EXHAUST GAS CLEANING SYSTEM AND METHOD FOR OPERATING EXHAUST GAS CLEANING SYSTEM

TECHNICAL FIELD

[0001] The present disclosure relates to an exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship, and a method for operating the exhaust gas cleaning system.

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 equivalent effect. 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 equivalent effect. Conventionally, for example in ultra-large ships such as ultra-large container ships (ULCS), low-sulfur fuel oil containing little sulfur is used to cope with this situation, but it is expected that the demand for installing a desulfurization device in the super-large ships as the alternative measure will increase in the future.

[0003] The amount of exhaust gas discharged from a main engine of a super-large ship (the amount of exhaust gas at 100% load) may reach, for example, 200,000 Nm^3/h or more. Further, to meet various electricity demands in the ship, the ultra-large ship is equipped with a plurality of power generation engines and boilers. Accordingly, the desulfurization device installed in the ultra-large ship requires a desulfurization tower having a large passage area in order to desulfurize a large amount of exhaust gas discharged from the main engine, the power generation engines, and the boilers.

[0004] Patent Document 1 discloses a marine exhaust gas cleaning system including a scrubbing water supply system for so-called open loop operation, in which scrubbing water introduced from the outside of the hull is used in a scrubber and then discharged to the outside

of the hull, and a scrubbing water supply system for so-called closed loop operation, in which scrubbing water (seawater or freshwater) circulating in the hull is cooled and then used in the scrubber. Further, Patent Document 1 discloses that the scrubbing water supply system for open loop operation and the scrubbing water supply system for closed loop operation are switchable from one to the other.

Citation List

Patent Literature

[0005] Patent Document 1: JP2017-19415A

SUMMARY

Problems to be Solved

[0006] Given the concern for further tightening of the exhaust gas regulations, it may be desired to modify an exhaust gas cleaning system having a facility that can perform open loop operation into one that is switchable to closed loop operation. This remodeling to the ship is desired to be easy and completed in a short time.

[0007] Further, since the ship to which the exhaust gas cleaning system is installed only has a limited space within the hull, if the occupied area (foot print) of the exhaust gas cleaning system is large, it may be difficult to install the exhaust gas cleaning system.

[0008] In view of the above, an object of at least one embodiment of the present invention is to provide an exhaust gas cleaning system that can be easily obtained by remodeling an exist exhaust gas cleaning system and can suppress an increase in occupied area.

Solution to the Problems

[0009] (1) According at least one embodiment of the present invention, an exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship comprises: a desulfurization tower defining therein a gas-liquid contact part for bringing the exhaust gas into contact with a scrubbing liquid, an intake part for taking

outboard water from an outside of a hull, a supply passage connecting the intake part and the desulfurization tower, a discharge passage for draining the scrubbing liquid discharged from the desulfurization tower to the outside of the hull, a circulation passage for returning the scrubbing liquid discharged from the desulfurization tower to the supply passage as a circulation liquid, the circulation passage joining the supply passage at a junction part, a supply-side switch device for switching a supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage, and a discharge-side switch device for switching an outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage.

[0010] According the above configuration (1), the exhaust gas cleaning system includes the supply-side switch device for switching the supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage, and the discharge-side switch device for switching the outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage. The exhaust gas cleaning system is switchable by the supply-side switch device and the discharge-side switch device between open loop operation, using the outboard water as the supply source and the discharge passage as the outlet of scrubbing liquid, and closed loop, using the circulation liquid as the supply source and the circulation passage as the outlet of scrubbing liquid.

[0011] Further, in the exhaust gas cleaning system, the desulfurization tower and portions of the supply passage downstream of the junction part are shared by both operating states of open loop operation and closed loop operation. Sharing the desulfurization tower and the portions of the supply passage downstream of the junction part enables easy modification from an existing exhaust gas cleaning system and suppresses an increase in footprint of the exhaust gas cleaning system.

[0012] (2) In some embodiments, the exhaust gas cleaning system described in the above

(1) further comprises: a water feed pump disposed downstream of the junction part on the supply passage; and a storage tank disposed on the circulation passage and capable of storing the circulation liquid.

[0013] With the above configuration (2), the water feed pump is also shared by both operating states of open loop operation and closed loop operation. Thus, as with the above configuration (1), the exhaust gas cleaning system can be easily obtained by remodeling an existing exhaust gas cleaning system, while suppressing an increase in footprint of the exhaust gas cleaning system.

Further, by storing the circulation liquid in the storage tank, the circulation liquid can be stably supplied to the desulfurization tower during closed loop operation. In addition, when the operating state is switched from closed loop operation to open loop operation, by storing the circulation liquid remaining in the circulation passage in the storage tank, it is possible to rapidly switch the operating state.

[0014] (3) In some embodiments, the exhaust gas cleaning system described in the above (2) further comprises: a storage amount acquisition device capable of acquiring a storage amount of the circulation liquid in the storage tank; an outboard water feed device capable of feeding the outboard water to the storage tank; and a control part configured to control a feed amount of the outboard water to the storage tank by the outboard water feed device, in accordance with the storage amount acquired by the storage amount acquisition device.

[0015] With the above configuration (3), since the control part controls the amount of outboard water fed to the storage tank by the outboard water feed device in accordance with the storage amount acquired by the storage amount acquisition device, the exhaust gas cleaning system can achieve an appropriate storage amount in the storage tank.

[0016] (4) In some embodiments, the exhaust gas cleaning system described in the above (3) further comprises: a pH detection device capable of detecting a pH of the circulation liquid in the storage tank; and a neutralizer addition device capable of adding a neutralizer to the storage tank. The control part is configured to control an addition amount of the neutralizer by the neutralizer addition device, in accordance with the pH detected by the pH detection

device.

[0017] With the above configuration (4), since the control part controls the amount of the neutralizer added by the neutralizer addition device in accordance with the pH detected by the pH detection device, the exhaust gas cleaning system can prevent excessive consumption of the neutralizer and reduce corrosion of the facility and pipes, such as the water feed pump, disposed downstream of the storage tank. By reducing corrosion of the facility and pipes such as the water feed pump, the exhaust gas cleaning system can stably clean exhaust gas over a long period of time.

[0018] (5) In some embodiments, the exhaust gas cleaning system described in the above (3) or (4) further comprises: a circulation liquid treatment device capable of removing an impurity from the circulation liquid; a treatment liquid passage for supplying the circulation liquid to the circulation liquid treatment device as a liquid to be treated by the circulation liquid treatment device; and a treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the treatment liquid passage.

[0019] With the above configuration (5), the circulation liquid containing concentrated impurities due to repeated exhaust gas cleaning is transferred to the circulation liquid treatment device via the treatment liquid passage as the liquid to be treated by the circulation liquid treatment device. This prevents clogging and scaling of the pipes, enabling stable operation.

[0020] (6) In some embodiments, the exhaust gas cleaning system described in the above (5) further comprises a specific gravity detection device capable of detecting a specific gravity of the scrubbing liquid after cleaning the exhaust gas. The control part is configured to control an opening degree of the treatment-liquid-flow-rate control valve, in accordance with the specific gravity of the scrubbing liquid after cleaning the exhaust gas detected by the specific gravity detection device.

[0021] Scrubbing liquid (circulation liquid) containing concentrated impurities due to repeated exhaust gas cleaning tends to have a higher specific gravity. With the above configuration (6), since the control part controls the opening degree of the treatment-liquid-

flow-rate control valve in accordance with the specific gravity of the scrubbing liquid after cleaning exhaust gas detected by the specific gravity detection device, the scrubbing liquid (liquid to be treated) flows through the treatment liquid passage at an appropriate flow rate. Flowing the scrubbing liquid (liquid to be treated) through the treatment liquid passage at an appropriate flow rate prevents clogging and scaling of the pipes, enabling stable operation. Further, since an excess amount of the scrubbing liquid is prevented from flowing through the treatment liquid passage, it is possible to reduce the treatment amount of the liquid to be treated by the circulation liquid treatment device.

[0022] (7) In some embodiments, the exhaust gas cleaning system described in the above (5) or (6) further comprises a treatment liquid storage tank disposed on the treatment liquid passage and capable of storing the liquid to be treated.

[0023] With the above configuration (7), since a part of the liquid to be treated by the circulation liquid treatment device is stored in the treatment liquid storage tank, the exhaust gas cleaning system can treat the liquid even with a downsized circulation liquid treatment device having a small treatment capacity per time unit. Further, by downsizing the circulation liquid treatment device, it is possible to reduce the space and equipment cost of the exhaust gas cleaning system.

[0024] (8) In some embodiments, in the exhaust gas cleaning system described in any one of the above (5) to (7), the treatment liquid passage includes a first treatment liquid passage connecting a first branching part disposed downstream of the water feed pump on the supply passage to the circulation liquid treatment device, and the treatment-liquid-flow-rate control valve includes a first treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the first treatment liquid passage.

[0025] With the above configuration (8), since the first treatment-liquid-flow-rate control valve controls the flow rate of the liquid to be treated in the first treatment liquid passage, in the exhaust gas cleaning system, an appropriate amount of the liquid flows into the circulation liquid treatment device from the supply passage via the first treatment liquid passage. Further, since the first treatment liquid passage is disposed downstream of the water feed

pump on the supply passage, pump pressure of the water feed pump acts on the liquid to be treated in the first treatment liquid passage. Accordingly, the first treatment liquid passage on which pump pressure of the water feed pump acts can increase the lift or horizontal distance from the water feed pump to the circulation liquid treatment device. Thus, it is possible to increase the degree of freedom in the piping design of the first treatment liquid passage.

[0026] (9) In some embodiments, in the exhaust gas cleaning system described in any one of the above (5) to (8), the treatment liquid passage includes a second treatment liquid passage connecting the storage tank to the circulation liquid treatment device, and the treatment-liquid-flow-rate control valve includes a second treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the second treatment liquid passage.

[0027] With the above configuration (9), since the second treatment-liquid-flow-rate control valve controls the flow rate of the liquid to be treated in the second treatment liquid passage, in the exhaust gas cleaning system, an appropriate amount of the liquid flows into the circulation liquid treatment device from the storage tank via the second treatment liquid passage. In addition, in the exhaust gas cleaning system, after closed loop operation is switched to open loop operation, the circulation liquid remaining in the storage tank can flow into the second treatment liquid passage. Thus, it is possible to rapidly switch closed loop operation to open loop operation.

[0028] (10) In some embodiments, in the exhaust gas cleaning system described in the above (9), the control part is configured to perform control to open the second treatment-liquid-flow-rate control valve when the storage amount acquired by the storage amount acquisition device exceeds an upper threshold.

[0029] With the above configuration (10), since the control part performs control to open the second treatment-liquid-flow-rate control valve when the storage amount acquired by the storage amount acquisition device exceeds the upper threshold, the exhaust gas cleaning system can rapidly discharge the excess circulation liquid stored in the storage tank from the

storage tank.

[0030] (11) In some embodiments, in the exhaust gas cleaning system described in any one of the above (3) to (10), the control part is configured to perform control to switch the supply source to the outboard water taken by the intake part through the supply-side switch device when the storage amount acquired by the storage amount acquisition device is less than a lower threshold.

[0031] With the above configuration (11), since the control part performs control to switch the supply source to outboard water taken by the intake part through the supply-side switch device when the storage amount acquired by the storage amount acquisition device is less than the lower threshold, the exhaust gas cleaning system can rapidly cover the shortage of the circulation liquid in the storage tank.

[0032] (12) In some embodiments, in the exhaust gas cleaning system described in any one of the above (2) to (11), the desulfurization tower further defines therein a liquid reservoir disposed below the gas-liquid contact part, and the storage tank disposed below the liquid reservoir.

[0033] With the above configuration (12), since the liquid reservoir and the storage tank are defined inside the desulfurization tower, it is unnecessary to separately provide the storage tank outside the desulfurization tower, so that it is possible to suppress an increase in footprint of the exhaust gas cleaning system.

[0034] (13) According at least one embodiment of the present invention, a method for operating exhaust gas cleaning system is for operating an exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship, comprising: a desulfurization tower defining therein a gas-liquid contact part for bringing the exhaust gas into contact with a scrubbing liquid; an intake part for taking outboard water from an outside of a hull; a supply passage connecting the intake part and the desulfurization tower; a discharge passage for draining the scrubbing liquid discharged from the desulfurization tower to the outside of the hull; a circulation passage for returning the scrubbing liquid discharged from the desulfurization tower to the supply passage as a circulation liquid, the

circulating passage joining the supply passage at a junction part; a water feed pump disposed downstream of the junction part on the supply passage; a supply-side switch device for switching a supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage; and a discharge-side switch device for switching an outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage. The method comprises: a first supply source switching step of switching the supply source of the scrubbing liquid by the supply-side switch device from the outboard water taken by the intake part to the circulation liquid returned to the supply passage via the circulation passage; and a first outlet switching step of switching the outlet of the scrubbing liquid by the discharge-side switch device from the discharge passage to the circulation passage.

[0035] According to the method described in the above (13), the exhaust gas cleaning system operating method can switch the operating state of the exhaust gas cleaning system from open loop operation to closed loop operation by performing the first supply source switching step of switching the supply source of the scrubbing liquid by the supply-side switch device from outboard water taken by the intake part to the circulation liquid returned to the supply passage via the circulation passage, and the first outlet switching step of switching the outlet of the scrubbing liquid by the discharge-side switch device from the discharge passage to the circulation passage.

[0036] (14) In some embodiments, in the method for operating the exhaust gas cleaning system described in the above (13), the exhaust gas cleaning system further comprises: a storage tank disposed on the circulation passage and capable of storing the circulation liquid; and a storage amount acquisition device capable of acquiring a storage amount of the circulation liquid in the storage tank. The method further comprises a storage amount acquisition step of acquiring the storage amount of the circulation liquid by the storage amount acquisition device. The first supply source switching step is performed after the first outlet switching step is performed and the storage amount acquired by the storage amount

acquisition step exceeds a predetermined amount.

[0037] With the above method (14), the exhaust gas cleaning system operating method can acquire the storage amount of the circulation liquid in the storage tank by the storage amount acquisition step. Further, after the first outlet switching step is performed and the storage amount in the storage tank exceeds the predetermined amount, the first supply source switching step is performed. In such an exhaust gas cleaning system operating method, since a sufficient amount of the circulation liquid is stored in the storage tank when the supply source is switched from outboard water to the circulation liquid, it is possible to suppress a reduction in exhaust gas cleaning capacity due to the lack of the circulation liquid.

[0038] (15) According at least one embodiment of the present invention, a method for operating exhaust gas cleaning system is for operating an exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship, comprising: a desulfurization tower defining therein a gas-liquid contact part for bringing the exhaust gas into contact with a scrubbing liquid; an intake part for taking outboard water from an outside of a hull; a supply passage connecting the intake part and the desulfurization tower; a discharge passage for draining the scrubbing liquid discharged from the desulfurization tower to the outside of the hull; a circulation passage for returning the scrubbing liquid discharged from the desulfurization tower to the supply passage as a circulation liquid, the circulating passage joining the supply passage at a junction part; a water feed pump disposed downstream of the junction part on the supply passage; a supply-side switch device for switching a supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage; and a discharge-side switch device for switching an outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage. The method comprises: a second supply source switching step of switching the supply source of the scrubbing liquid by the supply-side switch device from the circulation liquid returned to the supply passage via the circulation passage to the outboard water taken by the intake part; and a second outlet

switching step of switching the outlet of the scrubbing liquid by the discharge-side switch device from the circulation passage to the discharge passage.

[0039] According to the method described in the above (15), the exhaust gas cleaning system operating method can switch the operating state of the exhaust gas cleaning system from closed loop operation to open loop operation by performing the second supply source switching step of switching the supply source of the scrubbing liquid by the supply-side switch device from the circulation liquid returned to the supply passage via the circulation passage to outboard water taken by the intake part, and the second outlet switching step of switching the outlet of the scrubbing liquid by the discharge-side switch device from the circulation passage to the discharge passage.

[0040] (16) In some embodiments, in the method for operating the exhaust gas cleaning system described in the above (15), the exhaust gas cleaning system further comprises: a storage tank disposed on the circulation passage and capable of storing the circulation liquid; a circulation liquid treatment device capable of removing an impurity from the circulation liquid; a treatment liquid passage for supplying the circulation liquid to the circulation liquid treatment device as a liquid to be treated by the circulation liquid treatment device, the treatment liquid passage connecting the storage tank to the circulation liquid treatment device; and a treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the treatment liquid passage. The method further comprises a circulation liquid discharge step of, after the second supply source switching step and the second outlet switching step, opening the treatment-liquid-flow-rate control valve to transfer the circulation liquid stored in the storage tank to the circulation liquid treatment device.

[0041] With the above method (16), since the exhaust gas cleaning system operating method further includes the circulation liquid discharge step of, after the second supply source switching step and the second outlet switching step, opening the treatment-liquid-flow-rate control valve (second treatment-liquid-flow-rate control valve) to transfer the circulation liquid stored in the storage tank to the circulation liquid treatment device, when the operating state of the exhaust gas cleaning system is switched from closed loop operation to open loop

operation, it is possible to discharge the circulation liquid remaining in the storage tank to the circulation liquid treatment device disposed outside the storage tank.

Advantageous Effects

[0042] At least one embodiment of the present invention provides an exhaust gas cleaning system that can be easily obtained by remodeling an exist exhaust gas cleaning system and can suppress an increase in occupied area.

BRIEF DESCRIPTION OF DRAWINGS

[0043] FIG. 1 is a perspective view of a ship including an exhaust gas cleaning system according to an embodiment.

FIG. 2 is an enlarged perspective view of a steel plate structure and the vicinity thereof in the ship shown in FIG. 1.

FIG. 3 is a schematic configuration diagram of an exhaust gas cleaning system according to an embodiment.

FIG. 4 is a schematic configuration diagram of an exhaust gas cleaning system that can perform open loop operation according to a comparative example.

FIG. 5 is a schematic configuration diagram of an exhaust gas cleaning system according to another embodiment.

FIG. 6 is a schematic cross-sectional view of a storage tank, for describing control of the storage amount of the storage tank.

FIG. 7 is a schematic configuration diagram of an exhaust gas cleaning system according to another embodiment.

FIG. 8 is a schematic configuration diagram of an exhaust gas cleaning system according to another embodiment.

FIG. 9 is a flowchart for describing a method for operating an exhaust gas cleaning system according to an embodiment.

FIG. 10 is a flowchart for describing a method for operating an exhaust gas cleaning

system according to another embodiment.

DETAILED DESCRIPTION

[0044] Embodiments of the present invention will now be described in detail with reference to the accompanying drawings. It is intended, however, that unless particularly identified, dimensions, materials, shapes, relative positions, and the like of components described in the embodiments shall be interpreted as illustrative only and not intended to limit the scope of the present invention.

For instance, an expression of relative or absolute arrangement such as “in a direction”, “along a direction”, “parallel”, “orthogonal”, “centered”, “concentric” and “coaxial” shall not be construed as indicating only the arrangement in a strict literal sense, but also includes a state where the arrangement is relatively displaced by a tolerance, or by an angle or a distance whereby it is possible to achieve the same function.

For instance, an expression of an equal state such as “same” “equal” and “uniform” shall not be construed as indicating only the state in which the feature is strictly equal, but also includes a state in which there is a tolerance or a difference that can still achieve the same function.

Further, for instance, an expression of a shape such as a rectangular shape or a cylindrical shape shall not be construed as only the geometrically strict shape, but also includes a shape with unevenness or chamfered corners within the range in which the same effect can be achieved.

On the other hand, an expression such as “comprise”, “include”, “have”, “contain” and “constitute” are not intended to be exclusive of other components.

The same features can be indicated by the same reference numerals and not described in detail.

[0045] FIG. 1 is a perspective view of a ship including an exhaust gas cleaning system according to an embodiment. The exhaust gas cleaning system 20 is installed in a ship 1 as shown in FIG. 1. The ship 1 may be an ultra-large ship including a main engine the amount

of exhaust gas discharged from which (the amount of exhaust gas at 100% load) exceeds 200,000 Nm^3/h, for example as shown in FIG. 1. In the embodiment shown in FIG. 1, the ship 1 is an ultra-large container ship, called ULCS, having a container load capacity of 10,000 TEU or more.

[0046] As shown in FIG. 1, the ship 1 includes a hull 2 having a shell including an upper deck 3, a side shell 4, and a bottom shell 5, an accommodation house 6 protruding from the upper deck 3, and a steel plate structure 7 protruding from the upper deck 3. The steel plate structure 7 is referred to as a stack or an engine casing. In the embodiment shown FIG. 1, the accommodation house 6 is disposed relatively forward of center in the fore-aft direction, and the steel plate structure 7 is disposed aft of the accommodation house 6.

[0047] FIG. 2 is an enlarged perspective view of a steel plate structure and the vicinity thereof in the ship shown in FIG. 1. As shown in FIG. 2, an engine room 8 is formed inside the hull 2. In the embodiment shown in FIG. 2, the engine room 8 is disposed vertically below the steel plate structure 7. The engine room 8 is provided with a main engine 11 including a marine diesel engine for providing propulsion to the ship 1 and a main boiler for driving a main turbine, and a plurality of auxiliary engines including an auxiliary boiler for responding various heat demands in the ship 1 and an auxiliary engine for responding electricity demands. The main engine 11 and the auxiliary engines 12 correspond to an exhaust gas generating device 10 installed in the ship 1.

[0048] The steel plate structure 7 is a structure for emitting exhaust gas discharged from the exhaust gas generating device 10 such as the main engine 11 and the auxiliary engines 12 to the outside of the ship 1. In the embodiment shown in FIGs. 1 and 2, the steel plate structure 7 is formed in an elongated cylinder shape having a longitudinal direction along the starboard-port direction (width direction) of the ship 1.

[0049] As shown in FIG. 2, inside the steel plate structure 7, a desulfurization tower 30 for cleaning (desulfurizing) exhaust gas discharged from the exhaust gas generating device 10 such as the main engine 11 and the auxiliary engines 12, and an exhaust gas introducing device 13 for introducing exhaust gas discharged from the exhaust gas generating device 10

into the desulfurization tower 30 are disposed.

[0050] FIG. 3 is a schematic configuration diagram of an exhaust gas cleaning system according to an embodiment. As shown in FIG. 3, the desulfurization tower 30 includes a desulfurization tower body 31, an exhaust gas introducing part, 32, and an exhaust gas discharge part 33. The desulfurization tower body 31 defines therein an interior space 34. Further, a wall surface 35 of the desulfurization tower body 31 adjacent to the exhaust gas introducing part 32 has an exhaust gas introducing port 36 communicating with the interior space 34 (lower interior space 34B). Exhaust gas passing through the exhaust gas introducing part 32 and introduced from the exhaust gas introducing port 36 into the interior space 34 flows away from the exhaust gas introducing part 32 and then flows upward in the interior space 34.

[0051] As shown in FIG. 3, the desulfurization tower 30 further includes a spraying device 37 capable of spraying scrubbing liquid (e.g., seawater) to exhaust gas flowing in the interior space 34. The spraying device 37 may be any device that can efficiently bring liquid into contact with gas, and is not limited to a configuration which jets the scrubbing liquid downward as shown in FIG. 3, for example. In the embodiment shown in FIG. 3, the spraying device 37 includes a plurality of water spray pipes 37A extending along the horizontal direction and arranged at regular intervals, and at least one water spray nozzle 37B disposed on each of the plurality of water spray pipes 37A and capable of jetting the scrubbing liquid to the interior space 34. The interior space 34 includes a lower interior space 34B formed below the spraying device 37 and an upper interior space 34C formed above the spraying device 37. Further, the desulfurization tower 30 defines therein a gas-liquid contact part 38 for bringing exhaust gas into contact with the scrubbing liquid.

[0052] In the embodiment shown in FIG. 3, the spraying device 37 is disposed on a relatively upper side of the interior space 34 and jets the scrubbing liquid downward, i.e., in a direction opposite to the flowing direction of exhaust gas. Further, the spraying device 37 is configured to spray the scrubbing liquid to exhaust gas flowing in the lower interior space 34B and bring the scrubbing liquid into contact with the exhaust gas to remove sulfur

contained in the exhaust gas. In the above configuration, the lower interior space 34B corresponds to the gas-liquid contact part 38.

[0053] In the embodiment shown in FIG. 3, the interior space 34 has a mist eliminator 39 disposed at an upper portion of the upper interior space 34C and separating the upper interior space 34C from an outlet interior space 34D. The mist eliminator 39 is configured to remove moisture from exhaust gas passing through the mist eliminator 39. The exhaust gas having passed through the mist eliminator 39 is discharged from the exhaust gas discharge part 33, which is connected to the uppermost portion of the desulfurization tower body 31, to the outside of the ship 1 via the outlet interior space 34D.

[0054] Further, in the embodiment shown in FIG. 3, the desulfurization tower body 31 has a liquid reservoir 34A for storing the scrubbing liquid that has sprayed to exhaust gas introduced into the interior space 34, i.e., the scrubbing liquid after cleaning the exhaust gas. The liquid reservoir 34A is formed, at a lower portion of the lower interior space 34B, below the lower surface of the exhaust gas introducing port 36.

[0055] As shown in FIG. 3, the exhaust gas cleaning system 20 includes the above-described desulfurization tower 30, an intake part 41 for taking outboard water from the outside of the hull 2, a supply passage 40 connecting the intake part 41 and the desulfurization tower 30, a discharge passage 50 for draining the scrubbing liquid discharged from the desulfurization tower 30 to the outside of the hull 2, and a water feed pump 43 disposed on the supply passage 40. In this case, the exhaust gas cleaning system 20 can perform open loop operation. Here, the outboard water means water located outside the hull 2, including seawater, river water, and lake water. The intake part 41 is an opening formed below the waterline of the hull 2 and communicating with the outside of the hull 2.

[0056] In open loop operation, outboard water taken by the intake part 41 is transferred from the intake part 41 to the spraying device 37 of the desulfurization tower 30 via the supply passage 40 as the scrubbing liquid. At this time, the outboard water (scrubbing liquid) is transferred to the spraying device 37 by driving the water feed pump 43. Then, the scrubbing liquid is sprayed by the spraying device 37 and comes into contact with exhaust gas

flowing in the interior space 34 of the desulfurization tower 30 to clean the exhaust gas. In open loop operation, the scrubbing liquid after cleaning exhaust gas is discharged from the desulfurization tower 30 and then expelled to the outside of the hull 2 via the discharge passage 50.

[0057] As shown in FIG. 3, the exhaust gas cleaning system 20 may further include an effluent treatment device 51 disposed on the discharge passage 50 and capable of treating the scrubbing liquid (effluent) flowing in the discharge passage 50. The effluent treatment in the effluent treatment device 51 involves adding outboard water to effluent to dilute the effluent and adjust the pH of the effluent. Further, the effluent treatment in the effluent treatment device 51 may involve removing impurities (pollutants) from the effluent. The effluent is discharged outside the hull 2 after treatment by the effluent treatment device 51. Such an exhaust gas cleaning system 20 including the effluent treatment device 51 can suppress pollution of outboard water outside the hull 2 due to emission of the effluent outside the hull 2.

[0058] As shown in FIG. 3, the exhaust gas cleaning system 20 further includes a circulation passage 60 joining the supply passage 40 at a junction part 42 for returning the scrubbing liquid discharged from the desulfurization tower 30 to the supply passage 40 as circulation liquid, a supply-side switch device 71 for switching a supply source of the scrubbing liquid supplied to the desulfurization tower 30 to either one of outboard water taken by the intake part 41 or the circulation liquid returned to the supply passage 40 via the circulation passage 60, and a discharge-side switch device 72 for switching an outlet of the scrubbing liquid discharged from the desulfurization tower 30 to either one of the discharge passage 50 or the circulation passage 60. The water feed pump 43 is disposed downstream of the junction part 42 on the supply passage 40. In this case, the exhaust gas cleaning system 20 can perform open loop operation and closed loop operation, and the operating state of the exhaust gas cleaning system 20 can be switched between open loop operation and closed loop operation.

[0059] In closed loop operation, the scrubbing liquid after cleaning exhaust gas is returned to the supply passage 40 as the circulation liquid and transferred to the spraying

device 37 of the desulfurization tower 30 via the supply passage 40. At this time, the circulation liquid (scrubbing liquid) is transferred to the spraying device 37 by driving the water feed pump 43. Then, the circulation liquid is sprayed by the spraying device 37 and comes into contact with exhaust gas flowing in the interior space 34 of the desulfurization tower 30 to clean the exhaust gas.

[0060] As shown in FIG. 3, the supply-side switch device 71 is electrically connected to the control part 21 and is capable of switching the supply source of the scrubbing liquid supplied to the desulfurization tower 30 in response to a signal transmitted from the control part 21. The control part 21 comprises a microcomputer including a central processing unit (CPU), a random access memory (RAM), a read only memory (ROM), and an I/O interface. In the embodiment shown in FIG. 3, the supply-side switch device 71 is a supply-side three-way valve 73 disposed at the junction part 42 of the supply passage 40 with the circulation passage 60.

[0061] As shown in FIG. 3, the discharge-side switch device 72 is electrically connected to the control part 21 and is capable of switching the outlet of the scrubbing liquid discharged from the desulfurization tower 30 in response to a signal transmitted from the control part 21. In the embodiment shown in FIG. 3, the discharge-side switch device 72 is a discharge-side three-way valve 74 disposed at a branching part 52 of the discharge passage 50 from the circulation passage 60.

[0062] In the embodiment shown in FIG. 3, the supply passage 40 includes a supply pipe 40A connecting the intake part 41 to the supply-side three-way valve 73, a supply pipe 40B connecting the supply-side three-way valve 73 to the water feed pump 43, and a supply pipe 40C connecting the water feed pump 43 to the spraying device 37. The discharge passage 50 includes a discharge pipe 50A connecting the desulfurization tower 30 to the discharge-side three-way valve 74, and a discharge pipe 50B connecting the discharge-side three-way valve 74 to the effluent treatment device 51. Further, the circulation passage 60 is provided with a storage tank 61 defining therein an interior space 62 for storing the scrubbing liquid (circulation liquid). The circulation passage 60 includes a circulation pipe 60A sharing a

pipe with the discharge pipe 50A and connecting the desulfurization tower 30 to the discharge-side three-way valve 74, a circulation pipe 60B connecting the discharge-side three-way valve 74 to the storage tank 61, and a circulation pipe 60C connecting the storage tank 61 to the supply-side three-way valve 73.

[0063] In open loop operation, the supply-side switch device 71 sets outboard water taken by the intake part 41 as the supply source of the scrubbing liquid, and the discharge-side switch device 72 sets the discharge passage 50 as the outlet of the scrubbing liquid. In normal open loop operation, the scrubbing liquid flows through the supply pipes 40A, 40B, 40C and the discharge pipes 50A, 50B in this order.

[0064] In closed loop operation, the supply-side switch device 71 sets the circulation liquid returned to the supply passage 40 via the circulation passage 60 as the supply source of the scrubbing liquid, and the discharge-side switch device 72 sets the circulation passage 60 as the outlet of the scrubbing liquid. In normal closed loop operation, the scrubbing liquid (circulation liquid) flows through the circulation pipes 60A, 60B, 60C and the supply pipes 40B, 40C in this order.

[0065] Next, switching from open loop operation to closed loop operation will be described. First, the discharge-side switch device 72 switches the outlet of the scrubbing liquid from the discharge passage 50 (discharge pipe 50B) to the circulation passage 60 (circulation pipe 60B) in response to a signal transmitted from the control part 21 (first outlet switching step S202). Then, the supply-side switch device 71 switches the supply source of the scrubbing liquid from outboard water taken by the intake part 41 to the circulation liquid returned to the supply passage 40 via the circulation passage 60 in response to a signal transmitted from the control part 21 (first supply source switching step S201). By performing the first supply source switching step S201 and the first outlet switching step S202, the operating state of the exhaust gas cleaning system 20 is switched from open loop operation to closed loop operation.

[0066] Next, switching from closed loop operation to open loop operation will be described. First, the supply-side switch device 71 switches the supply source of the

scrubbing liquid from the circulation liquid returned to the supply passage 40 via the circulation passage 60 to outboard water taken by the intake part 41 in response to a signal transmitted from the control part 21 (second supply source switching step S301). Then, the discharge-side switch device 72 switches the outlet of the scrubbing liquid from the circulation passage 60 (circulation pipe 60B) to the discharge passage 50 (discharge pipe 50B) in response to a signal transmitted from the control part 21 (second outlet switching step S302). By performing the second supply source switching step S301 and the second outlet switching step S302, the operating state of the exhaust gas cleaning system 20 is switched from closed loop operation to open loop operation.

[0067] FIG. 4 is a schematic configuration diagram of an exhaust gas cleaning system that can perform open loop operation according to a comparative example. As shown in FIG. 4, the exhaust gas cleaning system 20A according to the comparative example includes the desulfurization tower 30, the supply passage 40, the intake part 41, the water feed pump 43, the discharge passage 50, and the effluent treatment device 51. The exhaust gas cleaning system 20A can be remodeled into the exhaust gas cleaning system 20 by adding the circulation passage 60, the supply-side switch device 71, and the discharge-side switch device 72. When remodeling the exhaust gas cleaning system 20A into the exhaust gas cleaning system 20, the water feed pump 43 may be replaced with one that can be used for closed loop operation.

[0068] As described above, the exhaust gas cleaning system 20 according to some embodiments includes, as shown in FIG. 3, the desulfurization tower 30, the intake part 41, the supply passage 40, the discharge passage 50, the circulation passage 60, the supply-side switch device 71, and the discharge-side switch device 72.

[0069] According the above configuration, the exhaust gas cleaning system 20 includes the supply-side switch device 71 for switching the supply source of the scrubbing liquid supplied to the desulfurization tower 30 to either one of outboard water taken by the intake part 41 or the circulation liquid returned to the supply passage 40 via the circulation passage 60, and the discharge-side switch device 72 for switching the outlet of the scrubbing liquid

discharged from the desulfurization tower 30 to either one of the discharge passage 50 or the circulation passage 60. The exhaust gas cleaning system 20 is switchable by the supply-side switch device 71 and the discharge-side switch device 72 between open loop operation, using outboard water as the supply source and the discharge passage 50 as the outlet of the scrubbing liquid, and closed loop, using the circulation liquid as the supply source and the circulation passage 60 as the outlet of the scrubbing liquid.

[0070] Further, in the exhaust gas cleaning system 20, the desulfurization tower 30 and portions (supply pipes 40B and 40C) of the supply passage 40 downstream of the junction part 42 are shared by both operating states of open loop operation and closed loop operation. Sharing the desulfurization tower 30 and the portions (supply pipes 40B and 40C) of the supply passage 40 downstream of the junction part 42 enables easy modification from an existing exhaust gas cleaning system (e.g., exhaust gas cleaning system 20A) and suppresses an increase in footprint of the exhaust gas cleaning system 20.

[0071] As described above, in some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes the water feed pump 43, and the storage tank 61 disposed on the circulation passage 60 and capable of storing the circulation liquid. In this case, the water feed pump 43 is also shared by both operating states of open loop operation and closed loop operation, as well as the desulfurization tower 30 and the portions (supply pipes 40B and 40C) of the supply passage 40 downstream of the junction part 42 are shared. This enables easy modification from an existing exhaust gas cleaning system (e.g., exhaust gas cleaning system 20A) and suppresses an increase in footprint of the exhaust gas cleaning system 20.

[0072] Further, by storing the circulation liquid in the storage tank 61, the circulation liquid can be stably supplied to the desulfurization tower 30 during closed loop operation. In addition, when the operating state is switched from closed loop operation to open loop operation, by storing the circulation liquid remaining in the circulation passage 60 in the storage tank 61, it is possible to rapidly switch the operating state.

[0073] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a storage amount acquisition device 63 capable of acquiring the storage

amount of the circulation liquid in the storage tank 61, and an outboard water feed device 64 capable of feeding outboard water to the storage tank 61. The control part 21 controls the amount of outboard water fed to the storage tank 61 by the outboard water feed device 64, in accordance with the storage amount acquired by the storage amount acquisition device 63.

[0074] In the embodiment shown in FIG. 3, the storage amount acquisition device 63 is a water level detection sensor disposed in the storage tank 61 and configured to detect the water level of the storage tank 61. The outboard water feed device 64 includes a second intake part 641 for taking outboard water (feedwater) from the outside of the hull 2, an outboard water feed passage 640 for supplying the outboard water (feedwater) from the second intake part 641 to the storage tank 61, a second water feed pump 642 disposed on a middle portion of the outboard water feed passage 640, and a feedwater-flow-rate control valve 643 capable of controlling the flow rate of the outboard water (feedwater) in the outboard water feed passage 640. The feedwater-flow-rate control valve 643 is disposed downstream of the second water feed pump 642 on the outboard water feed passage 640. Further, the feedwater-flow-rate control valve 643 is electrically connected to the control part 21 and performs open/close control of the valve or adjusts the opening degree of the valve in response to a signal transmitted from the control part 21 to control the amount of outboard water fed to the storage tank 61. The storage amount acquisition device 63 is configured to be capable of acquiring the storage amount of the circulation liquid in the storage tank 61, but is not limited to the water level detection sensor described above. Further, the storage amount acquisition device 63 may be disposed outside the storage tank 61. For instance, the storage amount acquisition device 63 may calculate the storage amount in the storage tank 61 based on a difference in flow rate of the circulation liquid flowing through the circulation pipes 60B and 60C.

[0075] With the above configuration, since the control part 21 controls the amount of outboard water fed to the storage tank 61 by the outboard water feed device 64 in accordance with the storage amount acquired by the storage amount acquisition device 63, the exhaust gas cleaning system 20 can achieve an appropriate storage amount in the storage tank 61.

[0076] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a pH detection device 65 capable of detecting the pH of the circulation liquid in the storage tank 61, and a neutralizer addition device 66 capable of adding a neutralizer to the storage tank 61. The control part 21 is configured to control the amount of the neutralizer added by the neutralizer addition device 66, in accordance with the pH detected by the pH detection device 65.

[0077] In the embodiment shown in FIG. 3, the pH detection device 65 is a pH meter disposed in the storage tank 61. The neutralizer addition device 66 includes a neutralizer storage tank 661 for storing the neutralizer, a neutralizer supply passage 660 for supplying the neutralizer from the neutralizer storage tank 661 to the storage tank 61, a neutralizer supply pump 662 disposed on a middle portion of the neutralizer supply passage 660, and a neutralizer amount control valve 663 capable of controlling the amount of the neutralizer in the neutralizer supply passage 660. The neutralizer amount control valve 663 is disposed downstream of the neutralizer supply pump 662 on the neutralizer supply passage 660. The neutralizer amount control valve 663 is electrically connected to the control part 21 and performs open/close control of the valve or adjusts the opening degree of the valve in response to a signal transmitted from the control part 21 to control the amount of the neutralizer added to the storage tank 61. The pH detection device 65 is configured to be capable of detecting the pH of the circulation liquid in the storage tank 61, but is not limited to the pH meter described above. Further, the pH detection device 65 may be disposed outside the storage tank 61.

[0078] With the above configuration, since the control part 21 controls the amount of the neutralizer added by the neutralizer addition device 66 in accordance with the pH detected by the pH detection device 65, the exhaust gas cleaning system 20 can prevent excessive consumption of the neutralizer and reduce corrosion of the facility and pipes, such as the water feed pump 43, disposed downstream of the storage tank 61. By reducing corrosion of the facility and pipes such as the water feed pump 43, the exhaust gas cleaning system 20 can stably clean exhaust gas over a long period of time.

[0079] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a cooler 44 for cooling the scrubbing liquid (circulation liquid) during closed loop operation. In the embodiment shown in FIG. 3, the cooler 44 is disposed at a portion (supply pipe 40C) of the supply passage 40 downstream of the water feed pump 43. The cooler 44 includes a third intake part 441 for taking outboard water (coolant) from the outside of the hull 2, a cooling part 442 capable of cooling a portion (supply pipe 40C) of the supply passage 40 downstream of the water feed pump 43 by heat exchange with the outboard water (coolant), a coolant passage 440 for supplying the outboard water (coolant) from the third intake part 441 to the cooling part 442, and a third water feed pump 443 disposed on a middle portion of the coolant passage 440. After heat exchange at the cooling part 442, the outboard water (coolant) is expelled outside the hull 2. The cooler 44 operates during closed loop operation. In this case, the cooler 44 cools the scrubbing liquid (circulation liquid) flowing through the supply passage 40.

[0080] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a parallel water feed pump 43B disposed in parallel to the water feed pump 43. In the embodiment shown in FIG. 3, the supply passage 40 includes a bypass 431 bypassing the water feed pump 43. The parallel water feed pump 43B is disposed on the bypass 431. The bypass 431 is composed of a pipe connecting a portion (supply pipe 40B) of the supply passage 40 upstream of the water feed pump 43 to a portion (supply pipe 40C) of the supply passage 40 downstream of the water feed pump 43. With the above configuration, when the amount of water required to be supplied by the water feed pump 43 increases or decreases in response to the switching of the operating state of the exhaust gas cleaning system 20, it is possible to supply the necessary amount of water by additionally using the parallel water feed pump 43B disposed in parallel to the water feed pump 43, or using the parallel water feed pump 43B instead of the water feed pump 43.

[0081] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a pair of connection passages 444, 445 connecting the water feed pump 43 and the third water feed pump 443 in parallel. In the embodiment shown in FIG. 3, the

connection passage 444 (upstream connection passage) is composed of a pipe connecting upstream sides of the water feed pump 43 and the third water feed pump, and the connection passage 445 (downstream connection passage) is composed of a pipe connecting downstream sides of the water feed pump 43 and the third water feed pump. In other words, the connection passage 444 is composed of a pipe connecting a portion (supply pipe 40B) of the supply passage 40 upstream of the water feed pump 43 to a portion (supply pipe 440A) of the coolant passage 440 upstream of the third water feed pump 443. The connection passage 445 is composed of a pipe connecting a portion (supply pipe 40C) of the supply passage 40 downstream of the water feed pump 43 to a portion (supply pipe 440B) of the coolant passage 440 downstream of the third water feed pump 443. A valve (open/close valve, flow control valve) may be disposed on the connection passages 444, 445. With the above configuration, since water is supplied by the parallel water feed pump 43B, when water is not supplied from the supply pipe 40B to the water feed pump 43, the water feed pump 43 can be used instead of the third water feed pump 443. In other words, water can be supplied to the cooler 44 by the water feed pump 43. Thus, the above configuration can eliminate the third water feed pump 443 from the exhaust gas cleaning system 20.

[0082] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a circulation liquid treatment device 81 capable of removing impurities from the circulation liquid, a treatment liquid passage 80 for supplying the circulation liquid to be treated by the circulation liquid treatment device 81 to the circulation liquid treatment device 81, and a treatment-liquid-flow-rate control valve 82 capable of controlling the flow rate of the liquid to be treated in the treatment liquid passage 80.

[0083] In the embodiment shown in FIG. 3, the treatment liquid passage 80 includes a first treatment liquid passage 83 connecting a first branching part 45 disposed downstream of the water feed pump 43 on the supply passage 40 to the circulation liquid treatment device 81, and a second treatment liquid passage 85 connecting the storage tank 61 to the circulation liquid treatment device 81. The treatment-liquid-flow-rate control valve 82 includes a first treatment-liquid-flow-rate control valve 84 capable of controlling the flow rate of the liquid to

be treated in the first treatment liquid passage 83, and a second treatment-liquid-flow-rate control valve 86 capable of controlling the flow rate of the liquid to be treated in the second treatment liquid passage 85. As shown in FIG. 3, between the storage tank 61 and the second treatment-liquid-flow-rate control valve 86 on the second treatment liquid passage 85, a fourth water feed pump 87 for supplying the circulation liquid (liquid to be treated) from the storage tank 61 to the circulation liquid treatment device 81 is disposed.

[0084] As shown in FIG. 3, impurities removed from the circulation liquid (treated liquid) in the circulation liquid treatment device 81 are stored in an impurity tank 100. Further, in the circulation liquid treatment device 81, the circulation liquid (treated liquid) from which impurities are removed is discharged through a treatment liquid discharge passage 102. In the embodiment shown in FIG. 3, the treatment liquid discharge passage 102 includes a treatment liquid pipe 102A connecting the circulation liquid treatment device 81 to a branching part 103, a treatment liquid pipe 102B connecting the branching part 103 to a middle portion of the discharge pipe 50B, and a treatment liquid pipe 102C connecting the branching part 103 to a treatment liquid tank 101 capable of storing the treated liquid. The treatment liquid pipe 102B is provided with a first treatment-liquid-flow-rate control valve 104 capable of controlling the flow rate of the liquid flowing through the treatment liquid pipe 102B after treatment by the circulation liquid treatment device 81. Further, the treatment liquid pipe 102C is provided with a second treatment-liquid-flow-rate control valve 105 capable of controlling the flow rate of the treated liquid flowing through the treatment liquid pipe 102C after treatment by the circulation liquid treatment device 81.

[0085] When closed loop operation is switched to open loop operation, the first treatment-liquid-flow-rate control valve 104 is opened, and the second treatment-liquid-flow-rate control valve 105 is closed. Further, the treated liquid discharged from the treatment liquid discharge passage 102 is transferred to the effluent treatment device 51 via the treatment liquid pipes 102A, 102B and the discharge pipe 50B. Since the circulation liquid remaining in the storage tank 61 can be treated and discharged via the second treatment liquid passage 85, it is possible to rapidly switch to open loop operation.

[0086] In closed loop operation, the second treatment-liquid-flow-rate control valve 105 is opened, and the first treatment-liquid-flow-rate control valve 104 is closed. Further, the treated liquid discharged from the treatment liquid discharge passage 102 is transferred to the treatment liquid tank 101 via the treatment liquid pipes 102A, 102C. After closed loop operation is switched to open loop operation, the treated liquid stored in the treatment liquid tank 101 is transferred to the effluent treatment device 51 via a second treatment liquid discharge passage 106.

[0087] With the above configuration, the circulation liquid containing concentrated impurities due to repeated exhaust gas cleaning is transferred to the circulation liquid treatment device 81 via the treatment liquid passage 80 as the liquid to be treated by the circulation liquid treatment device 81. This prevents clogging and scaling of the pipes (e.g., supply pipes 40B, 40C and circulation pipes 60A to 60C), enabling stable operation.

[0088] In other embodiments, the treatment liquid passage 80 may include only one of the first treatment liquid passage 83 or the second treatment liquid passage 85, or may include neither the first treatment liquid passage 83 not the second treatment liquid passage 85. Further, the treatment liquid passage 80 may include a treatment liquid passage other than the first treatment liquid passage 83 and the second treatment liquid passage 85.

[0089] In some embodiments, as shown in FIG. 3, the exhaust gas cleaning system 20 further includes a specific gravity detection device 67 capable of detecting the specific gravity of the scrubbing liquid after cleaning exhaust gas. Further, the control part 21 is configured to control the opening degree of the treatment-liquid-flow-rate control valve 82 (first treatment-liquid-flow-rate control valve 84) in accordance with the specific gravity of the scrubbing liquid after cleaning exhaust gas detected by the specific gravity detection device 67. In the embodiment shown in FIG. 3, the specific gravity detection device 67 is a specific gravity meter for detecting the specific gravity of the scrubbing liquid in the storage tank 61. In other embodiments, the specific gravity detection device 67 may be a specific gravity meter for detecting the specific gravity of the scrubbing liquid in the supply passage 40 (supply pipes 40B, 40C), the circulation passage 60 (circulation pipes 60A, 60B, 60C), and the liquid

reservoir 34A of the desulfurization tower 30. Further, in other embodiments, the control part 21 may be configured to control the opening degree of the second treatment-liquid-flow-rate control valve 86 in accordance with the specific gravity of the scrubbing liquid after cleaning exhaust gas detected by the specific gravity detection device 67.

[0090] Scrubbing liquid (circulation liquid) containing concentrated impurities due to repeated exhaust gas cleaning tends to have a higher specific gravity. With the above configuration, since the control part 21 controls the opening degree of the treatment-liquid-flow-rate control valve 82 in accordance with the specific gravity of the scrubbing liquid after cleaning exhaust gas detected by the specific gravity detection device 67, the scrubbing liquid (liquid to be treated) flows through the treatment liquid passage 80 at an appropriate flow rate. Flowing the scrubbing liquid (liquid to be treated) through the treatment liquid passage 80 at an appropriate flow rate prevents clogging and scaling of the pipes (e.g., supply pipes 40B, 40C and circulation pipes 60A to 60C), enabling stable operation. Further, since an excess amount of the scrubbing liquid is prevented from flowing through the treatment liquid passage 80, it is possible to reduce the treatment amount of the liquid to be treated by the circulation liquid treatment device 81.

[0091] FIG. 5 is a schematic configuration diagram of an exhaust gas cleaning system according to another embodiment. In some embodiments, the exhaust gas cleaning system 20 further includes, in addition to the treatment liquid passage 80, a treatment liquid storage tank 90 disposed on the treatment liquid passage 80 and capable of storing the liquid to be treated.

[0092] In the embodiment shown in FIG. 5, the treatment liquid passage 80 further includes a bypass passage 89 branching from the first treatment liquid passage 83 at a second branching part 88 disposed between the first branching part 45 and the first treatment-liquid-flow-rate control valve 84 on the first treatment liquid passage 83 and connected to the circulation liquid treatment device 81. The bypass passage 89 is provided with the treatment liquid storage tank 90 defining therein an interior space 91 for storing the circulation liquid (liquid to be treated) before being subjected to treatment by the circulation liquid treatment

device 81. On the upstream side of the treatment liquid storage tank 90 on the bypass passage 89, a bypass-passage-inlet-flow-rate control valve 92 capable of controlling the flow rate of the liquid to be treated transferred to the treatment liquid storage tank 90 via the bypass passage 89 is disposed. On the downstream side the treatment liquid storage tank 90 on the bypass passage 89, a bypass outlet flow control valve 93, a bypass-passage-outlet-flow-rate control valve 93 capable of controlling the flow rate of the liquid to be treated transferred from the treatment liquid storage tank 90 to the circulation liquid treatment device 81 via the bypass passage 89 is disposed.

[0093] In closed loop operation, the bypass-passage-inlet-flow-rate control valve 92 is opened, and the bypass-passage-outlet-flow-rate control valve 93 is closed. Thus, during closed loop operation, a part of the liquid to be treated flowing through the first treatment liquid passage 83 is transferred to the treatment liquid storage tank 90 via the bypass passage 89 and stored in the treatment liquid storage tank 90.

[0094] After closed loop operation is switched to open loop operation, the bypass-passage-inlet-flow-rate control valve 92 is closed, and the bypass-passage-outlet-flow-rate control valve 93 is opened. Thus, the liquid to be treated stored in the treatment liquid storage tank 90 during closed loop operation is transferred to the circulation liquid treatment device 81 during open loop operation.

[0095] With the above configuration, since a part of the liquid to be treated by the circulation liquid treatment device 81 is stored in the treatment liquid storage tank 90, the exhaust gas cleaning system 20 can treat the liquid even with a downsized circulation liquid treatment device 81 having a small treatment capacity per time unit. Further, by downsizing the circulation liquid treatment device 81, it is possible to reduce the space and equipment cost of the exhaust gas cleaning system 20.

[0096] As described above, in some embodiments, the treatment liquid passage 80 includes the first treatment liquid passage 83 connecting the first branching part 45 disposed downstream of the water feed pump 43 on the supply passage 40 to the circulation liquid treatment device 81. Further, the treatment-liquid-flow-rate control valve 82 includes the

first treatment-liquid-flow-rate control valve 84 capable of controlling the flow rate of the liquid to be treated in the first treatment liquid passage 83.

[0097] With the above configuration, since the first treatment-liquid-flow-rate control valve 84 controls the flow rate of the liquid to be treated in the first treatment liquid passage 83, in the exhaust gas cleaning system 20, an appropriate amount of the liquid flows into the circulation liquid treatment device 81 from the supply passage 40 via the first treatment liquid passage 83. Further, since the first treatment liquid passage 83 is disposed downstream of the water feed pump 43 on the supply passage 40, pump pressure of the water feed pump 43 acts on the liquid to be treated in the first treatment liquid passage 83. Accordingly, the first treatment liquid passage 83 on which pump pressure of the water feed pump 43 acts can increase the lift or horizontal distance from the water feed pump 43 to the circulation liquid treatment device 81. Thus, it is possible to increase the degree of freedom in the piping design of the first treatment liquid passage 83.

[0098] As described above, in some embodiments, the treatment liquid passage 80 includes the second treatment liquid passage 85 connecting the storage tank 61 to the circulation liquid treatment device 81. Further, the treatment-liquid-flow-rate control valve 82 includes the second treatment-liquid-flow-rate control valve 86 capable of controlling the flow rate of the liquid to be treated in the second treatment liquid passage 85.

[0099] With the above configuration, since the second treatment-liquid-flow-rate control valve 86 controls the flow rate of the liquid to be treated in the second treatment liquid passage 85, in the exhaust gas cleaning system 20, an appropriate amount of the liquid flows into the circulation liquid treatment device 81 from the storage tank 61 via the second treatment liquid passage 85. In addition, in the exhaust gas cleaning system 20, after closed loop operation is switched to open loop operation, the circulation liquid remaining in the storage tank 61 can flow into the second treatment liquid passage 85. Thus, it is possible to rapidly switch closed loop operation to open loop operation.

[0100] FIG. 6 is a schematic cross-sectional view of a storage tank, for describing control of the storage amount of the storage tank. In closed loop operation, the total amount of the

circulation liquid in the circulation passage 60 and the supply passage 40 gradually decreases as a part of the circulation liquid flows into the treatment liquid passage 80. In some embodiments, the control part 21 performs open/close control of the feedwater-flow-rate control valve 643 in the outboard water feed device 64 or adjust the opening degree of the valve so that the storage amount of the scrubbing liquid (circulation liquid) in the storage tank 61 is within a range between an upper limit value RU and a lower limit value RL as shown in FIG. 6. In other embodiments, the control part 21 may perform open/close control of the feedwater-flow-rate control valve 643 in the outboard water feed device 64 or adjust the opening degree of the valve so that the storage amount of the scrubbing liquid (circulation liquid) in the storage tank 61 approximates a target value T as shown in FIG. 6.

[0101] In some embodiments, the control part 21 is configured to perform control to open the second treatment-liquid-flow-rate control valve 86 when the storage amount acquired by the storage amount acquisition device 63 exceeds an upper threshold UL as shown in FIG. 6. With the above configuration, since the control part 21 performs control to open the second treatment-liquid-flow-rate control valve 86 when the storage amount acquired by the storage amount acquisition device 63 exceeds the upper threshold UL, the exhaust gas cleaning system 20 can rapidly discharge the excess circulation liquid stored in the storage tank 61 from the storage tank 61.

[0102] In some embodiments, the control part 21 is configured to perform control to switch the supply source to outboard water taken by the intake part 41 through the supply-side switch device 71 when the storage amount acquired by the storage amount acquisition device 63 is less than a lower threshold LL as shown in FIG. 6. With the above configuration, since the control part 21 performs control to switch the supply source to outboard water taken by the intake part 41 through the supply-side switch device 71 when the storage amount acquired by the storage amount acquisition device 63 is less than the lower threshold LL, the exhaust gas cleaning system 20 can rapidly cover the shortage of the circulation liquid in the storage tank 61.

[0103] FIG. 7 is a schematic configuration diagram of an exhaust gas cleaning system

according to another embodiment. In some embodiments, as shown in FIG. 7, the supply-side switch device 71 includes a first supply-side two-way valve 75 disposed between the junction part 42 and the water feed pump 43 on the supply passage 40, and a second supply-side two-way valve 76 disposed between the storage tank 61 and the junction part 42 on the circulation passage 60. Each of the first supply-side two-way valve 75 and the second supply-side two-way valve 76 is electrically connected to the control part 21. The first supply-side two-way valve 75 and the second supply-side two-way valve 76 can switch the supply source of the scrubbing liquid by controlling the open/close state of the valve in response to a signal transmitted from the control part 21. In other embodiments, the first supply-side two-way valve 75 may be disposed between the intake part 41 and the junction part 42 on the supply passage 40.

[0104] Further, in some embodiments, as shown in FIG. 7, the discharge-side switch device 72 includes a first discharge-side two-way valve 77 disposed between the branching part 52 and the effluent treatment device 51 on the discharge passage 50, and a second discharge-side two-way valve 78 disposed between the branching part 52 and the storage tank 61 on the circulation passage 60. Each of the first discharge-side two-way valve 77 and the second discharge-side two-way valve 78 is electrically connected to the control part 21. The first discharge-side two-way valve 77 and the second discharge-side two-way valve 78 can switch the outlet of the scrubbing liquid discharged from the desulfurization tower 30 by controlling the open/close state of the valve in response to a signal transmitted from the control part 21.

[0105] In the embodiment shown in FIG. 7, the supply passage 40 includes a supply pipe 40D connecting the intake part 41 to the first supply-side two-way valve 75, a supply pipe 40E connecting the first supply-side two-way valve 75 to the water feed pump 43, and the supply pipe 40C described above. The discharge passage 50 includes a discharge pipe 50C connecting the desulfurization tower 30 to the branching part 52, a discharge pipe 50D connecting the branching part 52 to the first discharge-side two-way valve 77, and a discharge pipe 50E connecting the first discharge-side two-way valve 77 to the effluent treatment device

51. Further, the circulation passage 60 includes a circulation pipe 60D sharing a pipe with the discharge pipe 50C and connecting the desulfurization tower 30 to the branching part 52, a circulation pipe 60E connecting the branching part 52 to the second discharge-side two-way valve 78, a circulation pipe 60F connecting the second discharge-side two-way valve 78 to the storage tank 61, a circulation pipe 60G connecting the storage tank 61 to the second supply-side two-way valve 76, and a circulation pipe 60H connecting the second supply-side two-way valve 76 to the junction part 42.

[0106] FIG. 8 is a schematic configuration diagram of an exhaust gas cleaning system according to another embodiment. In some embodiments, as shown in FIG. 8, the desulfurization tower 30 defines therein a liquid reservoir 34A disposed below the gas-liquid contact part 38, and a storage tank 61 (storage tank 61A) disposed below the liquid reservoir 34A. In other words, the desulfurization tower 30 and the storage tank 61 are integrally formed. In the embodiment shown in FIG. 8, a middle plate part 311, which forms the bottom of the liquid reservoir 34A and extends along the horizontal direction, defines the interior space 34 and the interior space 62, so that the liquid reservoir 34A and the storage tank 61A are formed inside the desulfurization tower 30.

[0107] In the embodiment shown in FIG. 8, the discharge passage 50 includes a discharge pipe 50F connecting the desulfurization tower 30 to the first discharge-side two-way valve 77, and the discharge pipe 50E described above. The circulation passage 60 includes a circulation pipe 60J connected to the liquid reservoir 34A and the interior space 62, and the circulation pipe 60C described above. Further, as shown in FIG. 8, the discharge-side switch device 72 includes the first discharge-side two-way valve 77 disposed between the desulfurization tower 30 and the effluent treatment device 51 on the discharge passage 50, and a third discharge-side two-way valve 79 disposed between the liquid reservoir 34A and the interior space 62 on the circulation passage 60 (circulation pipe 60J). Each of the first discharge-side two-way valve 77 and the third discharge-side two-way valve 79 is electrically connected to the control part 21. The first discharge-side two-way valve 77 and the third discharge-side two-way valve 79 can switch the outlet of the scrubbing liquid discharged from

the desulfurization tower 30 by controlling the open/close state of the valve in response to a signal transmitted from the control part 21.

[0108] With the above configuration, since the liquid reservoir 34A and the storage tank 61A are defined inside the desulfurization tower 30, it is unnecessary to separately provide the storage tank 61 outside the desulfurization tower 30, so that it is possible to suppress an increase in footprint of the exhaust gas cleaning system 20.

[0109] FIG. 9 is a flowchart for describing a method for operating an exhaust gas cleaning system according to an embodiment. FIG. 10 is a flowchart for describing a method for operating an exhaust gas cleaning system according to another embodiment. As shown in FIGs. 9 and 10, the exhaust gas cleaning system operating method 200A, 200B is a method for operating the exhaust gas cleaning system 20 for cleaning exhaust gas discharged from the exhaust gas generating device 10 installed in the ship 1. The exhaust gas cleaning system 20 in the exhaust gas cleaning system operating method 200A, 200B includes at least the desulfurization tower 30, the intake part 41, the supply passage 40, the discharge passage 50, the circulation passage 60, the supply-side switch device 71, and the discharge-side switch device 72, for example as shown in FIG. 3.

[0110] The exhaust gas cleaning system operating method 200A according to some embodiments includes the first supply source switching step S201 and the first outlet switching step S202 described above, as shown in FIG. 9. In this case, the exhaust gas cleaning system operating method 200A can switch the operating state of the exhaust gas cleaning system 20 from open loop operation to closed loop operation by performing the first supply source switching step S201 of switching the supply source of the scrubbing liquid by the supply-side switch device 71 from outboard water taken by the intake part 41 to the circulation liquid returned to the supply passage 40 via the circulation passage 60, and the first outlet switching step S202 of switching the outlet of the scrubbing liquid by the discharge-side switch device 72 from the discharge passage 50 to the circulation passage 60.

[0111] The exhaust gas cleaning system 20 in the exhaust gas cleaning system operating method 200A according to some embodiments further includes the storage tank 61 and the

storage amount acquisition device 63, for example as shown in FIG. 3. The exhaust gas cleaning system operating method 200A according to some embodiments further includes a storage amount acquisition step S203 of acquiring the storage amount of the circulation liquid by the storage amount acquisition device 63, as shown in FIG. 9. Further, the first supply source switching step S201 is performed after the first outlet switching step S202 is performed and the storage amount acquired by the storage amount acquisition step S203 exceeds a predetermined amount.

[0112] In the embodiment shown in FIG. 9, the exhaust gas cleaning system operating method 200A further includes a storage amount determination step S204 of determining whether the storage amount of acquired by the storage amount acquisition step S203 exceeds the predetermined amount. If the storage amount does not exceed the predetermined amount in the storage amount determination step S204 ("NO" in S204), the storage amount acquisition step S203 is performed again. If the storage amount exceeds the predetermined amount in the storage amount determination step S204 ("Yes" in S204), the first supply source switching step S201 is performed.

[0113] With the above method, the exhaust gas cleaning system operating method 200A can acquire the storage amount of the circulation liquid in the storage tank 61 by the storage amount acquisition step S203. Further, after the first outlet switching step S202 is performed and the storage amount in the storage tank 61 exceeds the predetermined amount, the first supply source switching step S201 is performed. In such an exhaust gas cleaning system operating method 200A, since a sufficient amount of the circulation liquid is stored in the storage tank 61 when the supply source is switched from outboard water to the circulation liquid, it is possible to suppress a reduction in exhaust gas cleaning capacity due to the lack of the circulation liquid.

[0114] In other embodiments, the first supply source switching step S201 may be performed after a lapse of a predetermined period from the execution of the first outlet switching step S202. In this case, assuming that the predetermined amount or more of the scrubbing liquid is stored in the storage tank after a lapse of a predetermined period, the

exhaust gas cleaning system operating method 200A can be simplified.

[0115] The exhaust gas cleaning system operating method 200B according to some embodiments includes the second supply source switching step S301 and the second outlet switching step S302 described above, as shown in FIG. 10. In this case, the exhaust gas cleaning system operating method 200B can switch the operating state of the exhaust gas cleaning system 20 from closed loop operation to open loop operation by performing the second supply source switching step S301 of switching the supply source of the scrubbing liquid by the supply-side switch device 71 from the circulation liquid returned to the supply passage 40 via the circulation passage 60 to outboard water taken by the intake part 41, and the second outlet switching step S302 of switching the outlet of the scrubbing liquid by the discharge-side switch device 72 from the circulation passage 60 to the discharge passage 50.

[0116] Further, since the desulfurization tower 30 and portions (supply pipes 40B and 40C) of the supply passage 40 downstream of the junction part 42 are shared by both operating states of open loop operation and closed loop operation, it is possible to wash away the polluted circulation liquid remaining in the pipes (e.g., supply pipes 40B, 40C and circulation pipes 60A to 60C) through which the circulation liquid flows during closed loop operation and the liquid reservoir 34A at a lower portion of the desulfurization tower 30. More specifically, when the second supply source switching step S301 is performed, all polluted circulation liquid remaining in the pipes (e.g., supply pipes 40B, 40C and circulation pipes 60A to 60C) and the liquid reservoir 34A at a lower portion of the desulfurization tower 30 is washed by outboard water such as seawater and introduced into the storage tank 61. Therefore, when the method proceeds to the second outlet switching step S302, since all scrubbing liquid flowing through discharge passage 50 have been replaced by outboard water, it is possible to rapidly and smoothly switch to open loop operation.

[0117] The timing of the transition from the second supply source switching step S301 to the second outlet switching step S302 may be determined based on a time required for all circulation liquid in the pipes (e.g., supply pipes 40B, 40C and circulation pipes 60A to 60C) and the liquid reservoir 34A to be replaced by outboard water. The control part 21 may

perform the second outlet switching step S302 based on the required time.

[0118] The exhaust gas cleaning system 20 in the exhaust gas cleaning system operating method 200B according to some embodiments further includes the storage tank 61, the circulation liquid treatment device 81, the second treatment liquid passage 85 (treatment liquid passage 80), and the second treatment-liquid-flow-rate control valve 86 (treatment-liquid-flow-rate control valve 82), for example as shown in FIG. 3. The exhaust gas cleaning system operating method 200B according to some embodiments further includes a circulation liquid discharge step S303 of, after the second supply source switching step S301 and the second outlet switching step S302, opening the second treatment-liquid-flow-rate control valve 86 (treatment-liquid-flow-rate control valve 82) to transfer the circulation liquid stored in the storage tank 61 to the circulation liquid treatment device 81, as shown in FIG. 10.

[0119] With the above method, since the exhaust gas cleaning system operating method 200B further includes the circulation liquid discharge step S303 of, after the second supply source switching step S301 and the second outlet switching step S302, opening the second treatment-liquid-flow-rate control valve 86 (treatment-liquid-flow-rate control valve 82) to transfer the circulation liquid stored in the storage tank 61 to the circulation liquid treatment device 81, when the operating state of the exhaust gas cleaning system 20 is switched from closed loop operation to open loop operation, it is possible to discharge the circulation liquid remaining in the storage tank 61 to the circulation liquid treatment device 81 disposed outside the storage tank 61.

[0120] The present invention is not limited to the embodiments described above, but includes modifications to the embodiments described above, and embodiments composed of combinations of those embodiments.

Reference Signs List

[0121]

1 Ship

2 Hull

3 Upper deck

4 Side shell

5 Bottom shell

6 Accommodation house

7 Steel plate structure

8 Engine room

10 Exhaust gas generating device

11 Main engine

12 Auxiliary engine

20, 20A Exhaust gas cleaning system

20 Marine desulfurization device

21 Control part

30 Desulfurization tower

40 Supply passage

41 Intake part

42 Junction part

43 Water feed pump

44 Cooler

50 Discharge passage

51 Effluent treatment device

60 Circulation passage

61, 61A Storage tank

63 Storage amount acquisition device

64 Outboard water feed device

65 pH detection device

66 Neutralizer addition device

67 Specific gravity detection device

71 Supply-side switch device

72 Discharge-side switch device

80 Treatment liquid passage

81 Circulation liquid treatment device

90 Treatment liquid storage tank

200A, 200B Exhaust gas cleaning system operating method

LL Lower threshold

RL Lower limit value

RU Upper limit value

T Target value

UL Upper threshold

CLAIMS

1. An exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship, the exhaust gas cleaning system comprising:

a desulfurization tower defining therein a gas-liquid contact part for bringing the exhaust gas into contact with a scrubbing liquid;

an intake part for taking outboard water from an outside of a hull;

a supply passage connecting the intake part and the desulfurization tower;

a discharge passage for draining the scrubbing liquid discharged from the desulfurization tower to the outside of the hull;

a circulation passage for returning the scrubbing liquid discharged from the desulfurization tower to the supply passage as a circulation liquid, the circulating passage joining the supply passage at a junction part;

a supply-side switch device for switching a supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage;

a discharge-side switch device for switching an outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage;-

a water feed pump disposed downstream of the junction part on the supply passage;

a storage tank disposed on the circulation passage and capable of storing the circulation liquid;

a storage amount acquisition device capable of acquiring a storage amount of the circulation liquid in the storage tank;

an outboard water feed device capable of feeding the outboard water to the storage tank;

a control part configured to control a feed amount of the outboard water to the storage tank by the outboard water feed device, in accordance with the storage amount acquired by the storage amount acquisition device;

a circulation liquid treatment device capable of removing an impurity from the circulation liquid;

a treatment liquid passage for supplying the circulation liquid to the circulation liquid treatment device as a liquid to be treated by the circulation liquid treatment device;

a treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the treatment liquid passage; and

a treatment liquid storage tank disposed on the treatment liquid passage and capable of storing the liquid to be treated.

2. The exhaust gas cleaning system according to claim 1, further comprising:

a pH detection device capable of detecting a pH of the circulation liquid in the storage tank; and

a neutralizer addition device capable of adding a neutralizer to the storage tank,

wherein the control part is configured to control an addition amount of the neutralizer by the neutralizer addition device, in accordance with the pH detected by the pH detection device.

3. The exhaust gas cleaning system according to claim 1 or 2, further comprising:

a specific gravity detection device capable of detecting a specific gravity of the scrubbing liquid after cleaning the exhaust gas,

wherein the control part is configured to control an opening degree of the treatment-liquid-flow-rate control valve, in accordance with the specific gravity of the scrubbing liquid after cleaning the exhaust gas detected by the specific gravity detection device.

4. An exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship, the exhaust gas cleaning system comprising:

a desulfurization tower defining therein a gas-liquid contact part for bringing the exhaust

gas into contact with a scrubbing liquid;

an intake part for taking outboard water from an outside of a hull;

a supply passage connecting the intake part and the desulfurization tower;

a discharge passage for draining the scrubbing liquid discharged from the desulfurization tower to the outside of the hull;

a circulation passage for returning the scrubbing liquid discharged from the desulfurization tower to the supply passage as a circulation liquid, the circulating passage joining the supply passage at a junction part;

a supply-side switch device for switching a supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage;

a discharge-side switch device for switching an outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage;

a water feed pump disposed downstream of the junction part on the supply passage;

a storage tank disposed on the circulation passage and capable of storing the circulation liquid;

a storage amount acquisition device capable of acquiring a storage amount of the circulation liquid in the storage tank;

an outboard water feed device capable of feeding the outboard water to the storage tank;

a control part configured to control a feed amount of the outboard water to the storage tank by the outboard water feed device, in accordance with the storage amount acquired by the storage amount acquisition device;

a circulation liquid treatment device capable of removing an impurity from the circulation liquid;

a treatment liquid passage for supplying the circulation liquid to the circulation liquid treatment device as a liquid to be treated by the circulation liquid treatment device; and

a treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the treatment liquid passage,

wherein the treatment liquid passage includes a first treatment liquid passage connecting a first branching part disposed downstream of the water feed pump on the supply passage to the circulation liquid treatment device, and

wherein the treatment-liquid-flow-rate control valve includes a first treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the first treatment liquid passage.

5. The exhaust gas cleaning system according to claim 4, further comprising:

a pH detection device capable of detecting a pH of the circulation liquid in the storage tank; and

a neutralizer addition device capable of adding a neutralizer to the storage tank,

wherein the control part is configured to control an addition amount of the neutralizer by the neutralizer addition device, in accordance with the pH detected by the pH detection device.

6. The exhaust gas cleaning system according to claim 4 or 5, further comprising:

a specific gravity detection device capable of detecting a specific gravity of the scrubbing liquid after cleaning the exhaust gas,

wherein the control part is configured to control an opening degree of the treatment-liquid-flow-rate control valve, in accordance with the specific gravity of the scrubbing liquid after cleaning the exhaust gas detected by the specific gravity detection device.

7. The exhaust gas cleaning system according to claim 4 or 6, further comprising:

a treatment liquid storage tank disposed on the treatment liquid passage and capable of storing the liquid to be treated.

8. An exhaust gas cleaning system for cleaning exhaust gas discharged from an exhaust gas generating device installed in a ship, the exhaust gas cleaning system comprising:

a desulfurization tower defining therein a gas-liquid contact part for bringing the exhaust gas into contact with a scrubbing liquid;

an intake part for taking outboard water from an outside of a hull;

a supply passage connecting the intake part and the desulfurization tower;

a discharge passage for draining the scrubbing liquid discharged from the desulfurization tower to the outside of the hull;

a circulation passage for returning the scrubbing liquid discharged from the desulfurization tower to the supply passage as a circulation liquid, the circulating passage joining the supply passage at a junction part;

a supply-side switch device for switching a supply source of the scrubbing liquid supplied to the desulfurization tower to either one of the outboard water taken by the intake part or the circulation liquid returned to the supply passage via the circulation passage;

a discharge-side switch device for switching an outlet of the scrubbing liquid discharged from the desulfurization tower to either one of the discharge passage or the circulation passage;

a water feed pump disposed downstream of the junction part on the supply passage;

a storage tank disposed on the circulation passage and capable of storing the circulation liquid;

a storage amount acquisition device capable of acquiring a storage amount of the circulation liquid in the storage tank;

an outboard water feed device capable of feeding the outboard water to the storage tank;

a control part configured to control a feed amount of the outboard water to the storage tank by the outboard water feed device, in accordance with the storage amount acquired by the storage amount acquisition device;

a circulation liquid treatment device capable of removing an impurity from the circulation liquid;

a treatment liquid passage for supplying the circulation liquid to the circulation liquid treatment device as a liquid to be treated by the circulation liquid treatment device; and

a treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the treatment liquid passage,

wherein the treatment liquid passage includes a second treatment liquid passage connecting the storage tank to the circulation liquid treatment device,

wherein the treatment-liquid-flow-rate control valve includes a second treatment-liquid-flow-rate control valve capable of controlling a flow rate of the liquid to be treated in the second treatment liquid passage, and

wherein the control part is configured to perform control to open the second treatment-liquid-flow-rate control valve when the storage amount acquired by the storage amount acquisition device exceeds an upper threshold.

9. The exhaust gas cleaning system according to claim 8, further comprising:

a pH detection device capable of detecting a pH of the circulation liquid in the storage tank; and

a neutralizer addition device capable of adding a neutralizer to the storage tank,

wherein the control part is configured to control an addition amount of the neutralizer by the neutralizer addition device, in accordance with the pH detected by the pH detection device.

10. The exhaust gas cleaning system according to claim 8 or 9, further comprising:

a specific gravity detection device capable of detecting a specific gravity of the scrubbing liquid after cleaning the exhaust gas,

wherein the control part is configured to control an opening degree of the treatment-liquid-flow-rate control valve, in accordance with the specific gravity of the scrubbing liquid after cleaning the exhaust gas detected by the specific gravity detection device.

11. The exhaust gas cleaning system according to 8 or 10, further comprising:

a treatment liquid storage tank disposed on the treatment liquid passage and capable of storing the liquid to be treated.

12. The exhaust gas cleaning system according to any one of claims 8, 10, 11,

wherein the treatment liquid passage includes a first treatment liquid passage connecting a first branching part disposed downstream of the water feed pump on the supply passage to the circulation liquid treatment device, and

wherein the treatment-liquid-flow-rate control valve includes a first treatment-liquid-flow-rate-control valve capable of controlling a flow rate of the liquid to be treated in the first treatment liquid passage.