embodiment is a ship including the hull integrated desulfurization device having the configuration in any one of (33) to (38), and a part of the hull structure is formed by the hull integrated desulfurization device.

According to the configuration described in (39), the hull integrated desulfurization device is formed as a part of the hull structure, eliminating a need to provide, around the absorber, an excess clearance or a reinforcing member intended to prevent vibration and shaking of the absorber. An attachment structure for the absorber may thus be compactified.

[0086] (40) In one embodiment, in the configuration described in (39), the hull structure includes an engine casing positioned below the casing of the hull integrated desulfurization device, and a lower end of a shell wall of the casing is connected to the engine casing by welding.

According to the configuration described in (40), the absorber is supported by the casing forming a part of the hull structure of the ship, allowing the casing to be easily arranged above the engine casing, which belongs to the same hull structure. Furthermore, a distance between the engine casing and the casing supporting the absorber is short, enabling a reduction in the length of exhaust gas piping through which exhaust gas discharged from the main engine housed in the engine casing is introduced into the absorber.

[0087] (41) In one embodiment, in the configuration described in (40), a first reinforcing member formed by ribs provided on an inner side surface of the shell wall of the casing and extending in an up-down direction or by stiffeners installed between the shell walls arranged

opposite to each other is aligned with a second reinforcing member formed by ribs or stiffeners provided in the engine casing.

According to the configuration described in (41), the first reinforcing member is aligned with the second reinforcing member, enabling an increase in bearing capacity of the engine casing supporting the casing supporting the absorber. The casing is stably supported by the engine casing.

[0088] (42) In one embodiment, in the configuration described in (39) to (41), the hull structure of the ship includes the casing; and another hull structure arranged adjacent to the casing in a width direction of the ship and welded to the casing.

According to the configuration described in (42), the hull structure arranged in the width direction of the ship is divided into the casing supporting the absorber and the other hull structure. This allows avoidance of a situation where the hull integrated desulfurization device has an excessive weight, leading to an insufficient crane capacity.

[0089] (43) A method for assembling a hull integrated desulfurization device to a ship according to one embodiment includes a forming step of forming a hull integrated desulfurization device that includes a casing forming a part of a hull structure of the ship, and an absorber supported by the casing to desulfurize exhaust gas discharged from an exhaust gas generation device mounted to the ship, and an installing step of installing the hull integrated desulfurization device to the ship, and the installing step includes joining the casing of the hull integrated desulfurization device to the hull structure of the ship other than the casing.

[0090] According to the method described in (43), in the formation step, the hull integrated desulfurization device is preliminarily formed, for example, on land, and after the ship enters a dock, the hull integrated desulfurization device is mounted to the ship. This enables a reduction in a construction period for mounting the absorber to the ship. Furthermore, before being integrated together, the absorber and the hull structure may be simultaneously and concurrently manufactured, enabling a reduction in a construction period for the hull integrated desulfurization device.

[0091] (44) In one embodiment, in the configuration described in (43), the forming step includes assembling the absorber and the casing together in order from a lower section to an upper section of the hull integrated desulfurization device.

According to the method described in (44), the absorber and the casing are assembled in order from the lower section to the upper section of the hull integrated desulfurization device, facilitating the assembly. The absorber and the casing are simultaneously and concurrently assembled, enabling a reduction in construction period.

[0092] (45) In one embodiment, in the method described in (43), the forming step includes forming an aggregation of a plurality of divisional sections into which the hull integrated desulfurization device is divided in an up-down direction, and the installing step includes sequentially stacking the divisional sections in the ship to install the hull integrated desulfurization device to the ship.

According to the method described in (45), the aggregation of the plurality of divisional sections into which the hull integrated desulfurization device is divided in the up-down direction is formed, and thus, in the installing step, the divisional sections may be conveyed one by one into the ship using a crane. This allows avoidance of a situation where the conveying capacity of the crane is insufficient.

Advantageous Effects

[0093] According to at least one embodiment of the present invention, a ship desulfurization device can be provided that is easily arranged in a ship such as an ultra large ship.

BRIEF DESCRIPTION OF DRAWINGS

[0094] FIG. 1 is a perspective view illustrating a ship according to one embodiment of the present invention.

FIG. 2A is a diagram illustrating dimensions of a 40-feet container, and FIG. 2B is an enlarged view of a periphery of a steel plate structure in the ship illustrated in FIG. 1.

FIG. 3 is a perspective view illustrating a ship desulfurization device according to one embodiment of the present invention.

FIG. 4 is a perspective view illustrating the ship desulfurization device according to one embodiment of the present invention as viewed from an angle different from the angle in FIG. 3.

FIG. 5 is a schematic diagram illustrating an absorber of the ship desulfurization device according to one embodiment of the present invention.

FIG. 6A, FIG. 6B, and FIG. 6C are diagrams illustrating the results of examinations of the planar shape of an interior space of the absorber body in the ship desulfurization device according to one embodiment of the present invention.

FIG. 7A, and FIG. 7B are diagrams illustrating a transverse member provided in a storage space of the absorber in the ship desulfurization device according to one embodiment of the present invention.

FIG. 8 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention.

FIG. 9 is a graph illustrating a relationship between the shape (aspect ratio) of the interior space of an absorber body unit and a desulfurization performance parameter in the ship desulfurization device according to one embodiment of the present invention.

FIG. 10 is a table illustrating the results of examinations of the relationship between the shape (aspect ratio) of the interior space of the absorber body unit and the desulfurization performance parameter in the ship desulfurization device according to one embodiment of the present invention.

FIG. 11 is a plan view illustrating arrangement conditions for spray nozzles in the interior space of the absorber body unit.

FIG. 12A, FIG. 12B, and FIG. 12C are diagrams illustrating a relationship between the planar shape and shape (aspect ratio L/W) of the interior space of the absorber body unit in the ship desulfurization device according to one embodiment of the present invention.

FIG. 13 is a schematic diagram illustrating the absorber of the ship desulfurization

device according to one embodiment of the present invention as viewed from an A direction illustrated in FIG. 5.

FIG. 14 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention and also illustrating an example of an absorber body with no packed layer (a liquid-jet column, a spray column, a tray absorber, and the like).

FIG. 15 is a perspective view (conceptual drawing) illustrating packing materials according to one embodiment of the present invention.

FIG. 16 is a schematic diagram illustrating an anticorrosion layer according to one embodiment of the present invention and also illustrating the absorber of the ship desulfurization device.

FIG. 17 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention and also illustrating wall surface reinforcing members and partitioning walls.

FIG. 18 is a diagram illustrating an exhaust gas cooling device of the ship desulfurization device according to one embodiment of the present invention.

FIG. 19 is a diagram illustrating the exhaust gas cooling device of the ship desulfurization device according to one embodiment of the present invention.

FIG. 20 is a diagram illustrating a cleaning liquid feeding line and a bypass line in the ship desulfurization device according to one embodiment of the present invention.

FIG. 21 is a diagram illustrating fixture between the absorber and the steel plate structure of the ship desulfurization device according to one embodiment of the present invention.

FIG. 22 is a diagram illustrating installation, on the ship, of the absorber and the steel plate structure of the ship desulfurization device according to one embodiment of the present invention.

FIG. 23 is a diagram illustrating connection between the absorber and an exhaust gas introducing pipe of the ship desulfurization device according to one embodiment of the

present invention.

FIG. 24A and FIG. 24B are diagrams illustrating the connection between the absorber and the exhaust gas introducing pipe of the ship desulfurization device according to one embodiment of the present invention; FIG. 24A is a schematic top view and FIG. 24B is a schematic front view.

FIG. 25 is a perspective view illustrating a case where a hull integrated desulfurization device according to one embodiment is assembled to a hull structure.

FIG. 26 is a perspective view illustrating the case where the hull integrated desulfurization device according to one embodiment is assembled to the hull structure.

FIG. 27 is a plan view of a casing including the hull integrated desulfurization device according to one embodiment.

FIG. 28 is a schematic diagram illustrating the case where the hull integrated desulfurization device according to one embodiment is assembled to a hull structure.

FIG. 29 is a schematic diagram illustrating the case where the hull integrated desulfurization device according to one embodiment is assembled to a hull structure.

FIG. 30 is a schematic diagram illustrating the case where the hull integrated desulfurization device according to one embodiment is assembled to a hull structure.

FIG. 31A, FIG. 31B, and FIG. 31C are schematic diagrams illustrating several hull integrated desulfurization devices.

FIG. 32 is a process diagram illustrating a method for assembling the hull integrated desulfurization device according to one embodiment.

FIG. 33 is a schematic diagram illustrating a method for assembling the hull integrated desulfurization device according to one embodiment to the hull structure.

DETAILED DESCRIPTION

[0095] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly specified, dimensions, materials, shapes, relative positions and the like of components

described in the embodiments or illustrated in drawings shall be interpreted as illustrative only and not limitative of the scope of the present invention.

For example, an expression such as “in a certain direction”, “along a certain direction”, “parallel”, “orthogonal”, “center”, “concentric”, or “coaxial” which represents a relative arrangement or an absolute arrangement is intended not only to strictly represent the arrangement but also to represent a state of relative displacement with a tolerance or through an angle or over a distance where the magnitudes of the angle and the distance are small enough to achieve the same function.

For example, expressions such as “same”, “equal”, and “homogeneous” which represent a state where things are equal are intended not only to represent an exactly equal state but also to represent a state where a tolerance or a difference the magnitude of which is small enough to achieve the same function is present.

For example, expressions for shapes such as a quadrilateral shape and a cylindrical shape are intended not only to represent shapes such as a quadrilateral shape and a cylindrical shape in a geometrically strict sense but also to represent shapes including recessed and protruding portions or chamfered potions to the extent that the same effect is produced.

An expression “being provided with”, “comprising”, “including”, “containing” or “having” a component is not an exclusive expression that excludes the presence of other components.

Furthermore, in the following description, the same components are denoted by the same reference numerals, and detailed descriptions thereof may be omitted.

[0096] FIG. 1 is a perspective view illustrating a ship according to one embodiment of the present invention. A ship 1 according to one embodiment of the present invention is, for example, an ultra large ship in which a main engine has an exhaust gas amount (exhaust gas amount under a 100% load) of more than 200,000 Nm^3/h. In the illustrated embodiment, the ship 1 is an ultra large container ship referred to as a ULCS and having a container load capacity of 10,000 TEU or more.

[0097] As illustrated in FIG. 1, the ship 1 includes a ship body 2, an accommodation

house 4 provided to protrude from an upper deck 3 at a position slightly in front of the center in a bow-stern direction, and a steel plate structure 6 provided to protrude from the upper deck 3 at a position closer to stern than the accommodation house 4. Here, the steel plate structure 6 is referred to as a funnel or an engine casing. Furthermore, a plurality of transverse bulkheads 8 extending in a starboard-port direction orthogonal to the bow-stern direction are provided in a hold of the ship body 2 at intervals. The ship body 2 is thus divided in the bow-stern direction into a plurality of areas for which a base unit is a length over which a 40-feet container 9 can be housed along a longitudinal direction of the container.

[0098] FIG. 2A illustrates dimensions of the 40-feet container 9. FIG. 2B is an enlarged view of a periphery of the steel plate structure in the ship illustrated in FIG. 1. As illustrated in FIG. 2B, the steel plate structure 6 is provided between a pair of adjacent transverse bulkheads 8A, 8B. An engine room 10 is formed inside the ship body 2 below the steel plate structure 6 in a vertical direction. The engine room 10 includes a main engine 12 installed therein and including a ship diesel engine for applying a propulsive force to the ship 1 and a main engine boiler for driving a main engine turbine, and a plurality of auxiliary engines 14 also installed therein and including an auxiliary boiler for meeting various thermal demands and the like in the ship 1 and an auxiliary engine for meeting a power demand and the like. The main engine 12 and the auxiliary engines 14 correspond to an exhaust gas generation device mounted to the ship 1 according to one embodiment of the present invention.

[0099] The steel plate structure 6 is a structure for releasing, to the outside of the ship, exhaust gas discharged from the main engine 12 and the auxiliary engines 14 and is shaped like a long tube having a longitudinal direction along the starboard-port direction (width direction) of the ship 1. A ship desulfurization device 20 is arranged inside the steel plate structure 6 to desulfurize exhaust gas discharged from the main engine 12 and the auxiliary engines 14 mounted to the ship 1. In certain embodiments, the steel plate structure 6 has an inner width (length in a direction orthogonal to the longitudinal direction) ranging from approximately 3 m to 8 m. The longitudinal length of the steel plate structure 6 is relatively unrestricted and may be set to range, for example, from 5 m to 20 m.

[0100] FIG. 3 is a perspective view illustrating the ship desulfurization device according to one embodiment of the present invention. FIG. 4 is a perspective view illustrating the ship desulfurization device according to one embodiment of the present invention as viewed from an angle different from the angle in FIG. 3.

As illustrated in FIG. 3 and FIG. 4, the ship desulfurization device 20 according to one embodiment of the present invention includes an absorber 30 including an absorber body unit 32, and an exhaust gas introducing device 40 for guiding exhaust gas discharged from the main engine 12 and the auxiliary engines 14 to the absorber body unit 32.

[0101] FIG. 5 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention. As illustrated in FIG. 5, the absorber 30 includes the absorber body unit 32, an exhaust gas introducing unit 34, and an exhaust gas discharge unit 36. The absorber body unit 32 defines an interior space 31 internally having a longitudinal direction. Furthermore, an exhaust gas inlet 33 in communication with the interior space 31 (lower-side interior space 31b) is formed on an end portion 39a of the absorber body unit 32 with respect to the longitudinal direction. The exhaust gas introduced into the interior space 31 through the exhaust gas inlet 33 flows through the lower-side interior space 31b from the end portion 39a toward the other end portion 39b and then upward through the interior space 31.

[0102] In the illustrated embodiment, in the interior space 31, a packed layer 35 separating the lower-side interior space 31b from an upper-side interior space 31c is formed at a position above the lower-side interior space 31b. The packed layer 35 includes, for example, a large number of regular packing materials stacked in layers. Furthermore, a spraying device 38 for spraying a cleaning liquid (for example, seawater or clear water) into the interior space 31 is positioned above the packed layer 35. The cleaning liquid is sprayed over exhaust gas passing through the packed layer 35 to bring the exhaust gas and the cleaning liquid into gas-liquid contact with each other, removing sulfurs contained in exhaust gas.

[0103] Furthermore, in the interior space 31, a mist eliminator 37 separating the upper-

side interior space 31c from an outlet-side interior space 31d is arranged at a position above the upper-side interior space 31c. The mist eliminator 37 is configured to eliminate moisture from exhaust gas passing through the mist eliminator 37. The exhaust gas having passed through the mist eliminator 37 is discharged from the exhaust gas discharge unit 36 connected to an uppermost portion of the absorber body unit 32, to the outside of the ship 1 via the outlet-side interior space 31d.

[0104] Furthermore, the absorber body unit 32 is provided with a storage space 31a in which the sprayed cleaning liquid sprayed over exhaust gas guided to the interior space 31 is stored. In the illustrated embodiment, the storage space 31a is formed below the lower-side interior space 31b and also below a lower surface of exhaust gas inlet 33.

[0105] Furthermore, as illustrated in FIG. 3 and FIG. 4, the ship desulfurization device 20 further includes a seawater feeding device 50 for feeding seawater to the above-described spraying device 38. The seawater feeding device 50 includes drainage dilution pumps 52a, seawater feeding pumps 54a, a drainage pipe 56, a seawater feeding pipe 58, and a seawater discharge pipe 59. Seawater introduced into the ship body 2 by the seawater feeding pump 54a is fed to the spraying device 38 via the seawater feeding pipe 58. Furthermore, scrubber drainage discharged from the absorber 30 is diluted by the drainage dilution pump 52a and drained to the outside of the ship 1 via the drainage pipe 56. In the illustrated embodiment, each of the plurality of drainage dilution pumps 52a is connected to a common No.1 sea chest 52. Similarly, each of the plurality of seawater feeding pumps 54a is connected to a common No. 2 sea chest 54.

[0106] As described above, the interior space 31 of the absorber body unit 32 is formed to have a planar shape having a longitudinal direction along an introducing direction of exhaust gas. The planar shape of the interior space 31 of the absorber body unit 32 will be described in detail based on FIGs. 6A to 6C. In FIGs. 6A to 6C, reference character L refers to the length of the interior space 31 (length in the longitudinal direction), and reference character W refers to the width of the interior space 31 (length in the direction orthogonal to the longitudinal direction). Furthermore, reference character D is an equivalent diameter of a

circular cross section having a cross-sectional area that is as large as a cross-sectional area for the length L and the width W of a rectangular cross section.

In the example described in the embodiment illustrated in FIGs. 6A to 6C, the interior space 31 of the absorber body unit 32 is planarly shaped like a rectangle defined by a pair of longitudinal wall surfaces extending parallel to each other and a pair of lateral wall surfaces extending parallel to each other. However, the planar shape of the interior space 31 is not limited to the rectangle, and the interior space 31 may also be shaped like a rectangle, an ellipse, an oval, or the like having a longitudinal direction so long as the planar shape allows advantageous effects of the present invention to be produced.

[0107] FIGs. 6A to 6C is a diagram showing a result of a study on the planar shape of the interior space of the absorber body unit in a ship desulfurization device according to an embodiment of the present invention. In the tables shown in FIGs. 6A to 6C, each planar shape is evaluated according to two items: “arrangement performance” refers to how easily the absorber 30 can be arranged in the ship 1 in terms of layout, and “desulfurization performance” refers to how uniform the exhaust gas flows through the interior space 31 in the absorber 30.

[0108] The “arrangement performance” was evaluated on the basis of the following evaluation criteria, in four stages of A, B, C, and D, which represent the arrangement performance in the descending order. This evaluation is based on the idea that, when the absorber 30 is to be placed in an area having an elongated shape such as the inside of the steel plate structure 6, the smaller maximum width W in the lateral direction relative to the equivalent diameter D, the higher the arrangement performance.

(Evaluation Criteria)

A: $(W/D)<0.50$

B: $0.50\leq(W/D)<0.75$

C: $0.75\leq (W/D)<0.90$

D: $0.90\leq (W/D)$

[0109] FIG. 9 is a graph showing a relationship between a desulfurization performance parameter and the shape (aspect ratio L/W) of the interior space of the absorber in a ship desulfurization device according to an embodiment of the present invention. The data is expressed in double logarithm in order to make its change stand out. FIG. 10 is a diagram showing a result of a study on the relationship between a desulfurization performance parameter and the shape (aspect ratio) of the interior space of the absorber body unit in a ship desulfurization device according to an embodiment of the present invention. FIG. 11 is a planar view for describing the arrangement condition of a spray nozzle in the interior space of the absorber body unit.

The relationship between the desulfurization performance and the shape of the interior space 31 of the absorber body unit 32 was studied by using the desulfurization performance parameter defined below.

Desulfurization performance parameter = perimeter ratio α × interference nozzle number ratio β

α: inverse ratio of perimeter to the standard condition (L/W=1)

=perimeter under standard condition / perimeter under aspect ratio to be studied

β: ratio of the number of interference nozzles to the standard condition

=the number of interference nozzles under the aspect ratio to be studied / the number of interference nozzles under standard condition

[0110] The perimeter is the outer perimeter length in a horizontal cross section of the absorber body unit 32. If the cleaning liquid adheres to the wall surface, it generates loss that does not contribute to desulfurization. Thus, when the cross section is the same, a longer perimeter is an obstructive factor that deteriorates the desulfurization performance. Since the perimeter is an obstructive factor, the perimeter ratio α is defined by an inverse ratio to the standard condition (L/W=1).

[0111] An interference nozzle refers to a spraying nozzle which is surrounded by other spraying nozzles on four sides. That is, as shown in FIG. 11, in a case where a plurality of rows of spraying nozzles 71 are disposed along the longitudinal direction and the width

direction in the interior space 31 of the absorber body unit 32, such that a plurality of spraying nozzles 71 are arranged in a grid pattern as a whole, the spraying nozzles 71b disposed inside the range 71A excluding the spraying nozzles 71a disposed on the outermost side are the above described interference nozzles.

If the cross-sectional area is the same and the number of interference nozzles increases, injected desulfurization liquid interferes (overlaps) in a larger area between adjacent spraying nozzles, and thus a larger number of interference nozzles is a promotional factor that improves the desulfurization performance. Since the number of interference nozzles is a promotional factor, the interference nozzle number ratio β is defined by the ratio to the standard condition (L/W=1). Further, the nozzle number was calculated assuming that the nozzles are arranged in a grid pattern using a predetermined nozzle pitch (in the present embodiment, 0.5m), and a decimal was rounded to an integer.

[0112] As shown in FIG. 9, under the condition that the cross-sectional area is the same, as the aspect ratio L/W becomes greater than one, the perimeter increases, and the number of interference nozzles decreases. Thus, the desulfurization performance parameter decreases. From FIG. 9, the desulfurization performance parameter is substantially constant when L/W is 2.0 or below, decreases in the range from 2.0 to 6.0, and decreases considerably when L/W is 6.0 or higher. Thus, it was determined that there are two inflection points at L/W 2.0 and 6.0.

[0113] The “desulfurization performance” was evaluated on the basis of the following evaluation criteria, in four stages of A, B, C, and D, which represents the desulfurization performance in the descending order. This is based on the idea that, the more uniform the exhaust gas flows through the absorber 30, the higher the desulfurization performance. Further, the uniformity of the exhaust gas flow inside the absorber 30 was evaluated from the above study results on the basis of the following study conditions. As shown in FIG. 9, when the aspect ratio is two or lower, it is possible to maintain the desulfurization performance parameter at a substantially constant high level, and it is possible to maintain the uniformity of the exhaust gas flow in the absorber 30 in a preferable state. Further, when the aspect ratio is greater than two and not greater than three, the desulfurization performance

gradually decreases with an increase in the aspect ratio, but the desulfurization performance parameter can be maintained at a high level. Further, also when the aspect ratio is greater than three and not greater than six, the desulfurization performance gradually decreases with an increase in the aspect ratio, but still the desulfurization performance parameter can be maintained at a relatively high level. On the other hand, as shown in FIG. 9, when the aspect ratio exceeds six, the desulfurization parameter decreases rapidly, and the uniformity of the exhaust gas in the absorber 30 can be considered to get out of the allowable range for exerting the required desulfurization performance. Accordingly, the aspect ratio was set to have an upper limit of six.

(Evaluation Criteria)

A: W: L= 1: over 1.1 and 1:2.0 or under 2.0

B: W: L= 1: over 2.0 and 1:3.0 or under 3.0

C: W: L= 1: over 3.0 and 1:6.0 or under 6.0

D: W: L= 1: over 6. 0

(Study condition)

Inlet gas flow velocity = 2 to 20m/s

Absorber interior flow velocity = 1 to 5 m/s

Spray amount = 30 to 200$m^3/m^2 \cdot h$

[0114] Further, on the basis of the evaluation results on the two items of “arrangement performance” and “desulfurization performance”, “comprehensive evaluation” was performed. The “comprehensive evaluation” was evaluated on the basis of the following evaluation criteria, in three stages of “Excellent”, “Good”, and “Passable”, in the descending order of the comprehensive evaluation.

Excellent: at least one A, with no C or D

Good: two Bs

Pass: at least one C, with no D

Fail: one or more D

[0115] As shown in FIGs. 6A to 6C, the planar shape of the interior space 31 where W: L is 1: over 1.5 and 1:2.0 or under 2.0 (between 1:1.5 and 1.2.0, excluding 1:1.5) was evaluated as “excellent” in the comprehensive evaluation. While “arrangement performance” and “desulfurization performance” have a trade-off relationship, by setting W: L in the above range, it is possible to provide a ship desulfurization device 20 with a good balance, which excels in both of the arrangement performance and the desulfurization performance.

[0116] Next, the planar shape of the interior space 31 where W: L is 1: over 2.0 and 1:3.0 or under 3.0 (between 1:2.0 and 1:3.0, excluding 1:2.0) was evaluated as “good” in the comprehensive evaluation. Next, the planar shape of the interior space 31 where W: L is 1: over 3.0 and 1:6.0 or under 6.0 (between 1:3.0 and 1.6.0, excluding 1:3.0) was evaluated as “passable” in the comprehensive evaluation.

Further, the planar shape of the interior space 31 where W: L is 1:1.1 or under 1.1 was evaluated as “fail”, for the “arrangement performance” is low, although the “desulfurization performance” is high. Furthermore, as described above, the planar shape of the interior space 31 where W: L is 1: over 6.0 was evaluated as “fail”, for the uniformity of the exhaust gas flow in the absorber 30 cannot be ensured, and the “desulfurization performance” is low.

[0117] The above-described ship desulfurization device 20 according to one embodiment of the present invention includes the absorber 30 including the absorber body unit 32 defining the interior space 31 and having the exhaust gas inlet 33 formed on the end portion 39a with respect to the longitudinal direction in communication with the interior space 31 (lower-side interior space 31b). In other words, the interior space 31 of the absorber body unit 32 is configured to have a longitudinal direction along an exhaust gas introducing direction. Thus, compared to conventional round (circular) absorbers, the absorber according to the embodiment is less likely to form a dead space, and is thus easily arranged in the ship 1. The absorber 30, having a planar shape with a longitudinal direction along the exhaust gas introducing direction, allows provision of a ship desulfurization device 20 that is easily arranged in the ship 1 such as an ultra large container ship described above. Furthermore, compared to a case where the interior space of the absorber body unit has a longitudinal

direction along the direction orthogonal to the exhaust gas introducing direction, the embodiment can reduce the risk that exhaust gas is discharged to the outside of the absorber without being desulfurized.

[0118] Furthermore, according to the above-described ship desulfurization device 20 according to one embodiment of the present invention, the ratio (W: L) of the maximum width W to the maximum length L of the interior space 31 is within a range of 1: over 1.1 and 1: 6.0 or under 6.0. The upper limit for the ratio (W: L) of the maximum width W to the maximum length L of the interior space 31 is thus set to 1 : 6.0, allowing the non-uniformity of exhaust gas flow in the absorber 30 to be limited to within a practical allowable range examined by the present inventors.

[0119] In certain embodiments, as illustrated in FIGs. 6A to 6C described above, the ratio (W: L) of the maximum width W to the maximum length L of the interior space 31 of the ship desulfurization device 20 is within the range of 1: over 1.5 and 1: 2.0 or under 2.0.

According to the embodiments, a well-balanced ship desulfurization device 20 can be provided that is particularly excellent in arrangement easiness and desulfurization performance.

[0120] In certain embodiments, as illustrated in FIG. 1 to FIG. 4 and the like described above, the absorber 30 is mounted to the ship 1 such that the longitudinal direction of the interior space 31 of the absorber body unit 32 extends along the width direction of the ship 1.

According to the embodiments, the absorber 30 having a longitudinal direction along the exhaust gas introducing direction allows provision of a ship desulfurization device 20 that is easily arranged in the ship 1 such as an ultra large container ship described above.

[0121] Furthermore, according to the embodiments, the absorber body unit 32 may be configured to have a longitudinal direction along the width direction of the ship 1. Thus, compared to absorbers having a longitudinal direction along the bow-stern direction of the ship 1, the absorber 30 is capable of reducing bending stress acting on the absorber during rolling of the ship 1 and is thus highly resistant to rolling.

[0122] In certain embodiments, as illustrated in FIG. 1 to FIG. 4 and the like described

above, the ship 1 includes the steel plate structure 6 for emitting exhaust gas discharged from the exhaust gas generation device (main engine 12, auxiliary engines 14), the steel plate structure 6 being formed like a long tube having a longitudinal direction along the width direction of the ship 1. The absorber 30 is arranged inside the steel plate structure 6.

[0123] In the illustrated embodiments, the steel plate structure 6 is planarly shaped like a rectangle. Furthermore, in certain embodiments, the steel plate structure 6 may be planarly shaped like a rectangle, an ellipse, an oval, or the like having a longitudinal direction.

[0124] According to the embodiments, the absorber 30 is arranged inside the steel plate structure 6 shaped like a long tube and having a longitudinal direction along the width direction of the ship 1, allowing minimization of adverse effects on a layout planning of other facilities and the like mounted to the ship 1. This facilitates retrofitting to the existing ship 1. Furthermore, compared to a case where the absorber 30 is arranged inside the ship 1, for example, inside the engine room 10, the arrangement of the absorber 30 inside the steel plate structure 6 is also excellent in installation workability and maintainability.

[0125] In certain embodiments, as illustrated in FIG. 3 and FIG. 4, a waste heat recovery device 60 is arranged inside the steel plate structure 6 to recover thermal energy from exhaust gas discharged from the exhaust gas generation device (main engine 12). The absorber 30 is arranged side by side with the waste heat recovery device 60 along the width direction of the ship 1.

[0126] In the illustrated embodiments, the waste heat recovery device 60 is an exhaust gas economizer using thermal energy collected from the exhaust gas to generate vapor. The waste heat recovery device 60 includes an exhaust gas inlet pipe 45 connected to a lower portion of waste heat recovery device 60 and through which exhaust gas discharged from the main engine 12 flows and an exhaust gas discharge pipe 43 connected to an upper portion of waste heat recovery device 60. An exhaust gas introducing pipe 42 described below branches off from the exhaust gas discharge pipe 43 to introduce the exhaust gas into the absorber 30. The exhaust gas inlet pipe 45, the exhaust gas discharge pipe 43, and the exhaust gas introducing pipe 42 constitutes a part of exhaust gas introducing device 40 for

guiding, to the absorber body unit 32, exhaust gas discharged from the main engine 12 and the auxiliary engines 14.

[0127] Furthermore, in the illustrated embodiments, the waste heat recovery device 60 is configured to have a longitudinal direction along the width direction of the ship 1, similarly to the absorber body unit 32. Additionally, the interior space is horizontally cross-sectionally shaped like a rectangle.

[0128] According to the embodiment, the absorber 30 and the waste heat recovery device 60 are arranged side by side inside the steel plate structure 6 along the width direction of the ship 1. Thus, compared to a case where the waste heat recovery device 60 and the absorber 30 are arranged away from each other, the exhaust gas introducing device 40 may be simply configured. Moreover, the waste heat recovery device 60 is shaped like a rectangle having a longitudinal direction along the width direction of the ship 1. When the absorber 30 and the waste heat recovery device 60 are arranged inside the steel plate structure 6 having a longitudinal direction along the width direction of the ship 1, formation of a dead space is less likely to occur, allowing the absorber 30 and the waste heat recovery device 60 to be efficiently arranged.

[0129] In certain embodiments, as illustrated in FIG. 3 to FIG. 5 described above, the absorber 30 has one end 34a connected to the exhaust gas inlet 33 of the absorber body unit 32 and further includes the exhaust gas introducing unit 34 extending upward from the one end 34a toward the other end 34b.

[0130] In the illustrated embodiments, the exhaust gas introducing unit 34 has a rectangular cross section, and the exhaust gas inlet 33 of exhaust gas introducing unit 34 is also shaped like a rectangle. The exhaust gas introducing unit 34 has an oblique portion 34A extending obliquely upward from the exhaust gas inlet 33 of the absorber body unit 32 and a vertical portion 34B extending upward from an end of the oblique portion 34A along a vertical direction. The exhaust gas introducing pipe 42 described below is connected to an end of the vertical portion 34B (the other end 34b of exhaust gas introducing unit 34).

[0131] According to the embodiment, an exhaust gas introducing line (exhaust gas

introducing pipe 42) is connected to the other end 34b of exhaust gas introducing unit 34 to allow the exhaust gas to be introduced into the absorber 30 arranged in a small and narrow space inside the steel plate structure 6.

[0132] In certain embodiments, as illustrated in FIG. 3 to FIG. 5 described above, the above-described exhaust gas introducing device 40 includes the exhaust gas introducing pipe 42 extending from the waste heat recovery device 60 side toward the other end 34b of exhaust gas introducing unit 34 along the width direction of the ship 1, and auxiliary-engine exhaust gas introducing pipes 44a to 44d connected to the exhaust gas introducing pipe 42 to guide exhaust gas discharged from the auxiliary engines 14 to the absorber body unit 32 via the exhaust gas introducing pipe 42.

[0133] In the illustrated embodiments, the one end side of exhaust gas introducing pipe 42 is connected to the above-described exhaust gas discharge pipe 43, and the other end side is connected to the other end 34b side of exhaust gas introducing unit 34. The exhaust gas introducing pipe 42 extends inside the steel plate structure 6 along a horizontal direction.

[0134] In the illustrated embodiments, on a downstream side of exhaust gas discharge pipe 43, an exhaust gas outlet pipe 46 extending upward inside the steel plate structure 6 and the exhaust gas introducing pipe 42 are connected via an exhaust gas damper 47. For example, when the exhaust gas generation device, including the main engine 12 and the auxiliary engines 14, is stopped, the exhaust gas damper 47 opens a channel leading from the exhaust gas discharge pipe 43 to the exhaust gas outlet pipe 46, while closing a channel leading from the exhaust gas discharge pipe 43 to the exhaust gas introducing pipe 42. Furthermore, for example, the exhaust gas generation device, including the main engine 12 and the auxiliary engines 14, is operated, the exhaust gas damper 47 opens the channel leading from the exhaust gas discharge pipe 43 to the exhaust gas introducing pipe 42, while closing the channel leading from the exhaust gas discharge pipe 43 to the exhaust gas outlet pipe 46.

[0135] Furthermore, in the illustrated embodiments, the exhaust gas introducing pipe 42 connected to the plurality of auxiliary-engine exhaust gas introducing pipes 44a to 44d,

through which exhaust gas discharged from the auxiliary engines 14 flows. Additionally, a plurality of auxiliary-engine exhaust gas discharge pipes 48a to 48d are respectively connected to the plurality of auxiliary-engine exhaust gas introducing pipes 44a to 44d via an auxiliary-engine exhaust gas damper not illustrated in the drawings. For example, when the auxiliary engines 14 are stopped, the exhaust gas damper not illustrated in the drawings opens channels leading from the plurality of auxiliary-engine exhaust gas introducing pipes 44a to 44d to the respective auxiliary-engine exhaust gas discharge pipe 48a to 48d, while closing a channel leading from channels leading from the plurality of auxiliary-engine exhaust gas introducing pipes 44a to 44d to the exhaust gas introducing pipe 42. Furthermore, for example, when the auxiliary engines 14 are operated, the exhaust gas damper not illustrated in the drawings opens the channels leading from the plurality of auxiliary-engine exhaust gas introducing pipes 44a to 44d to the exhaust gas introducing pipe 42, while closing the channels leading from the plurality of auxiliary-engine exhaust gas introducing pipes 44a to 44d to the respective auxiliary-engine exhaust gas discharge pipe 48a to 48d.

[0136] According to the embodiment, exhaust gas discharged from the main engine 12 and the auxiliary engines 14 can be guided to the absorber 30 arranged in the small and narrow space inside the steel plate structure 6.

[0137] In certain embodiments, as illustrated in FIG. 11, the absorber body unit 32 includes a pair of longitudinal wall surfaces 32a, 32b extending parallel to each other along the longitudinal direction of the interior space 31 and a pair of lateral wall surfaces 32c, 32d extending parallel to each other along the lateral direction of the interior space 31.

[0138] According to the embodiments, the interior space 31 of the absorber body unit 32 is planarly shaped like a rectangle defined by the pair of longitudinal wall surfaces 32a, 32b and the pair of lateral wall surfaces 32c, 32d. In this case, the rectangular shape according to the present embodiment includes a rectangle with rounded corners and a haunched rectangle. The absorber body unit 32 having such a rectangular interior space 31 is less likely to form a dead space when arranged in the ship, and is thus efficiently arranged in the ship.

[0139] FIGs. 7A and 7B are diagrams illustrating a transverse member provided in a

storage space of the absorber in the ship desulfurization device according to one embodiment of the present invention.

In certain embodiments, as illustrated in FIG. 5 described above, a storage space 31a is formed in the absorber body unit 32 to store the sprayed cleaning liquid sprayed over exhaust gas guided to the interior space 31. As illustrated in FIGs. 7A and 7B, the absorber body unit 32 has a transverse member 70 to which the pair of longitudinal wall surfaces 32a, 32b (see FIG. 11) is connected and which transverses the storage space 31a along the lateral direction of the interior space 31.

[0140] According to the embodiments, if rolling of the ship 1 or the like causes sloshing in which a surface of the cleaning liquid stored in the storage space 31a significantly swells, the transverse member 70 allows the swinging of the fluid surface to be suppressed. Furthermore, provision of the transverse member 70 to which the pair of longitudinal wall surfaces 32a, 32b is connected enables an increase in the strength of the absorber body unit 32 having the rectangular interior space 31.

[0141] In certain embodiments, as illustrated in FIG. 7A, the transverse member 70 is a transverse beam member 70A having an elongate shape.

In the illustrated embodiments, the transverse beam member 70A includes a plurality of (three) stages each formed of H-section steel having an H-shaped cross section, the stages being arranged at an approximately central position of the interior space 31 in the longitudinal direction and at intervals in an up-down direction. Furthermore, in certain embodiments, the transverse beam member 70A may be a beam member having one of an I-shaped cross section, an L-shaped cross section, a T-shaped cross section, and a tubular cross section.

[0142] According to the embodiments, the transverse beam member 70A having an elongate shape allows exertion of a suppression effect against the above-described sloshing and a reinforcement effect for the absorber body unit 32. Furthermore, the embodiments are particularly excellent in the reinforcement effect for the absorber body unit 32.

[0143] In certain embodiments, as illustrated in FIG. 7B, the transverse member 70 is a sheeting member 70B having a flat plate shape.

In the illustrated embodiments, the sheeting member 70B is a nonporous plate with no holes formed in a plate surface thereof and is installed at an approximately central position of the interior space 31 in the longitudinal direction. The sheeting member 70B may be a porous plate with a plurality of pores formed in the plate surface thereof.

[0144] According to the embodiments, the sheeting member 70B having a flat plate shape allows exertion of the suppression effect against the above-described sloshing and the reinforcement effect for the absorber body unit 32. Furthermore, the embodiments are particularly excellent in the suppression effect against the sloshing.

[0145] Furthermore, although not illustrated in the drawings, the transverse member 70 may include both the transverse beam member 70A and the sheeting member 70B.

[0146] In certain embodiments, as illustrated in FIG. 5 described above, the ship desulfurization device 20 further includes a spraying device 38 (38A) for spraying the cleaning liquid over exhaust gas guided to the interior space 31 of the absorber body unit 32. The spraying device 38A has a longitudinal spray pipe 38a1 extending through the interior space 31 of the absorber body unit 32 parallel to each longitudinal wall surface of the pair of longitudinal wall surfaces 32a, 32b (see FIG. 11) and a plurality of spray nozzles 38a2 provided in the longitudinal spray pipe 38a1.

[0147] In certain embodiments, one longitudinal spray pipe 38a1 may be provided at an approximately central position of the interior space 31 in the lateral direction. Furthermore, in certain embodiments, a plurality of longitudinal spray pipes 38a1 may be provided at regular intervals in the lateral direction of the interior space 31.

[0148] According to the embodiments, a distance from each of the plurality of spray nozzles 38a2 provided in the same longitudinal spray pipe 38a1 to the longitudinal wall surfaces 32a, 32b may be made constant. This enables the cleaning liquid to be uniformly sprayed in the interior space 31, thus allowing suppression of the adverse effect of defects in which the cleaning liquid is non-uniformly sprayed as a result of shaking (rolling, pitching, yawing, or the like) of the ship 1.

[0149] FIG. 8 is a schematic diagram illustrating the absorber of the ship desulfurization

device according to one embodiment of the present invention. The absorber 30 illustrated in FIG. 8 is different from the above-described absorber 30 illustrated in FIG. 5, only in the configuration of the spraying device 38. The same components are therefore denoted by the same reference numerals, and will not be described below.

[0150] In certain embodiments, as illustrated in FIG. 8, the ship desulfurization device 20 further includes a spraying device 38 (38B) for spraying the cleaning liquid over exhaust gas guided to the interior space 31 of the absorber body unit 32. The spraying device 38B has a plurality of lateral spray pipes 38b1 extending through the interior space 31 of the absorber body unit 32 parallel to each lateral wall surface of the pair of lateral wall surfaces 32c, 32d (see FIG. 11) and at least one spray nozzle 38b2 provided on each of the plurality of lateral spray pipes 38b1.

[0151] In certain embodiments, the plurality of spray nozzles 38b2 may be arranged on each of the plurality of lateral spray pipes 38b1 at regular intervals. Furthermore, in certain embodiments, installation positions of the spray nozzles 38b2 arranged on each of the adjacent lateral spray pipes 38b1 may be displaced in the lateral direction such that the installation positions do not overlap one another in the lateral direction. In certain embodiments, the plurality of spray nozzles 38b2 arranged on the plurality of lateral spray pipes 38b1 may be staggered in a plan view.

[0152] According to the embodiments, an equal spraying area may be set for the spray nozzles 38b2 provided in each of the plurality of lateral spray pipes 38b1. This enables the cleaning liquid to be uniformly sprayed in the interior space 31, thus allowing suppression of the adverse effect of defects in which the cleaning liquid is non-uniformly sprayed as a result of shaking (rolling, pitching, yawing, or the like) of the ship 1.

[0153] (Aspect Ratio)

As described above, the planar shape of the interior space 31 is not limited to the rectangle. The interior space 31 may be shaped like a rectangle, an ellipse, an oval, or the like having a longitudinal direction so long as the planar shape allows the advantageous effects of the present invention to be produced.

FIG. 12 is a diagram illustrating a relationship between the planar shape and shape (aspect ratio L/W) of the interior space of the absorber body unit in the ship desulfurization device according to one embodiment of the absorber body unit. As illustrated in FIG. 12A to FIG. 12C, in certain embodiments, the interior space 31 of the absorber body unit 32 includes a circular arc shape at least in a part of the planar shape. More specifically, in certain embodiments, as illustrated in FIG. 12A, the interior space 31 is shaped like an ellipse defined by a pair of lateral wall surfaces extending parallel to each other and a pair of circular-arc wall surfaces connecting ends of the pair of lateral wall surfaces together. In other certain embodiments, as illustrated in FIG. 12B, the interior space 31 of the absorber body unit 32 is shaped like an ellipse. In other certain embodiments, as illustrated in FIG. 12C, the interior space 31 is shaped like an oval defined by a pair of longitudinal wall surfaces extending parallel to each other and a pair of circular-arc wall surfaces connecting ends of the pair of longitudinal wall surfaces together.

[0154] According to this configuration, configurations in the above-described certain embodiments are provided to exert the above-described advantageous effects of the present invention. For example, the interior space of the absorber body unit is configured to have a longitudinal direction along the exhaust gas introducing direction, and thus, compared to a conventional round (circular) absorber, the absorber according to the configuration is less likely to form a dead space and is easily arranged in the ship. Furthermore, a ship desulfurization device can be provided that is easily arranged in certain types of ultra large ships (in which an absorber with a planar shape having a longitudinal direction along the exhaust gas introducing direction is more easily arranged), for example, ULCSs. Additionally, compared to a case where the interior space of the absorber body unit has a longitudinal direction along the direction orthogonal to the exhaust gas introducing direction, the embodiment enables a reduction in the risk that exhaust gas is discharged to the outside of the absorber without being desulfurized.

[0155] The upper limit for the ratio (W: L) of the maximum width W to the maximum length L of the interior space is set to 1 : 6.0, allowing the non-uniformity of exhaust gas flow

in the absorber to be limited to within the practical allowable range examined by the present inventors.

[0156] Moreover, according to the above-described configuration, the interior space 31 of the absorber body unit 32 includes a circular arc shape in at least a part of the planar shape. The absorber body unit 32 may therefore be provided with a space which is located in a part of the interior space 31 corresponding to an outer side of the part including the circular art and which may be utilized, for example, as a space through which piping is passed.

[0157] (Material)

The ship desulfurization device 20 is exposed outdoors, and an outer wall surface thereof may be rusted or corroded by sea breeze, rain water, and the like. Furthermore, if seawater is used as the cleaning liquid as described above, an inner wall surface defining the interior space 31 of the absorber 30 or the spraying device 38 may be rusted or corroded. Furthermore, since the ship desulfurization device 20 is installed to the ship 1, the weight, machinability, durability, and maintainability of the ship desulfurization device 20 need to be taken into account.

[0158] In certain embodiments, carbon steel (common steel), for example, SS400, is a material for the wall surface (including the longitudinal wall surfaces 32a, 32b and the lateral wall surfaces 32c, 32d) of the absorber 30 (including the absorber body unit 32, the exhaust gas introducing unit 34, and the exhaust gas discharge unit 36), and spray pipes 38c1 (including the longitudinal spray pipes 38a1 and the lateral spray pipes 38b1) and spray nozzles 38c2 (including the spray nozzles 38a2, 38b2) of the spraying device 38. The wall surface of the absorber 30 and inner and outer surfaces of the spray pipes and nozzles of the spraying device 38 are covered with anticorrosive coating. In this case, the absorber 30 and the spraying device 38 are easily machined due to the use of carbon steel, and are excellent in anticorrosion property due to the anticorrosion film with the anticorrosive coating.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0159] In other certain embodiments, anticorrosion lining such as resin lining or flake glass lining is applied to the wall surface of the absorber 30 and to the spray pipes and nozzles of the spraying device 38. Here, a resin used for the resin lining is, for example, FRP. In this case, the absorber 30 and the spraying device 38 are excellent in anticorrosive property due to the anticorrosion lining.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0160] In other certain embodiments, is high-corrosion-resistance stainless steel (stainless steel), for example, SUS316L, is the material for the wall surfaces of the absorber 30 and the spray pipes and nozzles of the spraying device 38. In this case, the absorber 30 and the spraying device 38 are excellent in machinability and anticorrosive property due to the use of the high-corrosion-resistance stainless steel. Furthermore, compared to the use of the anticorrosion film with the anticorrosive coating or the anticorrosion lining, the use of the high-corrosion-resistance stainless steel enables a reduction in manufacturing time and is excellent in durability and maintainability.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0161] In other certain embodiments, FRP (fiber reinforced plastics) are a material for at least a part of the absorber body unit 32 and the exhaust gas discharge unit 36, which are positioned in an upper portion of the absorber 30. In this case, at least a part of the absorber body unit 32 and the exhaust gas discharge unit 36, which are positioned in an upper portion of the absorber 30, are excellent in machinability and anticorrosive property due to the use of the FRP. Furthermore, compared to the use of the anticorrosion film with the anticorrosive coating or the anticorrosive lining, the use of the FRP enables a reduction in manufacturing time and is excellent in durability and maintainability. Compared to the use of the carbon steel or stainless steel, the use of the FRP enables a reduction in weight. Furthermore, since

the upper portion of the absorber 30, on which only a light load is imposed, has a small weight, the center of gravity of the absorber 30 may be set to a low position, allowing the absorber 30 to be made highly resistant to rolling.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0162] (Absorber Upper Portion)

As described above, when the absorber is planarly shaped to have a longitudinal direction along the exhaust gas introducing direction, the gas flow rate may vary significantly between the first side (exhaust gas inlet side) and the second side (side opposite to the exhaust gas inlet side) in the longitudinal direction. This may hinder a uniform exhaust gas flow in the absorber, leading to a non-uniform flow of exhaust gas in the absorber.

[0163] FIG. 13 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention as viewed from an A direction illustrated in FIG. 5. As illustrated in FIG. 13, in certain embodiments, the absorber 30 includes an interior-space confirmation device 80 for checking the state of the spraying of the cleaning liquid by the above-described spraying device 38, the flow of exhaust gas inside the interior space 31, and the like.

[0164] The interior-space confirmation device 80 includes, as illustrated in FIG. 13, a light-transmissive visual confirmation window 80A that allows the inside of the interior space 31 to be viewed from the outside of the absorber 30 (absorber body unit 32). The visual confirmation window 80A has a light-transmissive member with light transmissivity, for example, a glass surface, and is provided at a height position where the upper end (top end) of the cleaning liquid sprayed by the spraying device 38 may be checked. More specifically, as illustrated in FIG. 13, the visual confirmation window 80A is provided on the other end portion 39b at a position below the mist eliminator 37 and above the spraying device 38. In certain embodiments, as illustrated in FIG. 13, one visual confirmation window 80A is provided on the other end portion 39b at an approximately central position in the width

direction. Furthermore, in certain embodiments, a plurality of visual confirmation windows 80A are provided on the other end portion 39b at regular intervals in the width direction.

[0165] In the absorber 30 including the above-described packed layer 35, the upper end (top end) of the cleaning liquid sprayed by the spraying device 38 is positioned approximately 1 m above the spray nozzles 38c2 (including spray nozzles 38a2, 38b2) of the spraying device 38. Furthermore, in an absorber 30 not including the packed layer 35 as illustrated in FIG. 15 as described below, the upper end is positioned up to approximately 10 m above the spray nozzles 38c2 of the spraying device 38. Furthermore, some absorbers not including the packed layer 35 include the spray nozzles 38c2 installed to face downward, perform spraying, or include a tray for gas-liquid dispersion. The invention according to the above-described certain embodiments and certain embodiments described below is also applicable to the absorbers not including the packed layer 35. In certain embodiments, the visual confirmation window 80A is arranged at substantially the same height position as that of the upper end (top end) of the cleaning liquid. Furthermore, in other certain embodiments, as illustrated in FIG. 15, the visual confirmation window 80A is provided at a position on the second side (side opposite to the exhaust gas inlet) of the end portion 39c in the lateral direction of the absorber body unit 32.

[0166] According to the above-described configuration, the absorber 30 includes the interior-space confirmation device 80 (visual confirmation window 80A) to allow the check of the state of spraying of the cleaning liquid by the spraying device 38, the flow of exhaust gas inside the interior space 31, and the like. If the state of spraying by the spraying device 38 is inappropriate, the state of spraying by the spraying device 38 may be improved by executing a process such as cleaning of the spray nozzles 38c2 of the spraying device 38. Furthermore, the interior-space confirmation device 80 (visual confirmation window 80A) is provided on the other end portion 39b in the longitudinal direction or at a position on the second side (opposite to the exhaust gas inlet) of the end portion 39c in the lateral direction, a flow of exhaust gas opposite to the exhaust gas inlet can be checked, which is difficult to check with the interior-space confirmation device 80 (visual confirmation window 80A)

provided on the exhaust gas inlet side.

[0167] Furthermore, the absorber 30 includes the interior-space confirmation device 80 (visual confirmation window 80A) to enable check of the angle of the cleaning liquid sprayed through the spray nozzles 38c2 of the spraying device 38, allowing the state of sloshing to be determined from the angle of the cleaning liquid. Furthermore, in other certain embodiments, a mark such as a straight line extending in the vertical direction or the horizontal direction may be provided on the light-transmissive member of the visual confirmation window 80A to allow the angle of the cleaning liquid to be easily checked. Furthermore, the mark may be formed of a metal line to reinforce the visual confirmation window 80A.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0168] In certain embodiments, the interior-space confirmation device 80 (visual confirmation window 80A) may be used for purposes other than the check of the state of spraying of the spraying device 38. For example, the visual confirmation window 80A may be provided on the exhaust gas inlet side to allow check of exhaust gas flow on the exhaust gas inlet side or at a height position near a liquid level in the storage space 31a in which the cleaning liquid is stored, to allow the storage space 31a to be checked.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0169] FIG. 14 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention and also illustrating an example of an absorber body with no packed layer (a liquid-jet column, a spray column, a tray absorber, and the like). In certain embodiments, as illustrated in FIG. 13 and FIG. 14, the above-described ship desulfurization device 20 includes the absorber 30 including the above-described absorber body unit 32 and the above-described visual confirmation window 80A. In this case, the absorber 30 includes the absorber body unit 32 configured such that exhaust

gas flows through the interior space 31 and the light-transmissive visual confirmation window 80A that allows the interior space 31 to be viewed from the outside of the absorber body unit 32. In the ship desulfurization device 20 including the absorber 30, the operator or the like can check, for example, the flow of exhaust gas flowing through the interior space 31, via the visual confirmation window 80A.

[0170] In certain embodiments, in the ship desulfurization device 20 including the absorber 30 including the above-described absorber body unit 32 and visual confirmation window 80A, the interior space 31 of the absorber body unit 32 has a longitudinal direction, as illustrated in FIG. 13 and FIG. 14. The absorber body unit 32 has the exhaust gas inlet 33 on the end portion of the interior space 31 with respect to the longitudinal direction in communication with the interior space 31. Moreover, the visual confirmation window 80A is provided on the other end portion of the interior space 31 with respect to the longitudinal direction. Here, the “other end portion” refers to a side away from one side with respect to the longitudinal direction of the interior space 31 beyond the center in the longitudinal direction.

In the embodiment illustrated in FIG. 13, one visual confirmation window 80A is provided on the other end portion 39b at an approximately central position in the width direction. In other certain embodiments, a plurality of visual confirmation windows 80A are provided on the other end portion 39b at regular intervals in the width direction.

In the embodiment illustrated in FIG. 14, the visual confirmation window 80A is provided at a position on the second side (opposite to the exhaust gas inlet) of the end portion 39c in the lateral direction of the absorber body unit 32.

[0171] When the interior space 31 has a longitudinal direction, the gas flow rate may vary significantly between the exhaust gas inlet 33 side and the side opposite to the exhaust gas inlet 33, leading to a non-uniform exhaust gas flow in the absorber 30. In the above-described configuration, the absorber body unit 32 has the exhaust gas inlet 33 on the end portion of the interior space 31 with respect to the longitudinal direction in communication with interior space 31. The visual confirmation window 80A is provided, for example, on

the other end portion 39b with respect to the longitudinal direction of the interior space 31 or at a position on the second side (opposite to the exhaust gas inlet) of the end portion 39c in the lateral direction. The operator or the like can check, via the visual confirmation window 80A, the flow of exhaust gas opposite to the exhaust gas inlet 33, which would be difficult to check through a visual confirmation window provided on the exhaust gas inlet 33.

[0172] In certain embodiments, the ship desulfurization device 20 including the absorber 30 including the above-described absorber body unit 32 and visual confirmation window 80A includes the above-described spraying device 38. The spraying device 38 has the above-described spray nozzles 38c2 (including the spray nozzles 38a2, 38b2) capable of injecting the cleaning liquid into the interior space 31. The visual confirmation window 80A is arranged at a position where the spray nozzles 38c2 are visible. In this case, since the visual confirmation window 80A is arranged at a position where the spray nozzles 38c2 are visible, the operator or the like check, via the visual confirmation window 80A, the state of spraying of the cleaning liquid by the spraying device 38, such as the state of injection of the cleaning liquid by the spray nozzles 38c2. If the state of spraying of the cleaning liquid by the spraying device 38 is inappropriate, the state of spraying of the cleaning liquid by the spraying device 38 may be improved by, for example, cleaning the spray nozzles 38c2.

[0173] In certain embodiments, the ship desulfurization device 20 including the absorber 30 including the absorber body unit 32 and the visual confirmation window 80A includes the spraying device 38. The spraying device 38 has the spray nozzles 38c2 (including the spray nozzles 38a2, 38b2) capable of injecting the cleaning liquid into the interior space 31. The spray nozzles 38c2 are configured to be capable of injecting the cleaning liquid upward. The cleaning liquid injected upward through the spray nozzles 38c2 rises to the upper end (top end) in the interior space 31 and then fall freely. The visual confirmation window 80A is provided at a height position where the upper end (top end) of the cleaning liquid sprayed by the spraying device 38 can be checked. More specifically, the visual confirmation window 80A is provided at substantially the same height position as the designed upper end (top end) of the cleaning liquid. In this case, the visual confirmation window 80A is arranged at the

position where the upper end of the cleaning liquid sprayed by the spraying device 38 can be checked, allowing the operator or the like to confirm, via the visual confirmation window 80A, that the state of spraying of the cleaning liquid by the spraying device 38 is appropriate.

[0174] In certain embodiments, in the absorber 30 including the packed layer 35 as illustrated in FIG. 13, the visual confirmation window 80A is provided at a height position not less than 0.5 m and not greater than 1.5 m, preferably not less than 0.7 m and not greater than 1.3 m, more preferably not less than 0.8 m and not greater than 1.2 m above the spray nozzles 38c2 of the spraying device 38. In this case, the operator can check, via the visual confirmation window 80A, the upper end (top end) of the cleaning liquid sprayed by the spraying device 38.

[0175] In certain embodiments, in the absorber 30 not including the packed layer 35 as illustrated in FIG. 14, the visual confirmation window 80A is provided at a height position not less than 5 m and not greater than 15 m, preferably not less than 7 m and not greater than 13 m, more preferably not less than 8 m and not greater than 12 m above the spray nozzles 38c2 of the spraying device 38. In this case, the operator can check, via the visual confirmation window 80A, the upper end (top end) of the cleaning liquid sprayed by the spraying device 38.

[0176] In certain embodiments, in the ship desulfurization device 20 including the absorber 30 including the above-described absorber body unit 32 and visual confirmation window 80A, and the spraying device 38 having the spray nozzles 38c2, the absorber body unit 32 is configured such that exhaust gas flows from the lower side toward the upper side in the vertical direction, and has the above-described mist eliminator 37 provided above the spray nozzles 38c2 in the interior space 31. As illustrated in FIG. 13 and FIG. 14, the visual confirmation window 80A is arranged above the spray nozzles 38c2 and below the mist eliminator 37. In this case, the absorber body unit 32 is configured such that exhaust gas flows from the lower side toward the upper side in the vertical direction. The visual confirmation window 80A is provided above the spray nozzles 38c2 and below the mist eliminator 37. Exhaust gas comes into gas-liquid contact with the cleaning liquid below the mist eliminator 37. Thus, even if the visual confirmation window 80A is provided above the

mist eliminator 37, the state of spraying of the cleaning liquid by the spraying device 38 fails to be checked. With the visual confirmation window 80A arranged as described above, the operator can check, via the visual confirmation window 80A, the state of spraying of the cleaning liquid by the spraying device 38. In particular, if the spray nozzles 38c2 are configured to be capable of injecting the cleaning liquid upward, the operator can confirm, via visual confirmation window 80A, that the state of spraying of the cleaning liquid is appropriate by checking the upper end of the cleaning liquid sprayed by the spraying device 38.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0177] (Packing Material)

As described above, the packed layer 35 includes, for example, a large number of regular packing materials stacked in layers. Here, the packing materials in the packed layer 35 are intended to increase the efficiency of gas-liquid contact between exhaust gas and the cleaning liquid inside the absorber 30. In the absorber 30, when the packing materials stacked in the packed layer 35 are moved and non-uniformly arranged by shaking (rolling, pitching, yawing, or the like) of the ship 1, exhaust gas may be discharged to the outside of the absorber without being desulfurized.

[0178] FIG. 15 is a perspective view (conceptual drawing) illustrating the packing materials according to one embodiment of the present invention. As illustrated in FIG. 15, in certain embodiments, a plurality of packing materials 35A in the packed layer 35 are arranged in a matrix. As illustrated in FIG. 15, each of the packing materials 35A is shaped generally like a rectangular parallelepiped. Each of the packing materials 35A has outer shape dimensions of 500 mm, 500 mm, and 100 mm. The plurality of packing materials 35A are arranged in a matrix at a position in the interior space 31 where the packed layer 35 is provided. In the packed layer 35, the plurality of packing materials 35A may be laterally arranged in one layer without being stacked.

[0179] According to the above-described configuration, the packing materials 35A in the packed layer 35 are arranged side by side at least in the lateral direction, limiting movement caused by shaking of the ship 1 to prevent non-uniform arrangement. This enables a reduction in the risk that exhaust gas is discharged to the outside of the absorber without being desulfurized.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0180] In certain embodiments, each of the packing materials 35A at least partly includes a regular packing material. In other certain embodiments, each of the packing materials 35A at least partly includes an irregular packing material. Here, the “regular packing material” represents a packing material suitable for regular stacking, and the “irregular packing material” represents a packing material irregularly stacked during packing. The irregular packing material has a larger needed pressure drop than the regular packing material but enables dispersibiliy of the cleaning liquid to be improved. Thus, for the packing materials 35A, whether the regular packing materials or the irregular packing materials are to be used or what ratio between the regular packing materials and the irregular packing materials is to be used are selectively determined based on the needed pressure drop and throughput of the cleaning liquid.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0181] In certain embodiments, the above-described ship desulfurization device 20 includes the absorber 30 including the above-described absorber body unit 32, the above-described spraying device 38, and the packing materials 35A packed in the packed layer 35 provided in the above-described interior space 31, the packing materials 35A being configured to bring the cleaning liquid into gas-liquid contact with exhaust gas passing through the packed layer 35. In this case, the ship desulfurization device 20 is capable of bringing the cleaning liquid into gas-liquid contact with exhaust gas; the cleaning liquid has an increased contact area with surfaces of the packing materials 35A packed in the packed layer 35 when

exhaust gas flows between the packing materials 35A (through the gap between the packing materials 35A), and the flow of exhaust gas is disturbed by the packing materials 35A. According to the ship desulfurization device 20, the packing materials 35A enable an increase in the efficiency of the gas-liquid contact between the cleaning liquid and exhaust gas. Thus, compared to a case where the packing materials 35A are not provided, the embodiments allow sulfurs contained in exhaust gas to be effectively removed.

[0182] FIG. 16 is a schematic diagram illustrating an anticorrosion layer according to one embodiment of the present invention and also illustrating the absorber of the ship desulfurization device. As illustrated in FIG. 16, in certain embodiments, an anticorrosion layer 84 is formed on at least a part of the wall surface (including the longitudinal wall surfaces 32a, 32b and the lateral wall surfaces 32c, 32d) defining the interior space 31 of the absorber body unit 32, the part being other than the wall surface partitioning the packed layer 35. The anticorrosion layer 84 is not formed on the wall surface partitioning the packed layer of the absorber body unit 32. The anticorrosion layer 84 includes the above-described anticorrosion film with the anticorrosive coating and the above-described anticorrosive lining.

[0183] The absorber 30 (absorber body unit 32) is assembled by a block construction method. That is, the absorber 30 (absorber body unit 32) is completed by manufacturing each of a number of layered portions of the absorber 30 like round slices and stacking and joining the layered portions together.

[0184] The absorber body unit 32 is completed by stacking and joining a first layered portion 32A, a second layered portion 32B, and a third layered portion 32C separated from one another by alternate long and two short dashes lines in FIG. 16; the first layered portion 32A has a wall surface defining the packed layer 35, the second layered portion 32B is a portion located below the first layered portion 32A in the absorber body unit 32 and having a wall surface defining the storage space 31a and the lower-side interior space 31b, and the third layered portion 32C is a portion located above the first layered portion 32A in the absorber body unit 32 and having a wall surface defining the upper-side interior space 31c.

[0185] Carbon steel (common steel), for example, SS400, is a material for the second

layered portion 32B, the third layered portion 32C, and the exhaust gas introducing unit 34. As illustrated in FIG. 16, the anticorrosion layer 84 is formed on wall surfaces (inner wall surfaces) of the second layered portion 32B, the third layered portion 32C, and the exhaust gas introducing unit 34. In contrast, a material for the first layered portion 32A is high-corrosion-resistance stainless steel (stainless steel), for example, SUS316L. As illustrated in FIG. 16, the anticorrosion layer 84 is not formed on a wall surface (inner wall surface) of the first layered portion 32A.

[0186] In the ship desulfurization device 20, hot exhaust gas flows inside the absorber body unit 32, and thus, for example, the wall surface (inner wall surface) defining the interior space 31 of the absorber body unit 32 may be corroded with, for example, sulfurs contained in exhaust gas. Furthermore, if seawater is used as the cleaning liquid, the seawater may corrode the above-described wall surface and the like. Typically, to protect the above-described wall surface, the anticorrosion layer 84 may be provided all over the above-described wall surface. However, shaking of the ship may move the packing materials 35A, which may collide against the anticorrosion layer 84 protecting the wall surface partitioning the packed layer 35 to peel off or damage the anticorrosion layer 84. Peel-off of the anticorrosion layer 84 or damage thereto may contribute to corrosion of the wall surface protected by the anticorrosion layer 84.

[0187] In the above-described configuration, the anticorrosion layer 84 is formed on a part of the wall surface (inner wall surface) defining the interior space 31 of the absorber body unit 32, the part being other than a part of the wall surface partitioning the packed layer 35. When the anticorrosion layer 84 is formed on the part of the wall surface partitioning the packed layer 35, shaking of the ship may move the packing materials 35A, which may collide against the anticorrosion layer 84 to peel off or damage the anticorrosion layer 84. The anticorrosion layer 84 is thus not formed on the part of the wall surface partitioning the packed layer 35, and instead, a layered portion (the above-described first layered portion 32A) of the absorber body unit 32 surrounding the packed layer 35 is formed of an anticorrosive material, for example, stainless steel to suppress corrosion of the wall surface. Such a ship

desulfurization device 20 is capable of suppressing corrosion of the wall surface defining the interior space 31 while preventing the packing materials 35A from damaging the anticorrosion layer 84.

[0188] In certain embodiments, in the ship desulfurization device 20 including the absorber 30 including the above-described absorber body unit 32, the above-described spraying device 38, and the above-described packing materials 35A, the packing materials 35A are regular packing materials. In this case, the packing materials 35A are the regular packing materials. Thus, compared to a case where the packing materials 35A are irregular packing materials, the ship desulfurization device 20 enables a reduction in pressure drop of exhaust gas and an increase in exhaust gas throughput. Compared to the ship desulfurization device 20 using the irregular packing materials as the packing materials 35A, the ship desulfurization device 20 using the regular packing materials as the packing materials 35A thus enables a reduction in the size of the absorber 30. Furthermore, compared to the irregular packing materials, the regular packing materials are less likely to be moved or non-uniformly arranged by shaking of the ship 1. Compared to the ship desulfurization device 20 using the irregular packing materials as the packing materials 35A, the ship desulfurization device 20 using the regular packing materials as the packing materials 35A is thus capable of reducing the risk that exhaust gas is discharged to the outside of the absorber 30 without being desulfurized.

[0189] In certain embodiments, in the ship desulfurization device 20 including the absorber 30 including the above-described absorber body unit 32, the above-described spraying device 38, and the above-described packing materials 35A, the absorber body unit 32 is configured such that exhaust gas flows from the lower side toward the upper side in the vertical direction. The spraying device 38 is configured to inject the cleaning liquid upward. In this case, the spraying device 38 is configured to inject the cleaning liquid upward. The cleaning liquid injected upward disperses at the upper end (top) and is then micronized and falls down. The cleaning liquid is thus dispersively present, for example, on the surfaces of the packing materials 35A in the interior space 31. When flowing through the interior space

31 from the lower side toward the upper side in the vertical direction, exhaust gas comes into gas-liquid contact with the cleaning liquid adhering to the surfaces of the packing materials 35A or the falling cleaning liquid, thus removing sulfurs contained in exhaust gas.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0190] In certain embodiments, at least an upper surface of each packing material 35A has a strength sufficient to accommodate a human load. In this case, the packing materials 35A may be utilized as a platform in a case where parts are installed in the interior space 31 or during maintenance work.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0191] In certain embodiments, a spacing Hn between the packed layer 35 and the spraying device 38 illustrated in FIG. 13 is not less than 2 m. In this case, a working space is provided, allowing efficient performance of an operation of installing or replacing the spraying device 38. Furthermore, in response to expansion of the working space, the size of a manhole joining the interior space 31 to the outside is increased to allow more efficient performance of an operation of installing or replacing the spraying device 38.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0192] In certain embodiments, as illustrated in FIG. 14, a pH adjuster 81 is arranged in at least a part of the storage space 31a. More specifically, as illustrated in FIG. 14, the pH adjuster 81 includes rock-like alkaline agents 81A that are packed in a net and with which at least a part of a bottom surface of the storage space 31a is paved. Furthermore, in certain embodiments, the entire bottom surface of the storage space 31a is paved with the rock-like alkaline agents 81A.

[0193] According to the above-described configuration, the rock-like alkaline agents 81A are arranged in at least a part of the storage space 31a, and may thus be brought into contact

with seawater (cleaning liquid) subjected to low-pH desulfurization and containing sulfurous acid. This allows the seawater subjected to the low-pH desulfurization to be neutralized to increase a pH value. Furthermore, when the entire bottom surface of the storage space 31a is paved with the rock-like alkaline agents 81A, possible swashing during sloshing can be mitigated, enabling a reduction in force exerted on the absorber body unit 32 during sloshing. Furthermore, mitigated swashing during sloshing is particularly advantageous if a partition 82 is provided that allows the cleaning liquid to flow to a seawater discharge pipe 59 positioned on a downstream side when the amount of cleaning liquid stored in the storage space 31a of the absorber 30 exceeds a given value as illustrated in FIG. 14. This allows the cleaning liquid to be refrained from flowing downstream before the amount of cleaning liquid reaches the given value, as a result of swashing during sloshing.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0194] Furthermore, in certain embodiments, in the absorber 30, a seawater passing space 82a is formed between the storage space 31a and an interior space 59a of a seawater discharge pipe 59 as illustrated in FIG. 14; the seawater passing space 82a is defined by the above-described partition 82, a lower end of the other end portion 39b with respect to the longitudinal direction, the bottom surface of the storage space 31a, and a ceiling portion 83 extending from the other end portion 39b toward the seawater discharge pipe 59 side along the vertical direction. The entire bottom surface of the seawater passing space 82a is paved with the rock-like alkaline agents 81A.

[0195] According to the above-described configuration, the rock-like alkaline agents 81A are arranged in at least a part of the seawater passing space 82a, and may thus be brought into contact with the seawater (cleaning liquid) subjected to the low-pH desulfurization and containing sulfurous acid. This allows the seawater subjected to the low-pH desulfurization to be neutralized to increase the pH value.

The invention according to the embodiments is also applicable to a square absorber with

an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0196] In certain embodiments, an openable and closable hatch 83a is provided on the ceiling portion 83 positioned above the seawater passing space 82a. In this case, opening the hatch 83a enables the rock-like alkaline agents 81A in the seawater passing space 82a to be replaced along with the net, allowing efficient performance of an operation of replacing the rock-like alkaline agents 81A.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0197] As illustrated in FIG. 14, in certain embodiments, the absorber 30 does not include the packed layer 35 separating the lower-side interior space 31b from the upper-side interior space 31c. Here, in FIG. 14, the lower-side interior space 31b is located below the spraying device 38, and the upper-side interior space 31c is located above the spraying device 38. The spraying device 38 is arranged at a lower position in the absorber body unit 32 than in the case where the packed layer 35 is provided. As a result, the upper-side interior space 31c has a length along the vertical direction

[0198] According to the above-described configuration, the upper-side interior space 31c has a length along the vertical direction, allowing the upper end (top end) of the cleaning liquid sprayed from the spraying device 38 to be set at a high position. The absorber 30 enables, in spite of a lack of the packed layer 35, a reduction in the risk that exhaust gas is discharged to the outside of the absorber 30 without being desulfurized.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0199] FIG. 17 is a schematic diagram illustrating the absorber of the ship desulfurization device according to one embodiment of the present invention and also illustrating wall surface reinforcing members and partitioning walls. As illustrated in FIG. 17, in certain

embodiments, the absorber 30 includes a wall surface reinforcing member 92 inside the absorber body unit 32. As illustrated in FIG. 17, the wall surface reinforcing member 92 is fixed to one of the pair of longitudinal wall surfaces 32a, 32b and the pair of lateral wall surfaces 32c, 32d and provided to protrude from the fixed wall surfaces toward the interior space 31 side. The wall surface reinforcing member 92 has a longitudinal direction along the fixed wall surfaces in the horizontal direction. In this case, the wall surface reinforcing member 92 allows the structural strength of the absorber 30 to be maintained.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0200] In certain embodiments, as illustrated in FIG. 17, the absorber 30 includes at least one partitioning wall 93 arranged in the interior space 31 and extending along the longitudinal direction to divide the interior space 31 into a plurality of spaces. In this case, the partitioning wall 93 enables the structural strength of the absorber 30 to be maintained and allows exhaust gas to be rectified.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0201] In certain embodiments, in the absorber 30, the pair of longitudinal wall surfaces 32a, 32b is formed to be thicker than the pair of lateral wall surfaces 32c, 32d. In this case, the pair of longitudinal wall surfaces 32a, 32b is thicker than the pair of lateral wall surfaces 32c, 32d, allowing the structural strength of the absorber 30 to be maintained.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0202] (Spray)

In certain embodiments, as illustrated in FIG. 5, FIG. 8, and FIG. 14, the above-described ship desulfurization device 20 includes the absorber 30 including the above-described absorber body unit 32, and the above-described spraying device 38. The spraying device 38 has the spray pipes 38c1 (including the longitudinal spray pipes 38a1 and the lateral spray pipes 38b1) extending through the interior space 31 and the plurality of spray nozzles 38c2

(including the spray nozzles 38a2, 38b2) arranged on the spray pipes 38c1 at predetermined intervals. In this case, the ship desulfurization device 20 injects the cleaning liquid flowing through the spray pipes 38c1, through each of the plurality of spray nozzles 38c2 arranged on the spray pipes 38c1 at the predetermined intervals, allowing the cleaning liquid to be uniformly sprayed into the interior space 31. The ship desulfurization device 20 is therefore capable of suppressing the adverse effect of defects in which the cleaning liquid is non-uniformly sprayed as a result of shaking (rolling, pitching, yawing, or the like) of the ship 1.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0203] In certain embodiments, the absorber 30 is formed to be elongate and to have a longitudinal direction, and further includes at least one support capable of supporting the spray pipes 38c1 of the spraying device 38 from below. The support may be a round rod or a square rod and may be shaped like a flat plate or L-shaped. The support is arranged such that the longitudinal direction thereof crosses the longitudinal direction of the spray pipe. Longitudinally opposite ends of the support are fixed to the wall surface of the absorber body unit 32. If a plurality of supports are provided, the supports are arranged at regular intervals such that the longitudinal directions of the supports overlap one another. The spray pipes 38c1 may be configured to be fixed to the support.

[0204] According to the above-described configuration, the spray pipes 38c1 of the spraying device 38 are supported by the support from below, and thus, the spray pipes 38c1 itself may not have a structural strength. This enables a reduction in the size and weight of the spray pipe 38c1. Furthermore, during installation and replacement of the spray pipes 38c1, the operation can be achieved with the spray pipes 38c1 loaded on the support, allowing the installation and replacement operations to be efficiently performed. Additionally, if the supports are arranged at regular intervals, the spray nozzles 38c2 can be easily uniformly arranged by providing each spray nozzle 38c2 between the supports.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0205] In certain embodiments, the absorber 30 further includes a plurality of the supports. The plurality of supports are arranged at regular intervals in a height direction of the absorber 30.

[0206] According to the above-described configuration, the plurality of supports are arranged at the regular intervals in the height direction of the absorber 30, allowing the height position of the spraying device 38c1 to be changed. Furthermore, the plurality of supports may be used, for example, to install a work platform for maintenance of lining. This allows time and effort needed for the work platform to be saved, reducing the time for the installation operation. Furthermore, the plurality of supports may be freely utilized for purposes other than the installation of the work platform, allowing maintainability of the absorber 30 to be improved. Here, the ship 1 is limited in work period in dock or a period when the ship is berthed at a pier, due to anchorage costs and the like, and thus, maintainability of the absorber 30 provided in the ship 1 and a reduction in maintenance period are particularly important.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0207] In certain embodiments, the spray pipes 38c1 of the spraying device 38 has a structural strength sufficient to eliminate a need to support the spray pipes 38c1 from below. In this case, no support needs to be installed in the absorber 30.

Furthermore, in certain embodiments, the spray pipes 38c1 of the spraying device 38 have a strength sufficient to accommodate a human load. In this case, the spray pipes 38c1 may be utilized as a platform in a case where parts are installed in the interior space 31 or during maintenance work.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0208] In certain embodiments, the spray pipes 38c1 of the spraying device 38 are removably fixed to the absorber body unit 32, for example, by fastening means such as bolting. In this case, the spray pipes 38c1 are removably fixed to the absorber body unit 32, facilitating a replacement operation for the spray pipes 38c1. Maintainability of the absorber

30 can thus be improved.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0. Further, the invention according to the embodiments is also applicable to both an absorber including a support and an absorber not including a support.

[0209] In certain embodiments, the spray nozzles 38c2 of the spraying device 38 are removably fixed to the spray pipes 38c1, for example, by fastening means such as bolting or screwing. In this case, the spray nozzles 38c2 are removably fixed to the spray pipes 38c1, facilitating a replacement operation for the spray nozzles 38c2. Maintainability of the absorber 30 can thus be improved.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0. Further, the invention according to the embodiments is also applicable to both an absorber including a support and an absorber not including a support.

[0210] (Absorber Preceding Stage)

FIG. 18 is a diagram illustrating an exhaust gas cooling device of the ship desulfurization device according to one embodiment of the present invention. As illustrated in FIG. 18, in certain embodiments, the ship desulfurization device 20 further includes an exhaust gas cooling device 85 is arranged in a vertical portion 34B of exhaust gas introducing unit 34 to spray cooling water over exhaust gas guided into the exhaust gas introducing unit 34. The exhaust gas cooling device 85 has a spray pipe 85a extending in a direction parallel or perpendicular to a pair of wall surfaces positioned on opposite sides of exhaust gas introducing unit 34 in the width direction thereof, and a plurality of cooling water nozzles 85b provided on the spray pipe 85a. Here, the spray pipe 85a and the cooling water nozzles 85b are respectively configured similarly to the above-described spray pipes 38c1 (including the longitudinal spray pipes 38a1 and the lateral spray pipes 38b1) and the spray nozzles 38c2 (including the spray nozzles 38a2, 38b2), and description of common items is thus omitted.

[0211] According to the above-described configuration, spraying of cooling water enables

a reduction in the temperature of exhaust gas guided into the exhaust gas introducing unit 34. This allows suppression of a rise in the temperature in the exhaust gas introducing unit 34. Here, the temperature of exhaust gas guided into the exhaust gas introducing unit 34 is higher in the absorber 30 of the ship than in a land absorber in which a heat exchanger exchanging heat of exhaust gas is arranged on an upstream side. More specifically, in the land absorber, exhaust gas is cooled to approximately 170°C before being guided into the exhaust gas introducing unit 34, whereas, in the ship absorber, exhaust gas at approximately 300°C is directly guided into the exhaust gas introducing unit 34. Furthermore, if an anticorrosion lining (anticorrosion layer 84) is applied to the exhaust gas introducing unit 34 of the ship absorber 30, the heat of exhaust gas may damage the anticorrosion lining. Additionally, spraying by the spraying device 38 of the absorber body unit 32 fails to cool an inlet side of exhaust gas introducing unit 34. The exhaust gas cooling device 85 is particularly advantageous if provided in the ship absorber 30. Furthermore, spraying of cooling water enables a reduction in the volume of exhaust gas guided into the exhaust gas introducing unit 34, allowing a large amount of exhaust gas to be treated in the absorber 30.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0212] In certain embodiments, as illustrated in FIG. 18, the exhaust gas cooling device 85 is configured to receive seawater introduced into the ship body 2 by a seawater feeding pump 54a via a cooling water feeding pipe 58a (cooling water piping) branching off, at a branch point TP1, from a seawater feeding pipe 58 of a seawater feeding device 50. In this case, the seawater feeding device 50 may be used with the spraying device 38, allowing prevention of an increase in the size of the ship desulfurization device 20, and complication of the structure.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0213] In certain embodiments, as illustrated in FIG. 18, the ship desulfurization device 20 further includes an emergency cooling device 87 for feeding emergency cooling water to the exhaust gas cooling device 85 in case of emergency. Here, “in case of emergency” refers to, for example, a case where exhaust gas becomes hot without being subjected to spraying by the spraying device 38 in the absorber 30. The emergency cooling device 87 includes an emergency tank 86 in which emergency cooling water is stored, and emergency cooling water conduit 88 connected to the spray pipe 85a of exhaust gas cooling device 85 and to the emergency tank 86 to feed emergency cooling water from the emergency tank 86 to the spray pipe 85a. The emergency cooling device 87 needs no power supply and is configured to be operable even at the time of loss of power. For example, the emergency cooling device 87 may include a pressure tank as the emergency tank 86, and the emergency tank may be arranged at a high position to feed emergency cooling water to the spray pipe 85a based on a difference in height. Furthermore, as illustrated in FIG. 18, an emergency on-off valve 90 may be provided in the emergency cooling water conduit 88. The emergency on-off valve 90 is closed while the power supply is supplying electricity and is opened when loss of power occurs. In this case, the emergency cooling device 87, which is operable even at the time of loss of power, sprays cooling water in case of emergency to enable a reduction in the temperature of exhaust gas guided into the absorber 30. This enables suppression of a rise in the temperature in the absorber 30, allowing the absorber 30 to be prevented from failing due to high temperature.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0214] In certain embodiments, as illustrated in FIG. 18, the ship desulfurization device 20 further includes an emergency bypass device 89 for causing exhaust gas to bypass the absorber 30 in case of emergency. The emergency bypass device 89 includes a switching damper 89a provided in the middle of exhaust gas piping connected to the main engine 12 and to the absorber 30 and a switching damper 89b provided in the middle of exhaust gas piping

connected to the auxiliary engines 14 and to the absorber 30. In a normal state, for the switching damper 89a and the switching damper 89b, a bypassing channel is closed, whereas a channel leading to the absorber 30 is open. In case of emergency, for the switching damper 89a and the switching damper 89b, the bypassing channel is open, whereas the channel leading to the absorber 30 is closed. In this case, in time of emergency, emergency bypass device 89 allows exhaust gas to bypass the absorber 30, precluding exhaust gas from flowing to the absorber 30. This enables suppression of a rise in the temperature in the absorber 30 in case of emergency, allowing the absorber 30 to be prevented from failing as a result of high temperature.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0215] FIG. 19 is a diagram illustrating the exhaust gas cooling device of the ship desulfurization device according to one embodiment of the present invention. In certain embodiments, as illustrated in FIG. 19, the above-described ship desulfurization device 20 includes the absorber 30 including the absorber body unit 32 provided with the above-described exhaust gas inlet 33 and exhaust gas introducing unit 34 connected to the exhaust gas inlet 33, and the above-described exhaust gas cooling device 85 capable spraying cooling water over exhaust gas introduced into the exhaust gas introducing unit 34. The exhaust gas cooling device 85 has the cooling water nozzles 85b configured to inject cooling water toward the upstream side in the flow direction of exhaust gas.

[0216] According to the above-described configuration, the ship desulfurization device 20 uses the exhaust gas cooling device 85 to spray cooling water over exhaust gas introduced into the exhaust gas introducing unit 34. This enables a reduction in the temperature of exhaust gas guided into the exhaust gas introducing unit 34 to allow suppression of a rise in the temperature in the exhaust gas introducing unit 34. Exhaust gas hotter than exhaust gas in a land desulfurization device provided in a power plant is introduced in the ship desulfurization device 20, and thus, reducing the temperature of exhaust gas is important for

mitigating adverse effects on the desulfurization device and improving desulfurization performance. Furthermore, the exhaust gas cooling device 85 is used to spray cooling water to enable a reduction in the volume of exhaust gas guided into the exhaust gas introducing unit 34. This allows a large amount of exhaust gas to be treated in the absorber 30. Additionally, the cooling water nozzles 85b of exhaust gas cooling device 85 inject cooling water toward the upstream side in the flow direction of exhaust gas. This enables a reduction in the temperature of exhaust gas introduced into the exhaust gas introducing unit 34 before exhaust gas reaches the cooling water nozzles 85b. The cooling water nozzles 85b can thus be restrained from being damaged by the heat of exhaust gas.

[0217] In certain embodiments, as illustrated in FIG. 19, the above-described exhaust gas cooling device 85 includes a first exhaust gas cooling device 85C configured to receive, as cooling water, seawater fed from the seawater feeding pump 54a, and a first exhaust gas cooling device 85D configured to receive, as emergency cooling water, industrial water fed from the emergency cooling device 87. In other words, the ship desulfurization device 20 may have dedicated devices and piping used to inject emergency cooling water through the cooling water nozzles 85b.

[0218] As described above, in certain embodiments, the above-described cooling water is seawater introduced into the ship 1. In this case, the ship desulfurization device 20 uses seawater introduced into the ship 1 as cooling water to allow suppression of an increase in the consumption of water such as industrial water which is needed during navigation of the ship 1.

[0219] In certain embodiments, the above-described ship desulfurization device 20 includes: the absorber 30 including the absorber body unit 32 provided with the above-described exhaust gas inlet 33 and the exhaust gas introducing unit 34 connected to the exhaust gas inlet 33; and the exhaust gas cooling device 85 having the cooling water nozzles 85b. The exhaust gas introducing unit 34 is configured such that exhaust gas flows from the upper side toward the lower side in the vertical direction. Moreover, the cooling water nozzles 85b are configured to inject cooling water upward.

[0220] Here, when the exhaust gas cooling device 85 is used to spray cooling water over

exhaust gas introduced into the exhaust gas introducing unit 34 to reduce the temperature of exhaust gas, sulfurous acids may be generated. Furthermore, if seawater is used as the cooling water, the temperature may increase to precipitate salt from the seawater. Sulfuric acids and salts adhering to the cooling water nozzle 85b may degrade spraying performance.

[0221] According to the above-described configuration, the cooling water nozzles 85b are configured to inject cooling water upward. Cooling water injected upward comes into contact with exhaust gas above the cooling water nozzles 85b to reduce the temperature of exhaust gas, and falls onto the cooling water nozzles 85b and the like. The cleaning liquid having fallen onto the cooling water nozzles 85b allows sulfurous acids and salts adhering to the cooling water nozzles 85b to be washed away. Furthermore, the cooling water nozzle 85b is kept wet with the cleaning liquid having fallen onto the cooling water nozzles 85b, allowing sulfurous acids and salts to be restrained from adhering to the cooling water nozzles 85b and also allowing suppression of an increase in the temperature of the cooling water nozzles 85b.

[0222] In certain embodiments, the above-described ship desulfurization device 20 includes the absorber 30 including the absorber body unit 32 provided with the above-described exhaust gas inlet 33 and the exhaust gas introducing unit 34 connected to the exhaust gas inlet 33, and the above-described exhaust gas cooling device 85. The exhaust gas cooling device 85 has the above-described cooling water nozzles 85b, the above-described cooling water feeding pipe 58a (cooling water piping) for feeding cooling water to the cooling water nozzles 85b, and a cooling water control valve 94 provided in the cooling water feeding pipe 58a (cooling water piping) and capable of controlling the spraying amount of cooling water sprayed through the cooling water nozzles 85b.

[0223] Pressure of cooling water on a primary side that is an upstream side (seawater feeding pump 54a side) with respect to the cooling water control valve 94 fluctuates significantly according to fluctuation factors such as the height of a waterline and the number of seawater feeding pumps 54a (pumps) operated. If the cooling water control valve 94 is not provided, the spraying amount of cooling water sprayed through the cooling water nozzles

85b varies significantly due to the fluctuation factors. This may result in insufficient cooling of exhaust gas introduced into the exhaust gas introducing unit 34. In contrast, according to the above-described configuration, the exhaust gas cooling device 85 uses the cooling water control valve 94 to control the spraying amount of cooling water sprayed through the cooling water nozzles 85b, allowing sufficient cooling of exhaust gas introduced into the exhaust gas introducing unit 34.

[0224] In certain embodiments, the cooling water control valve 94 adjusts a valve lift such that the pressure of cooling water on a secondary side that is a downstream side (cooling water nozzles 85b side) with respect to the cooling water control valve 94 is constant, thereby controlling the spraying amount of cooling water sprayed through the cooling water nozzles 85b.

[0225] As illustrated in FIG. 19, when a part of the cooling water feeding pipe 58a located on a downstream side with respect to (located on a wake flow side of) the cooling water control valve 94 is designated as a downstream-side cooling water feeding pipe 58b, the downstream-side cooling water feeding pipe 58b is provided with a pressure gauge 95 (fluid pressure detection device). The pressure gauge 95 is configured to be capable of detecting the pressure of cooling water in the downstream-side cooling water feeding pipe 58b. The cooling water control valve 94 is configured to adjust the valve lift such that the pressure detected by the pressure gauge 95 is constant.

[0226] When the cooling water control valve 94 is used to keep the pressure of cooling water on the downstream side (wake flow side) of the cooling water control valve 94 constant, the pressure of cooling water as injected through the cooling water nozzles 85b is also kept constant. At least a constant amount of cooling water can thus be sprayed to a constant height through the cooling water nozzles 85b. This enables at least the constant amount of cooling water to be sprayed through the cooling water nozzles 85b, allowing continuous cooling of exhaust gas guided into the exhaust gas introducing unit 34.

[0227] Furthermore, compared to other detection devices that, for example, use a thermometer to continuously detect the temperature of cooling water in the downstream-side

cooling water feeding pipe 58b, the pressure gauge 95, which continuously detects the pressure of cooling water in the downstream-side cooling water feeding pipe 58b, facilitates detection. Furthermore, the pressure on the primary side fluctuates significantly as described above, and thus, using this as an indicator for valve lift adjustment of the cooling water control valve 94 is unsuitable. The pressure on the secondary side detected by the pressure gauge 95 is thus used as an indicator for valve lift adjustment for the cooling water control valve 94 to facilitate control of the spraying amount of cooling water sprayed through the cooling water nozzles 85b via the cooling water control valve 94.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0228] In certain embodiments, the ship desulfurization device 20 further includes the above-described emergency cooling device 87, the above-described emergency bypass device 89, and an exhaust gas temperature monitoring device for monitoring the temperature of exhaust gas discharged through an outlet of the absorber 30. The exhaust gas temperature monitoring device includes a temperature sensor. If the exhaust gas temperature monitoring device detects a high temperature, the emergency cooling device 87 is activated to spray cooling water, and the emergency bypass device 89 is activated to prevent inflow of exhaust gas into the absorber 30. The exhaust gas temperature monitoring device may be configured to monitor the temperature of exhaust gas inside the absorber 30. This enables suppression of a rise in the temperature in the absorber 30, allowing prevention of the absorber 30 from failing as a result of a high temperature.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0229] In certain embodiments, a hypochlorous acid is added to water such as the cleaning liquid and cooling water used in the ship desulfurization device 20. In this case, the addition of the hypochlorous acid allows biofouling to be prevented, allowing biological corrosion to be suppressed. Land desulfurization devices use seawater for a boiler condenser

and the like and take no biological corrosion measures for desulfurization devices only.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0230] In certain embodiments, the exhaust gas introducing unit 34 includes an outer wall configured to have a double structure. In this case, the exhaust gas introducing unit 34, which is the first component in the absorber 30 that comes into contact with exhaust gas, and the cooling water nozzles 85b, are susceptible to corrosion, and even if the exhaust gas introducing unit 34 or any of the cooling water nozzles 85b is damaged by corrosion, the double structure allows exhaust gas to be prevented from leaking to the outside. Furthermore, in the ship 1, the absorber 30 is provided in the steel plate structure 6, which defines a closed space, and thus, leakage of exhaust gas is dangerous. The double structure allows this danger to be avoided.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0231] In certain embodiments, the exhaust gas introducing unit 34 includes a leakage sensing device for sensing gas leakage or liquid leakage resulting from, for example, corrosion of lining, and is configured to cause gas leakage or liquid leakage resulting from corrosion to flow out to the outside of the absorber 30. This enables sensing of gas leakage and liquid leakage resulting from corrosion in the exhaust gas introducing unit 34, and allows gas leakage and liquid leakage resulting from corrosion to flow out to the outside of the absorber 30.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0232] In certain embodiments, the ship desulfurization device 20 further includes a cooling tower as a preprocess for the absorber 30. In this case, the cooling tower is provided

as a preprocess for the absorber 30, allowing impurities such as heavy metal to be removed in the cooling tower. In certain embodiments, the cooling tower is of a water circulating type. This allows suppression of an increase in the consumption of water used during navigation of the ship 1. Moreover, in certain embodiments, instead of seawater, cooling industrial water is used for the cooling tower of the water circulating type. In this case, compared to seawater, which may contain unspecified impurities, the cooling industrial water needs removal of only particular impurities such as heavy metal, facilitating a drainage process.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0233] (Desulfurization System)

In certain embodiments, ship desulfurization device 20 further includes a heat exchanger that recovers heat from exhaust gas and heats desulfurized exhaust gas. In certain embodiments, examples of the heat exchanger include a rotary heat exchanger such as a Ljungstroem type and a fixed heat exchanger. In other certain embodiments, the heat exchanger may be a gas gas heater (GGH). That is, the heat exchanger includes a heat recovery unit that recovers heat from exhaust gas and a reheat unit that uses heat transferred from the heat recovery device to heat exhaust gas.

[0234] According to the above-described configuration, the heat exchanger is capable of heating desulfurized exhaust gas, preventing exhaust gas to be turned into white smoke, and improving diffusivity of exhaust gas.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0235] In certain embodiments, the ship 1 is equipped with a heating-medium-circulating non-leak gas gas heater. In this case, the non-leak gas gas heater may be used to recover heat from exhaust gas discharged from, for example, the main engine 12 and the auxiliary engines 14 in the engine room 10. Recovered heat may be used to heat vapor used in the

ship 1 or may be used for heat source equipment such as heating appliances, reducing the amount of fuel used in the ship 1.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0236] In certain embodiments, the ship desulfurization device 20 is configured to reduce flange connections at piping joints. This allows piping joining operations to be efficiently achieved.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0237] In certain embodiments, in the ship desulfurization device 20, for example, those of instruments and parts for piping which may be fixed to the absorber 30 and the waste heat recovery device 60 are prefixed during prefabrication described below, which is a preprocess for an operation of conveyance to the ship 1 using a crane or the like. This allows prevention of possible misalignment of the instruments and parts during conveyance to the ship 1. Furthermore, assembly operations in the ship 1 may be reduced, allowing efficient achievement of an operation of installing the ship desulfurization device 20 to the ship 1.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0238] In certain embodiments, pipes in the ship desulfurization device 20 are made of resin and have ends configured to be capable of being connected together using sockets. Furthermore, in certain embodiments, resin materials are wound around the pipes in the ship desulfurization device 20 and the sockets connecting the pipes together. This allows improvement of the corrosion resistance of the pipes and sockets. Additionally, in certain embodiments, rubber pipes are used for areas where actual pipes are connected together without reliance on drawing specifications, to facilitate alignment between the pipes. In this

case, the pipes are easily aligned with one another, allowing installation operations for piping to be efficiently achieved.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0239] In certain embodiments, a ship bottom is configured to generate bubbles into seawater. This allows navigation resistance of the ship 1 to be reduced using the bubbles. Furthermore, bubbles are generated near a bottom drainage unit, enabling an increase in the pH value of drainage water discharged from the ship desulfurization device 20 to the outside of the ship. Here, drainage water discharged from the ship desulfurization device 20 to the outside of the ship is diluted by mixing into seawater outside the ship, and thus has a pH value increased to some degree compared to a value obtained immediately after discharge from the ship desulfurization device 20. Compared to drainage water immediately after discharge from the ship desulfurization device 20, drainage water with a pH value increased to some degree promotes decarbonation treatment using bubbles, allowing the pH value to be significantly increased.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0240] (Desulfurization Tower Assembly Method)

For example, land desulfurization devices provided in power plants are assembled by a block construction method or a panel construction method. However, ship desulfurization devices are not easy to assemble due to possible differences in the aspect ratio of the absorber. Assembly of a ship desulfurization device on a ship in which the ship desulfurization device is to be installed is not practical due to constraints in work space and work time on the ship. Assembly of the ship desulfurization device thus involves three operations, that is, an assembly operation on land, an operation of lifting and loading into the ship, and an installation operation in the ship. For a reduced work time on the ship, the installation

operation in the ship needs to be decreased. Furthermore, the ship desulfurization device is lifted and loaded into the ship using the crane or the like, and thus, a structure for safe installation is needed.

[0241] In certain embodiments, the absorber 30 is prefabricated in an assembly area such as the nearest factory or vacant land, and the prefabricated absorber 30 is lifted and conveyed using the crane or the like, and installed to the ship 1. In this case, the absorber 30 is prefabricated before being installed on the ship 1, enabling a reduction in the installation operation on the ship 1 and thus in the work time on the ship 1.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0242] In certain embodiments, in the absorber 30, piping arranged around the absorber 30 is integrally fixed to the wall surfaces constituting the absorber 30, allowing the piping to easily maintain horizontality. Furthermore, since, in the absorber 30, the piping is integrally fixed to the wall surfaces, the installation operation is facilitated, enabling a reduction in the work time for the installation operation.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0243] In certain embodiments, the absorber 30 is assembled by the block construction method. That is, the absorber 30 is completed by manufacturing each of a number of layered portions of the absorber 30 like round slices and stacking and joining the layered portions together. In this case, the absorber 30 is completed by stacking and joining the layered portions together, enabling a reduction in the work time in the assembly area. The block construction method takes more time and effort than the panel construction method.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0244] In certain embodiments, the absorber 30 is assembled by the panel construction method. That is, the wall surfaces, a bottom surface, and the like of the absorber 30 are composed of plate-like members (panels), and the absorber 30 is completed by installing the

plate-like members to pillars, beams, and the like. In this case, since the absorber 30 is composed of the plate-like materials, the pillars, the beams, and the like, the plate-like materials, the pillars, the beams, and the like may be transported to the assembly area, facilitating transportation of the members constituting the absorber 30. The panel construction method involves more operations in the assembly area than the block construction method.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0245] In certain embodiments, in the ship desulfurization device 20, at least one main part is modularized. In this case, at least one main part is modularized, enabling a reduction in the work time in the assembly area.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0246] In certain embodiments, the absorber 30 has a free-standing structure. The above-described spray pipes (including the longitudinal spray pipes 38a1, the lateral spray pipes 38b1, and the spray pipe 85a) are inserted and installed into the free-standing absorber 30. Further, the packing materials 35A described above are also inserted and installed into the free-standing absorber 30. In this case, since the absorber 30 has a free-standing structure, the above-described spray pipes and the packing materials 35A can be easily installed and arranged inside the absorber 30. The absorber 30 enables a reduction in the work time in the assembly area.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0247] In certain embodiments, a plurality of the above-described longitudinal spray pipes 38a1 are provided at regular intervals in the lateral direction of the interior space 31 and arranged in a staggered pattern such that adjacent longitudinal spray pipes 38a1 lie at different height positions.

In other certain embodiments, a plurality of the above-described lateral spray pipes 38b1

are provided at regular intervals in the longitudinal direction of the interior space 31 and arranged in a staggered pattern such that adjacent lateral spray pipes 38b1 lie at different height positions.

In other certain embodiments, a plurality of the above-described spray pipes 85a are provided at regular intervals and arranged in a staggered pattern such that adjacent spray pipes 85a lie at different height positions.

This allows the cleaning liquid and cooling water to be uniformly fed, enabling a reduction in a local bias in spraying capacity.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0248] In certain embodiments, the spray nozzles 38a2 are integrated with the longitudinal spray pipes 38a1 without bolts or the like.

In other certain embodiments, the spray nozzles 38b2 are integrated with the lateral spray pipes 38b1 without bolts or the like.

In other certain embodiments, the cooling water nozzles 85b are integrated with the spray pipes 85a without bolts or the like.

In these cases, the spray nozzles are integrated with the spray pipes to increase strength. Seawater desulfurization is insusceptible to clogging, thus allowing the spray nozzles to be integrated with the spray pipes.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0249] (Shipboard Installation Method)

For example, land desulfurization devices provided in power plants are assembled in an installation area by the block construction method or the panel construction method. However, ship desulfurization devices are not easy to assemble due to possible differences in the aspect ratio of the absorber. Assembly of a ship desulfurization device on a ship in which the ship desulfurization device is to be installed is not practical due to constraints in work space and work time on the ship. Assembly of the ship desulfurization device thus

involves an operation of assembling a desulfurization device on land and then using the crane or the like to lift and load the desulfurization device into the ship. The ship desulfurization device needs a strength sufficient to withstand the operation of using the crane or the like to lift and load the desulfurization device into the ship, reinforcements for the operation, and the like. The ship desulfurization device may be subjected to deformation of the absorber or peel-off of the lining inside the absorber during the operation of using the crane or the like to lift and load the desulfurization device into the ship.

[0250] In certain embodiments, the absorber 30 is delivered in an integral state where internal parts are pre-installed to the absorber 30. The absorber 30 may be installed to the ship 1 in a shipyard while remaining in the integral state. At the time of maintenance work, the absorber 30 may be replaced while in the integral state, enabling a reduction in the time for the maintenance work.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0251] FIG. 21 is a diagram illustrating fixture between the absorber and the steel plate structure of the ship desulfurization device according to one embodiment of the present invention. FIG. 22 is a diagram illustrating installation, on the ship, of the absorber and the steel plate structure of the ship desulfurization device according to one embodiment of the present invention. In certain embodiments, the absorber 30 and the exhaust gas introducing device 40 are assembled on land, and as illustrated in FIG. 21, firmly fixed to the steel plate structure 6 surrounding the periphery of the absorber 30 and the exhaust gas introducing device 40. Then, as illustrated in FIG. 22, the absorber 30 and the exhaust gas introducing device 40 are lifted and suspended by the crane or the like along with the steel plate structure 6 and loaded onto the ship 1, and installed to the ship 1 along with the steel plate structure 6. The steel plate structure 6 may exclusively cover the absorber 30. Furthermore, the waste heat recovery device 60, a device such as the above-described heat exchanger which is associated with the desulfurization treatment for exhaust gas, piping, wiring, or the like may be fixed to the steel plate structure 6.

[0252] According to the above-described configuration, the absorber 30 and the exhaust gas introducing device 40 are lifted and suspended by the crane or the like along with the steel plate structure 6. This allows the absorber 30 and the exhaust gas introducing device 40 to be prevented from being deformed during suspension and during loading onto the ship 1, and also allows the lining inside the absorber 30 to be prevented from being peeled off.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0253] In certain embodiments, as illustrated in FIG. 21, the steel plate structure 6 has a fixing member 91 arranged in the steel plate structure 6 and used to fix the absorber 30 and the exhaust gas introducing device 40 to the steel plate structure 6. As illustrated in FIG. 21, the fixing member 91 includes prismatic longitudinal fixing members 91A extending parallel to each wall surface of the pair of longitudinal wall surfaces positioned on the opposite sides in the lateral direction of the steel plate structure 6 and prismatic lateral fixing members 91B extending parallel to each wall surface of the pair of lateral wall surfaces positioned on the opposite sides in the longitudinal direction of the steel plate structure 6. For each of the longitudinal fixing members 91A and the lateral fixing members 91B, both ends are fixed to the steel plate structure 6, and the middle of the length is connected to the absorber 30 or the exhaust gas introducing device 40. Some of the longitudinal fixing members 91A and the lateral fixing members 91B may be fixed to piping connected to the absorber 30 or the exhaust gas introducing device 40. This allows the steel plate structure 6 to be firmly fixed to the absorber 30 and the exhaust gas introducing device 40.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0254] In certain embodiments, the absorber 30 is assembled and installed to the ship 1 by the following method. That is, the absorber 30 is assembled on land by the block construction method or the panel construction method. The absorber 30 is configured to have a free-standing structure. After the absorber 30 is assembled, attachments such as the above-described spray pipes and the above-described packing materials 35A are installed in

the absorber 30. After the attachments are installed, the steel plate structure 6 is placed around the absorber 30, and the absorber 30 and the steel plate structure 6 are firmly fixed together. Piping for connection to the absorber 30 is installed in the steel plate structure 6. Once the installation in the steel plate structure 6 is completed, the steel plate structure 6 is moved to a side of the ship 1, and the steel plate structure 6 is lifted and loaded onto the ship 1 for installation.

[0255] According to the above-described configuration, the absorber 30 is assembled on land, and the attachments in the absorber 30 and the piping in the steel plate structure 6 are attached to the absorber 30. Since the attachments and the piping are attached before the steel plate structure 6 is placed around the absorber 30, a large working area can be provided. For example, this is advantageous in an operation of transferring the spray piping from the outside of the absorber 30 into the absorber 30. The absorber 30 and the steel plate structure 6 are firmly fixed together on land, enabling a reduction in operations on the ship. Furthermore, the absorber 30, fixed in the steel plate structure 6, is lifted and suspended by the crane or the like along with the steel plate structure 6. This allows the steel plate structure 6 to be used as a reinforcement during suspension and during loading onto the ship 1, allowing the absorber 30 to be prevented from being deformed. This also prevents peel-off of the lining inside the absorber 30 and fall-off of the piping in the steel plate structure 6.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0256] In certain embodiments, the absorber 30 is assembled and installed to the ship 1 by the following method. That is, in a land assembly area, the steel plate structure 6 is installed first, and the absorber 30 is assembled in the steel plate structure 6. A maintenance stage for weatherability may be provided in the steel plate structure 6.

[0257] According to the above-described configuration, the absorber 30 is assembled in the steel plate structure 6 on land, allowing avoidance of a situation where the absorber 30 fails to be housed in the steel plate structure 6. Furthermore, the absorber 30 is fixed to the steel plate structure 6, allowing the attachments in the absorber 30 to be attached to the

absorber 30 even if the absorber 30 does not have a free-standing structure.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0258] In certain embodiments, the absorber 30 is assembled and installed to the ship 1 by the following method. That is, the absorber 30 and the steel plate structure 6 are integrally assembled by manufacturing each of a number of layered portions of the absorber 30 and the steel plate structure 6 like round slices and stacking and joining the layered portions together.

[0259] According to the above-described configuration, the absorber 30 and the steel plate structure 6 are integrally assembled on land by the block construction method, enabling a reduction in the work time in the assembly area. Furthermore, the attachments in the absorber 30 can be attached to the absorber 30 even if the absorber 30 does not have a free-standing structure. Since the absorber 30 and the steel plate structure 6 are integrally assembled on land, the operations on the ship can be reduced.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0260] (Control, Operation Method, and Seawater Adjustment)

While the ship 1 is navigating, operating conditions may vary according to meteorological conditions and the waters in which the ship 1 is navigating. Furthermore, the ship 1 desirably avoids wasting power during navigation.

[0261] FIG. 20 is a diagram illustrating a cleaning liquid feeding line and a bypass line in the ship desulfurization device according to one embodiment of the present invention. As illustrated in FIG. 20, in certain embodiments, the above-described ship desulfurization device 20 includes the absorber 30 including the above-described absorber body unit 32, the above-described spraying device 38, and a cleaning liquid feeding device 96 capable of spraying the cleaning liquid to the spraying device 38.

[0262] As illustrated in FIG. 20, the cleaning liquid feeding device 96 has a cleaning liquid feeding line 97A for feeding the cleaning liquid to the spraying device 38, a bypass line 97B branching off, at a branch point TP2, from the cleaning liquid feeding line 97A and

feeding the cleaning liquid to the above-described storage space 31a in which the sprayed cleaning liquid sprayed over exhaust gas guided to the interior space 31 is stored, and a control valve 98 provided in the bypass line 97B and capable of controlling the feeding amount of cleaning liquid flowing through the bypass line 98B.

[0263] In the illustrated embodiment, the cleaning liquid feeding device 96 includes the above-described seawater feeding device 50 for feeding seawater to the spraying device 38 as the cleaning liquid. Furthermore, the cleaning liquid feeding line 97A includes a seawater feeding pipe 58, and the bypass line 97B includes a dividing pipe 58c. The dividing pipe 58c has one end connected to the seawater feeding pipe 58, joining the seawater feeding pump 54a to the spray pipes 38c1 of the spraying device 38, at a branch point TP2 provided on the seawater feeding pipe 58, and the other end connected to the storage space 31a (interior space 31) of the absorber 30. A portion of the cleaning liquid (seawater) flowing through the seawater feeding pipe 58 thus flows through the dividing pipe 58c into the storage space 31a. In other embodiments, the cleaning liquid feeding device 96 may feed water other than seawater to the spraying device 38 as the cleaning liquid.

[0264] For example, between the emission control areas (ECAs) and the common waters, the required desulfurization performance varies and thus, the needed amount of cleaning liquid fed to the spraying device 38 also varies. If the amount of cleaning liquid fed to the spraying device 38 is smaller than the needed amount of cleaning liquid, a needed desulfurization effect may fail to be produced. Furthermore, if the amount of cleaning liquid fed to the spraying device 38 is greater than the needed amount of cleaning liquid, the pressure drop of exhaust gas may increase. To allow an appropriate amount of cleaning liquid to be fed to the spraying device 38, a control valve may be provided in the cleaning liquid feeding line 97A for feeding the cleaning liquid to the spraying device 38 to control the feeding amount of cleaning liquid flowing through the cleaning liquid feeding line 97A. However, a conduit constituting the cleaning liquid feeding line 97A has a large diameter, and thus, the size and cost of the control valve provided in the cleaning liquid feeding line 97A may be increased. Furthermore, there is difficulty in controlling the feeding amount of

cleaning liquid in the cleaning liquid feeding line 97A including the conduit with a large diameter.

[0265] According to the above-described configuration, the cleaning liquid feeding device 96 uses the control valve 98 provided in the bypass line 97B to control the feeding amount of cleaning liquid flowing through the bypass line 97B to allow indirect control of the feeding amount of cleaning liquid flowing through the cleaning liquid feeding line 97A. In this case, the conduit (dividing pipe 58c) constituting the bypass line 97B may have a smaller diameter than the conduit (seawater feeding pipe 58) constituting the cleaning liquid feeding line 97A, and thus, the control valve 98 provided in the bypass line 97B has a smaller size and a lower cost than the control valve provided in the cleaning liquid feeding line 97A. Furthermore, the bypass line 97B allows the feeding amount of cleaning liquid to be more easily controlled than the cleaning liquid feeding line 97A.

[0266] In certain embodiments, a flowmeter 99 (flow rate detecting device) is provided on a downstream side (spraying device 38 side) of the branch point TP2 of the cleaning liquid feeding line 97A from which the bypass line 97B branches off. The flowmeter 99 is configured to be capable of measuring the flow rate (volume flow rate) of cleaning liquid flowing on the downstream side of the branch point TP2 of the cleaning liquid feeding line 97A. The control valve 98 is configured to adjust the valve lift thereof such that the flow rate detected by the flowmeter 99 falls within a predetermined range. In this case, a desired amount of cleaning liquid is fed to the spraying device 38, allowing the needed desulfurization effect to be produced and also enabling control of an increase in pressure drop. In other embodiments, the flow rate may be indirectly detected by multiplying, by a cross-sectional area, the flow rate detected by the flowmeter. In other words, the flow rate detecting device includes a flow velocity meter. The branch point TP2 may be positioned on an upstream side or a downstream side of the branch point TP1.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0.

[0267] In certain embodiments, the ship 1 further includes a control device for controlling

devices and equipment such as the absorber 30 of the ship desulfurization device 20. The control device is an electronic control unit controlling devices and equipment in the ship 1. The control device may be configured as a microcomputer including a central processing unit (CPU) including a processor, a random access memory (RAM), a read only memory (ROM), and an I/O interface.

[0268] In certain embodiments, the control device controls the number of the spray nozzles operated or the number of pumps operated. The spray nozzles to be operated may be selected according to the positions of the spray nozzles. This allows the power consumption of the ship 1 to be suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0269] In certain embodiments, the control device uses, for example, a movable vane pump to adjust the valve lift or controls the number of pumps operated to adjust the amounts of cleaning liquid and cooling water fed to the spray nozzles. This allows the power consumption of the ship 1 to be suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0270] In certain embodiments, the control device executes at least one of control of the number of the spray nozzles operated, control of the number of pumps operated, and controllable adjustment of the amount of liquids fed to the spray nozzles based on the adjustment of the valve lift, according to an SO2 concentration of exhaust gas discharged from the absorber 30. In this case, the control may comply with exhaust gas throughput of the absorber 30, allowing the power consumption of the ship 1 to be efficiently suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0271] In certain embodiments, the control device executes at least one of control of the number of the spray nozzles operated and controllable adjustment of the amount of liquids fed to the spray nozzles based on the adjustment of the valve lift, according to properties of seawater introduced into the ship body 2 by the seawater feeding pump 54a, such as the pH value and alkalinity of seawater. In this case, the control may comply with the properties of seawater obtained, allowing the power consumption of the ship 1 to be efficiently suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0272] In certain embodiments, the control device determines the operating load on the absorber 30 based on power of the ship 1, the SO2 concentration of exhaust gas not desulfurized by the absorber 30 yet, S components in fuel, and the SO2 concentration of exhaust gas desulfurized by the absorber 30, singly or as a combination thereof, to execute at least one of control of the number of the spray nozzles operated and controllable adjustment of the amount of liquids fed to the spray nozzles based on the adjustment of the valve lift, according to the operating load. In this case, the control may comply with the operating load on the absorber 30, allowing the power consumption of the ship 1 to be efficiently suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0273] In certain embodiments, a pressure gauge is attached to a header portion of each of the spray nozzles to monitor clogging of the spray nozzles and an operating state of the seawater feeding pump 54a. In this case, the pressure gauge may be used to monitor clogging of the spray nozzles and the operating state of the seawater feeding pump 54a, and thus, the control device is capable of efficiently controlling the ship desulfurization device 20.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0274] In certain embodiments, an analyzer is attached to the drainage pipe 56 or the seawater discharge pipe 59 to constantly monitor properties of desulfurization drainage (scrubber drainage or diluted drainage), for example, the pH value and a desulfurization rate. In this case, the analyzer may be used to constantly monitor the properties of the desulfurization drainage, and thus, the control device is capable of efficiently controlling the ship desulfurization device 20.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0275] In certain embodiments, the control device controllably operates a minimum required number of seawater pumps (seawater feeding pump 54a and drainage dilution pump 52a) such that the pH value of desulfurization drainage and the desulfurization rate meet predetermined conditions in spite of a fluctuation in the number of absorbers 30 cleaning exhaust gas, the load on each of the absorbers 30, and the S components of fuel oil. In this case, the minimum required number of seawater pumps are operated, allowing the power consumption of the ship 1 to be efficiently suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0276] In certain embodiments, the control device is used to execute the following control method for the ship desulfurization device 20. That is, a database is created that indicates the needed amount of seawater for each combination of four items including the S components of fuel oil, the load on the engine, a seawater concentration in each area, and the draft varying with load capacity. The control device executes feedforward control based on the database to feed an appropriate amount of seawater to the device and equipment in the ship 1 such as the absorber 30. In this case, the appropriate amount of seawater is fed based on the feedforward control, allowing the power consumption of the ship 1 to be efficiently suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0277] In certain embodiments, the control device is used to execute the following control method for the ship desulfurization device 20. That is, the pH value or the sulfurous acid concentration at the drainage unit of the ship 1 or the SO2 concentration of exhaust gas discharged from the absorber 30 is sensed, and the control device executes feedback control based on the pH value or the sulfurous acid concentration to feed the appropriate amount of seawater to the device and equipment in the ship 1 such as the absorber 30. In this case, the appropriate amount of seawater is fed based on the feedback control, allowing the power consumption of the ship 1 to be efficiently suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0278] In certain embodiments, as an analysis method for monitoring the sulfurous acid concentration in the desulfurization drainage, a method, in which a portion of the desulfurization drainage is continuously fed to a separable flask with a stirrer, while a constant amount of acid is being continuously fed to the separable flask, is used. An infrared SO2 meter (infrared gas analyzer) is used to measure the gas concentration of sulfur dioxide (SO2) that shifts from sulfurous acid to a gas phase during the continuous feeding. This allows the sulfurous acid concentration in the desulfurization drainage to be monitored, and the control device can execute, on the spray nozzles, control corresponding to the sulfurous acid concentration in the desulfurization drainage.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0279] In certain embodiments, the control device is configured to execute at least one of control of the number of pumps, movable-vane opening control, and VVVF inverter rotation-

speed control to control the amount of seawater. This allows the amount of seawater fed to the absorber 30 and the like to be adjusted to an appropriate value.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0280] (Maintenance Method and Structure)

The ship desulfurization device 20 is configured to feed exhaust gas into the absorber 30 through an aggregation of exhaust gas introducing pipes from all the engines including the main engine 12 and the auxiliary engines 14 on the ship 1. For at least one of the exhaust gas dampers, hot exhaust gas flows on the primary side (the upstream side of the exhaust gas damper). Thus, if exhaust gas leaks from the exhaust gas damper during inspection of the absorber 30, an operator engaged in the inspection operation may get into danger. Furthermore, during maintenance work in the ship 1, at least one of the main engine 12 and the auxiliary engines 14 needs to be operated during maintenance work, precluding stoppage of all of the main engine 12 and the auxiliary engines 14 and also precluding stoppage of discharge of exhaust gas.

[0281] In certain embodiments, the ship desulfurization device 20 includes two exhaust gas dampers arranged in series in at least one area and between which compressed air is fed. In this case, the two exhaust gas dampers are arranged in series and compressed air is fed to between the exhaust gas dampers for air sealing, allowing exhaust gas to be reliably prevented from flowing one damper to the other across the area between the dampers.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0282] In certain embodiments, in the ship desulfurization device 20, at least one exhaust gas damper includes a switching blank flange. In this case, the exhaust gas damper includes the switching blank flange, allowing exhaust gas to be reliably prevented from flowing one damper to the other across the area between the dampers.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0283] In certain embodiments, in the ship desulfurization device 20, at least one exhaust gas damper includes a guillotine damper (gate damper). Here, the guillotine damper is electrically opened, and the opening takes time. However, the guillotine damper is instantaneously closed. Each of a plurality of exhaust gas dampers may include a guillotine damper, and the guillotine damper may, for example, configured to close a round duct. In this case, the exhaust gas damper includes the guillotine damper, allowing exhaust gas to be reliably prevented from flowing one damper to the other across the area between the dampers.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0284] In certain embodiments, the ship desulfurization device 20 further includes a bypass channel through which exhaust gas is passed during maintenance work, to prevent exhaust gas from passing through the exhaust gas dampers. In this case, during maintenance work, exhaust gas flows through the bypass channel rather than through the exhaust gas dampers.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0285] In certain embodiments, in the ship desulfurization device 20, at least one exhaust gas damper includes a guillotine damper. During maintenance work, at least one of the main engine 12 and the auxiliary engines 14 is operated, and the guillotine damper corresponding to the operated engine is closed. In this case, the guillotine damper corresponding to the at least one of the main engine 12 and the auxiliary engines 14 that is operated is closed, allowing the operator engaged in the inspection operation to be prevented from getting into danger.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0286] (Connection of Exhaust Gas Channel to Absorber)

The absorber 30 occupies a given range in the steel plate structure 6, and thus, an operation of routing piping in the steel plate structure 6 may be difficult or may be disabled.

[0287] In certain embodiments, as illustrated in FIG. 3 and FIG. 4, the exhaust gas introducing pipe 42 connects to the auxiliary-engine exhaust gas introducing pipes 44a to 44d for guiding, to the absorber body unit 32, exhaust gas discharged from the auxiliary engines 14. In certain embodiments, the auxiliary-engine exhaust gas introducing pipes 44c, 44d are connected to a side wall 34c (see FIG. 23 described below) on the other end 34b side of the exhaust gas introducing unit 34 to directly guide exhaust gas to the exhaust gas introducing unit 34. Alternatively, the auxiliary-engine exhaust gas introducing pipes 44a, 44b may be connected to the side wall 34c on the other end 34b side of the exhaust gas introducing unit 34. This increases the degree of freedom for connection positions of the auxiliary-engine exhaust gas introducing pipes 44a to 44d, allowing the auxiliary-engine exhaust gas introducing pipes 44a to 44d to be connected to positions where the routing operation is easy. Furthermore, an increase in the length of each of the auxiliary-engine exhaust gas introducing pipes 44a to 44d can be suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0288] FIG. 23 is a diagram illustrating connection between the absorber and an exhaust gas introducing pipe of the ship desulfurization device according to one embodiment of the present invention. In certain embodiments, as illustrated in FIG. 23, the auxiliary-engine exhaust gas introducing pipes 44c, 44d are connected to a side wall 32e opposite to a side to which the exhaust gas introducing unit 34 of the absorber body unit 32 is connected, to directly guide exhaust gas to the interior space 31 of the absorber body unit 32.

Alternatively, the auxiliary-engine exhaust gas introducing pipes 44a, 44b may be connected to the side wall 32e, and the auxiliary-engine exhaust gas introducing pipes 44a to 44d may be connected to a side wall 32f adjacent to the side wall to which the exhaust gas introducing unit 34 of the absorber body unit 32 is connected. This increases the degree of freedom for the connection positions of the auxiliary-engine exhaust gas introducing pipes 44a to 44d, allowing the auxiliary-engine exhaust gas introducing pipes 44a to 44d to be connected to the positions where the routing operation is easy. Furthermore, an increase in the length of each of the auxiliary-engine exhaust gas introducing pipes 44a to 44d can be suppressed.

The invention according to the embodiments is also applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

[0289] In the configuration described above for the certain embodiments, one exhaust gas inlet 33 is provided, but a plurality of exhaust gas inlets 33 may be provided. FIG. 24A and FIG. 24B are diagrams illustrating the connection between the absorber and the exhaust gas introducing pipe of the ship desulfurization device according to one embodiment of the present invention; FIG. 24A is a schematic top view and FIG. 24B is a schematic front view. As illustrated in FIG. 24A and FIG. 24B, the exhaust gas inlet 33 may be provided on both sides of the absorber 30. In this case, particularly for a square absorber 30 with an aspect ratio of 1: 1.1 or under 1.1 is installed to span the entire width of the steel plate structure 6, the exhaust gas introducing pipe need not bypass the side of the absorber 30. This eliminates a need for routing of a generator exhaust gas inlet.

[0290] FIG. 25 and FIG. 26 illustrate a hull integrated desulfurization device 100 according to one embodiment is assembled to a hull structure. FIG. 25 illustrates that, when assembled into a hull structure of the ship 1, the hull integrated desulfurization device 100 is lifted and suspended by a crane 108. FIG. 26 illustrates that the hull integrated desulfurization device 100 is loaded onto a top portion of an engine casing 106 described below.

[0291] As illustrated in FIG. 25 and FIG. 26, the hull integrated desulfurization device 100

includes a casing 102 forming a part of the hull structure of the ship, an absorber 104 supported by a casing 102. The absorber 104 desulfurizes exhaust gas discharged from the exhaust gas generation device such as the main engine 12 or the auxiliary engines 14 mounted to the ship.

The conventional ship desulfurization device is independent from the hull structure as a piece of machinery mounted to the ship.

In contrast, before the hull integrated desulfurization device 100 is mounted to the ship, the absorber 104 is already supported by the casing 102 forming a part of the hull structure. The casing 102 of the hull integrated desulfurization device 100 is connected to another hull structure of the ship on the ship

[0292] According to the above-described configuration, the casing 102 supporting the absorber 104 forms a part of the hull structure, eliminating a need to provide, around the absorber 104, an extra clearance or a reinforcing member intended to prevent vibration and shaking of the absorber 104. An attachment structure for the absorber 104 may thus be compactified.

[0293] In one embodiment, as illustrated in FIG. 25 and FIG. 26, the absorber 104 is connected by welding to the casing 102 surrounding an outer periphery of the absorber 104 and is formed integrally with the casing 102.

According to the configuration, the absorber 104 is connected by welding to the casing 102 surrounding an outer periphery of the absorber 104, and thus, a force applied from the absorber 104 to the casing 102 is distributed over the periphery of the casing 102. The load of the absorber 104, which otherwise concentrates on a base of the absorber 104, is therefore distributed over the casing 102, allowing a support structure for the absorber 104 to be compactified.

[0294] In one embodiment, as illustrated in FIG. 26, when the hull integrated desulfurization device 100 is mounted to the ship, the hull integrated desulfurization device 100 is placed at the top of the engine casing 106. The absorber 104 is peripherally supported by the casing 102, eliminating a need for a support unit supporting the absorber 104 from

below. This allows a gap s1 to be formed between the absorber 104 and the engine casing 106 of the ship positioned below the absorber 104.

According to the embodiment, the need for a support unit supporting the absorber 104 from below is eliminated, and the gap s1 can be formed. This advantageously allows piping to be arranged in the gap s1; the piping includes liquid piping through which an absorbing liquid stored in the engine casing 106 flows (seawater feeding pipe and seawater discharge pipe), exhaust gas piping through which exhaust gas discharged from the exhaust gas generation device such as the main engine is introduced into the absorber 104, and the like.

[0295] In one embodiment, the casing 102 is formed of a common hull material such as steel, and an exhaust gas contact portion of the absorber 104 is formed of anticorrosive stainless steel or alloy.

In one embodiment, a vibration analysis concerning hull integrated desulfurization devices is conducted to design a structure that does not resonate with a natural frequency of a main engine or a propeller.

In one embodiment, to avoid resonance with the natural frequency of a main engine 12 or a propulsion propeller (not illustrated in the drawings), a muffler installation space is provided in an upper area R_1 of the casing 102. Furthermore, when an area R_2 adjacent to an installation space for the absorber 104 is vacant, accessory devices of the absorber 104 and piping may be provided in the area R_2.

[0296] In one embodiment, the casing 102 may be formed such that a length along a width direction (the direction of arrow a in FIG. 25) of the ship 1 is larger than a length along a front-back direction of the ship.

According to the embodiment, a longitudinal direction of the casing 102 is arranged along the width direction of the ship 1, and thus, the absorber 104 supported by the casing 102 has a longitudinal direction arranged along the width direction of the ship. Compared to an absorber having a longitudinal direction along the bow-stern direction of the ship, the absorber 104 enables a reduction in bending stress acting on the absorber 104 during rolling of the ship. The absorber 104 is thus highly resistant to rolling.

[0297] In one embodiment, as illustrated in FIG. 25 and FIG. 26, the casing 102 is shaped like a long tube having a longitudinal direction arranged along the width direction of the ship and an axial direction arranged along the vertical direction. The absorber 104 is therefore supported by the casing 102 surrounding an outer periphery of the absorber 104, and thus, a force applied from the absorber 104 to the casing 102 is distributed over the periphery of the casing 102. The load of the absorber 104, which otherwise concentrates on a base of the absorber 104, is therefore distributed over the casing 102, allowing a support structure for the absorber 104 to be compactified.

In FIG. 25 and FIG. 26, for visualization of the casing 102, a wall in the front of the casing 102 is deleted.

[0298] As illustrated in FIG. 25 and FIG. 26, the ship 1 according to one embodiment includes the hull integrated desulfurization device 100, which forms a part of the hull structure.

According to this configuration, the hull integrated desulfurization device 100 is formed as a part of the hull structure, eliminating a need to provide, around the absorber 104, an extra clearance or a reinforcing member intended to prevent vibration and shaking of the absorber 104. The attachment structure for the absorber 104 may thus be compactified.

[0299] In one embodiment, as illustrated in FIG. 25 and FIG. 26, the hull structure includes the engine casing 106 positioned below the casing 102 of the hull integrated desulfurization device 100. A lower end of a shell wall 110 of the casing 106 is connected to the engine casing 106 by welding.

According to this configuration, the absorber 104 is supported by the casing 102 forming a part of the hull structure of the ship 1, allowing the casing 102 to be easily arranged above the engine casing 106, which belongs to the same hull structure. Furthermore, a distance between the engine casing 106 and the casing 102 supporting the absorber 104 is short, enabling a reduction in the length of exhaust gas piping through which exhaust gas discharged from the main engine housed in the engine casing 106 is introduced into the absorber 104.

[0300] In one embodiment, as illustrated in FIG. 25 and FIG. 26, a first reinforcing member formed by ribs 112 provided on an inner side surface of the shell wall 110 of the casing 102 and extending in an up-down direction or by stiffeners 114 (see FIG. 27) installed between the shell walls 110 arranged opposite to each other is aligned with a second reinforcing member formed by ribs 118 or stiffeners 120 provided in the engine casing 106. That is, the ribs 112 or the stiffeners 114 are loaded on and supported by the ribs 118 or the stiffeners 120.

[0301] In one embodiment, as illustrated in FIG. 27, the stiffeners 114 are installed between the opposite shell walls 110 of the casing 102. The stiffeners 120 are installed between the opposite shell walls 110 and on an inner side of, for example, an upper area of each of opposite shell walls 116 of the engine casing 106. The plurality of ribs 118 are provided in the engine casing 106 in parallel with one another.

According to the embodiment, the first reinforcing member is aligned with the second reinforcing member as viewed in the up-down direction. This enables an increase in the bearing capacity of the engine casing 106 with respect to the casing 102 supporting the absorber 104, allowing the casing 102 to be stably supported.

[0302] In one embodiment, as illustrated in FIG. 25, particular ribs 112a and 112b (see FIG. 25) of the ribs 112 constituting the shell wall 110 are inclined at the lowermost portion of the casing 102 to align with the ribs 118 or stiffeners 120 constituting the second reinforcing member of the engine casing 106. This enables an increase in the capacity of bearing of the casing 102 by the engine casing 106.

In one embodiment, the stiffeners 114 illustrated in FIG. 27 are inclined to align with the ribs 118 or the stiffeners 120 constituting the second reinforcing member. This enables an increase in the capacity of bearing of the casing 102 by the engine casing 106.

[0303] In one embodiment, in a state where the hull integrated desulfurization device 100 is mounted to the ship 1, the absorber 104 is positioned above the exhaust gas piping 122 of the exhaust gas generation device such as the main engine 12 or the auxiliary engines 14, as illustrated in FIG. 28.

According to the embodiment, the absorber 104 is positioned above an exhaust gas piping 122 of the exhaust gas generation device, enabling a reduction in the length of the exhaust gas piping 122 through which exhaust gas discharged from the exhaust gas generation device is introduced into the absorber 104.

[0304] In one embodiment, as illustrated in FIG. 29, piping 124 is supported by the casing 102. The piping 124 includes at least one of: gas piping connecting the exhaust gas piping 122 of the exhaust gas generation device to the exhaust gas inlet of the absorber 104; and liquid piping through which an absorbing liquid used in the absorber 104 flows.

According to the embodiment, the piping is supported by the casing 102 forming a part of the hull structure of the ship 1, allowing compactification of the support structure for the accessory devices of the absorber 104 including the piping. Furthermore, even if the positional relationship between the absorber 104 and the main engine varies among ships, the variation can be accommodated simply changing the length of the piping. The piping may thus be modularized, enabling a cost reduction.

[0305] In one embodiment, as illustrated in FIG. 30, the hull structure of the ship 1 includes the casing 102 and another hull structure 103 located adjacent to the casing 102 in the width direction (direction of arrow a) of the ship 1 and welded to the casing 102.

According to the embodiment, the hull structure arranged in the width direction of the ship 1 is divided between the casing 102 supporting the absorber 104 and the other hull structure 103, and thus, the divisional portions may be separately conveyed into the ship by the crane 108. This allows avoidance of a situation where the hull integrated desulfurization device 100 has an excessively heavy weight, for which the crane capacity is insufficient.

[0306] In certain embodiments, as illustrated in FIG. 31A and FIG. 31B, a space s2 that appears square in a plan view is formed between frames 126 constituting the casing 102. FIG. 31A illustrates an example in which the absorber 104 (104a) with a square contour in a plan view is arranged in the square space s2. FIG. 31B illustrates an example in which the absorber 104 (104b) with a circular contour in a plan view is arranged in the square space s2. FIG. 31C illustrates an example in which the outer periphery of the absorber 104 (104b)

illustrated in FIG. 31B is fixed to the frame 126 at a plurality of welding points p. In this manner, the absorber 104 (104a, 104b) may be installed in the casing 102 of the hull integrated desulfurization device 100.

[0307] FIG. 32 is a process diagram illustrating a method for assembling the hull integrated desulfurization device 100 to the ship according to one embodiment. As illustrated in FIG. 32, first, the hull integrated desulfurization device 100 including the casing 102 forming a part of the hull structure of the ship, and the absorber 104 is formed on land (desulfurization device forming step S10). Then, the hull integrated desulfurization device 100 formed in the desulfurization device forming step S10 is installed to the ship (ship installing step S12). In the desulfurization device forming step S10, the casing 102 of the hull integrated desulfurization device 100 is joined to the parts of hull structure of the ship 1 other than the casing 102.

[0308] According to the method, in the desulfurization device forming step S10, the hull integrated desulfurization device 100 is preliminarily formed in a land factory or the like. After the ship enters a dock, the hull integrated desulfurization device 100 is mounted to the ship. This enables a reduction in a construction period for mounting the absorber to the ship. Furthermore, before being integrated together, the absorber 104 and the casing 102 may be simultaneously and concurrently manufactured, enabling a reduction in a construction period for the hull integrated desulfurization device 100.

[0309] In one embodiment, in the desulfurization device forming step S10, the absorber 104, the casing 102 and the absorber 104 are assembled together in order from a lower section to an upper section of the hull integrated desulfurization device 100.

According to the embodiment, the absorber 104 and the casing 102 are assembled in order from the lower section to the upper section of the hull integrated desulfurization device 100, facilitating the assembly. The absorber 104 and the casing 102 are simultaneously and concurrently assembled, enabling a reduction in construction period.

[0310] In one embodiment, as illustrated in FIG. 33, in the forming step, an aggregation of a plurality of divisional sections 100a, 100b, and 100c into which the hull integrated

desulfurization device 100 is divided in the up-down direction. In the ship installing step S12, the divisional sections 100a to 100c are sequentially stacked in the ship 1 to install the hull integrated desulfurization device 100 to the ship.

According to the embodiment, the aggregation of the plurality of divisional sections 100a to 100c into which the hull integrated desulfurization device 100 is divided in the up-down direction is formed, and thus, in the ship installing step S12, the divisional sections may be conveyed one by one into the ship using the crane 108. This allows avoidance of a situation where the conveying capacity of the crane 108 is insufficient.

[0311] In the embodiment, divisional sections 104a, 104b, and 104c of the absorber 104 are assembled in the respective divisional sections 100a to 100c. When the divisional sections 100a to 100c are assembled in the ship, the divisional sections 104a to 104c are integrally assembled in the absorber 104.

[0312] The preferred embodiments of the present invention have been described. However, the present invention is not limited to the above-described embodiments, and various changes may be made to the embodiments without departing from the object of the present invention. The ship desulfurization device according to the present invention may be suitably used for ultra large container ships (ULCSs) having a container load capacity of not less than 10,000 TEU. However, the ship desulfurization device according to the present invention may also be used for large, medium, or small-sized container ships having a container load capacity of not greater than 10,000 TEU, or ships other than container ships, for example, cargo ships such as tankers or bulk carriers or general commercial ships such as passenger boats.

[0313] The present invention includes appropriate combinations of the above-described embodiments. For example, the absorber 30 may include the interior-space confirmation device 80 and the exhaust gas cooling device 85. Furthermore, the inventions according to the above-described certain embodiments include inventions applicable to a square absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and inventions applicable to a round absorber. These inventions may be applied to a square

absorber with an aspect ratio falling outside the range of 1: over 1.1 and 1: 6.0 or under 6.0 and to a round absorber.

Industrial Applicability

[0314] According to one embodiment, a ship desulfurization device can be implemented that is easily arranged in a ship such as an ultra large ship.

Reference Signs List

[0315]

1	Ship
2	Ship body
3	Upper deck
4	Accomodation house
6	Steel plate structure
8, 8A, 8B	Lateral bulkhead
9	Container
10	Engine room
12	Main engine
14	Auxiliary engine
20	Ship desulfurization device
30	Absorber
31	Interior space
31a	Storage space
31b	Lower-side interior space
31c	Upper-side interior space
31d	Outlet-side interior space
32	Absorber body unit
32a, 32b	Longitudinal wall surface

32c, 32d	Lateral wall surface
33	Exhaust gas inlet
34	Exhaust gas introducing unit
34A	Oblique portion
34B	Vertical portion
34a	One end
34b	Other end
35	Packed layer
35A	Packing material
36	Exhaust gas discharge unit
37	Mist eliminator
38, 38A, 38B	Spraying device
38a1	Longitudinal spray pipe
38a2	Spray nozzle
38b1	Lateral spray pipe
38b2	Spray nozzle
39a	End portion
39b	Other end portion
39c	End portion
40	Exhaust gas introducing device
42	Exhaust gas introducing pipe
43	Exhaust gas discharge pipe
44a to 44d	Auxiliary-engine exhaust gas introducing pipe
45	Exhaust gas inlet pipe
46	Exhaust gas outlet pipe
48a to 48d	Auxiliary-engine exhaust gas discharge pipe
50	Seawater feeding device
52	No. 1 sea chest

52a	Drainage dilution pump
54	No. 2 sea chest
54a	Seawater feeding pump
56	Seawater introducing pipe
58	Seawater feeding pipe
59	Seawater discharge pipe
60	Waste heat recovery device
70	Transverse member
70A	Transverse beam member
70B	Sheeting member
80	Interior space confirmation device
80A	Visual confirmation window
81	pH adjuster
81A	Rock-like alkaline agent
82	Partition
83	Ceiling portion
84	Anticorrosion layer
85	Exhaust gas cooling device
86	Emergency tank
87	Emergency cooling device
88	Emergency cooling water conduit
89	Emergency bypass device
90	Emergency on-off valve
91	Fixing member
92	Wall surface reinforcing member
93	Partitioning wall
94	Cooling water control valve
95	Pressure gauge

96	Cleaning liquid feeding device
97A	Cleaning liquid feeding line
97B	Bypass line
98	Control valve
99	Flowmeter
100	Hull integrated desulfurization device
102	Casing
103	Hull structure
104	Absorber
106	Engine casing
108	Crane
110, 116	Shell wall
112, 112a, 112b, 118	Rib
114, 120	Stiffener
122	Exhaust gas piping
124	Piping
126	Frame
p	Welding point

CLAIMS

1. A ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device comprising:

an absorber including an absorber body unit defining an interior space and configured such that exhaust gas flows through the interior space, and a visual confirmation window enabling the interior space to be viewed from outside of the absorber body unit, and

a spraying device capable of spraying a cleaning liquid over exhaust gas flowing through the interior space, wherein

the spraying device has a spray nozzle capable of injecting the cleaning liquid into the interior space,

the visual confirmation window is arranged at a position where a visual confirmation of a state of spraying of the cleaning liquid from the spray nozzle is enabled,

the interior space has a longitudinal direction,

the absorber body has an exhaust gas inlet at an end portion thereof with respect to the longitudinal direction, the exhaust gas inlet communicating with the inner space, and

the visual confirmation window is provided on the other side with respect to the longitudinal space direction.

2. A ship desulfurization device for desulfurizing exhaust gas discharged from an exhaust gas generation device mounted to a ship, the ship desulfurization device comprising:

an absorber including an absorber body unit defining an interior space and configured such that exhaust gas flows through the interior space, and a visual confirmation window enabling the interior space to be viewed from outside of the absorber body unit, and

the absorber body unit is configured such that exhaust gas flows from a lower side toward an upper side in a vertical direction, the absorber body unit having a mist eliminator provided above the spray nozzle in the interior space, and

the visual confirmation window is arranged above the spray nozzle and below the mist eliminator.

3. A ship comprising the ship desulfurization device according to claim 1 or 2 mounted therein.