Development and Installation of Marine-use Hybrid SOx Scrubber System that Complies with IMO SOx Emission Regulations

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As a solution to meet the International Maritime Organization (IMO) regulations on SOx emissions from ships, Mitsubishi Heavy Industries, Ltd. (MHI) and Mitsubishi Kakoki Kaisha, Ltd. (MKK) jointly developed a marine-use flue gas desulfurization (FGD) system called the "Hybrid SOx Scrubber System." One of the advantages of this system is hybrid cleaning, which has two methods for cleaning the flue-gas: the freshwater closed-cycle mode and seawater open-cycle mode. These specifications provide sufficient FGD performance that is applicable in various sailing areas. A packaged module that houses the elemental components enables the efficient use of the limited area on a ship and shortens the construction work period. This system was delivered to Kawasaki Kisen Kaisha, Ltd. ("K" Line) for its car carrier that entered service in February 2016. The sea trials showed the sufficient desulfurization performance of this system under real maritime conditions.

1. Introduction

The reduction of flue gas emitted from ships to the atmosphere has been urged and the sulfur content standards for ship fuels have been tightened in stages to reduce SOx emissions from ships under the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI Regulation 14. In Emission Control Areas (ECAs) including the North Sea area, Baltic Sea area, and North American coastal zone, the sulfur content of fuel oils must be 0.1% or lower from January 1, 2015, under this Regulation. For outside the ECAs, the sulfur content is required to be 0.5% or lower from as early as January 1, 2020. The ECAs may be further expanded, and there are indications that some countries will establish their own emission regulations.

Regulation 4 of MARPOL Annex VI allows the use of an exhaust gas cleaning system (EGCS) as an alternative to using low-sulfur fuel oil only if the EGCS reduces the sulfur content of flue gas from the fuel combustion engines to below the limits. Low-sulfur fuel oil is more expensive than conventional heavy fuel oil, and it is unclear whether the supply capacity of low-sulfur fuel oil can meet the increasing demand in the future. On the other hand, EGCSs allows ship owners to keep using conventional inexpensive heavy fuel oil for which there is sufficient supply capacity while meeting the SOx emission limits, so EGCSs are in greater demand and are being rapidly diffused, particularly for ships that travel in ECAs.

2. Development of marine-use SOx scrubber system

To meet the increasing demand for EGCSs, MHI and MKK have jointly developed a marine-use wet-type FGD system, a type of EGCS, since 2010. MKK, a manufacturer of FGD systems for onshore conditions, has significant production expertise. MHI built a scrubber demonstration plant at MHI's Nagasaki Research & Development Center that treats flue gas from a 2-stroke 1-cylinder diesel test engine (rated at 762 kW). Several tests were conducted to collect data on the FGD performance of the scrubber system treating the diesel test engine, which found that the system sufficiently satisfies the regulation in terms of desulfurization performance at a desulfurization rate of 98% or higher. **Figure 1** shows the appearance of the scrubber

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demonstration plant. **Figure 2** is an example of the SOx content variation at the SOx scrubber outlet in the test.

The "Hybrid SOx Scrubber System" presented in this paper is a commercial product designed based on the demonstration results to meet the IMO MEPC.259 (68) "2015 Guidelines for Exhaust Gas Cleaning System" (EGCS Guidelines). The EGCS Guidelines prescribe the requirements to ensure sulfur contents equivalent to fuel oils determined in Regulation 14.1 and Regulation 14.4 of MARPOL Annex VI.

Figure 1 SOx scrubber demonstration plant

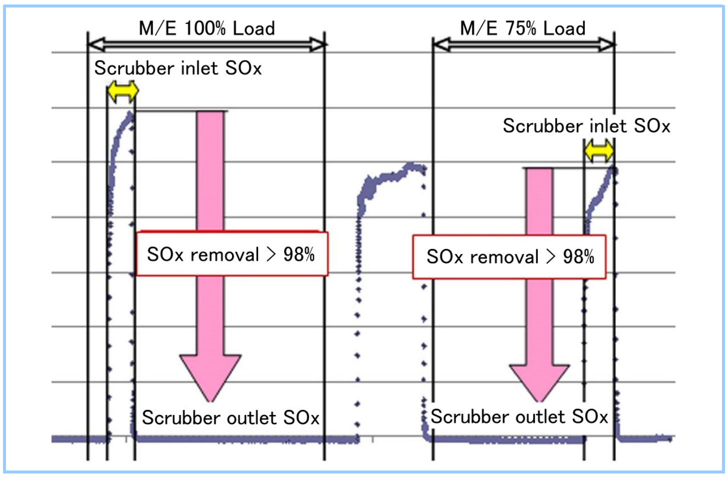

Figure 2 Behavior example of SO_2 concentration at scrubber outlet at FGD test

3. Outline of Hybrid SOx Scrubber System

This system provides two hybrid cleaning methods: freshwater closed-cycle mode (**Figure 3**) and seawater open-cycle mode (**Figure 4**). The former circulates the freshwater while neutralizing it with NaOH for recycling, and the latter pumps seawater and directly splays it into the flue gas. Thanks to its specifications, this system provides sufficient FGD capacity that is applicable in various sailing areas including oceans, rivers, and bays.

This system consists of many elemental components such as a scrubber tower, pumps, a heat exchanger, a circulation water treatment unit, an exhaust & effluent monitoring unit and a compliance data storage unit, NaOH tanks, and sludge tanks. The scrubber tower is a multi-stream type, where flue gas from several engines is treated in a single tower. This scrubber tower, which has quite a simple internal structures with no moving parts inside, is easy to maintain and the pressure loss is very low.

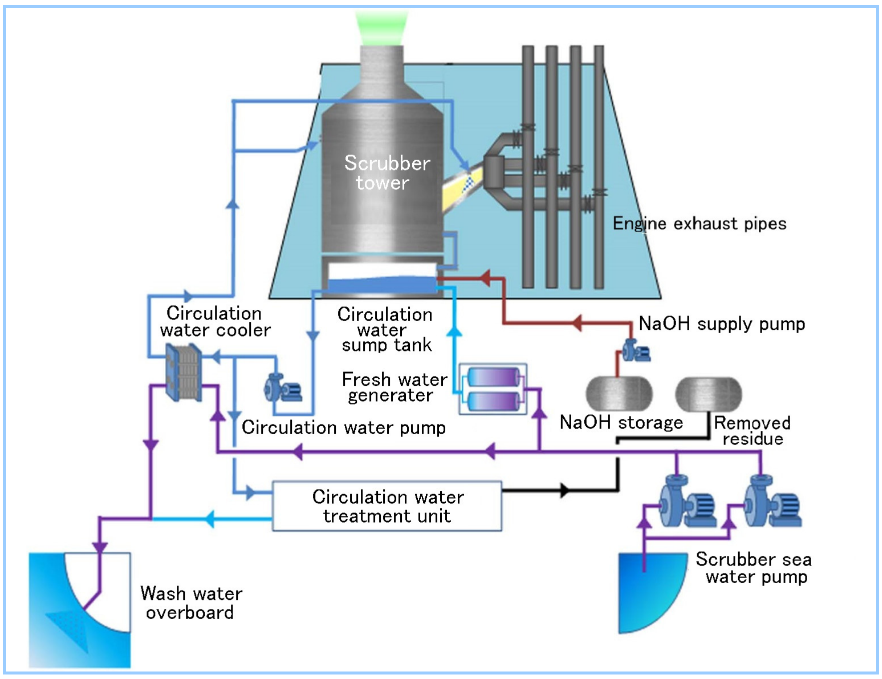

Figure 3 Freshwater closed-cycle mode

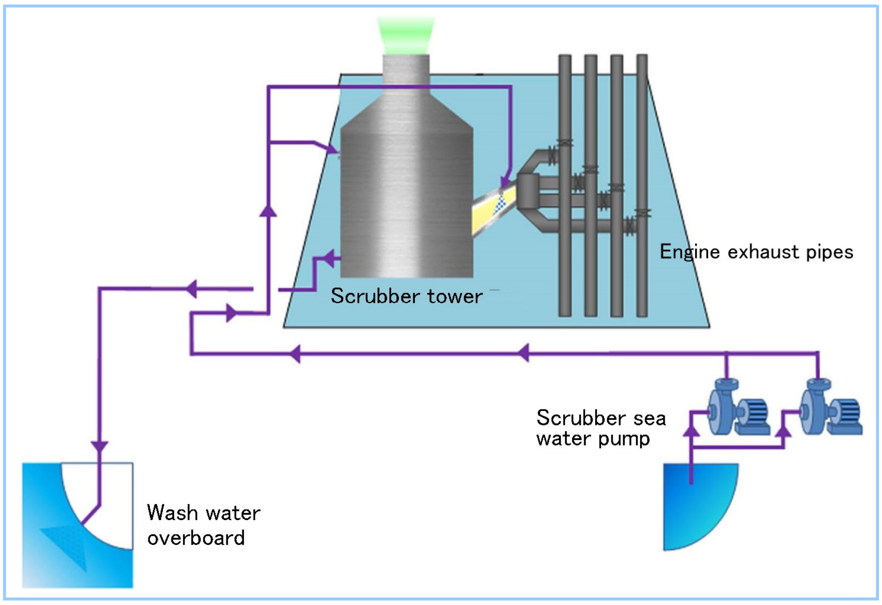

Figure 4 Seawater open-cycle mode

4. Features of Hybrid SOx Scrubber System

4.1 System automation

The elemental components of this system are integrated so as to be controlled and monitored through a SOx scrubber operation panel in the machinery control room. Scrubber on/off and mode selection are done through the simple touch panel automatically without complicated valve operations.

4.2 Component packaging

A container-type module, an ISO-standard container housing some of the main components (freshwater circulation pump, heat exchanger, NaOH tank and sludge tank), is also available. Packaging these main components into a container enables the limited space on a ship to be used more efficiently and shorten the duration of construction work. The container-type module can be installed even on an exposed deck depending on the type of ship. **Figure 5** shows the layout of the main components that are installed separately inside a ship. **Figure 6** shows the container-type module housing the main components mounted on an exposed deck. The container-type module is also easy to retrofit to ships already in service by adding just two components inside the ship: a scrubber tower in a funnel casing and a seawater pump to be mounted on the ship bottom. If installed on the exposed deck of a delivered ship, the container-type module can be easily moved to another ship for reuse when the older ship is retired.

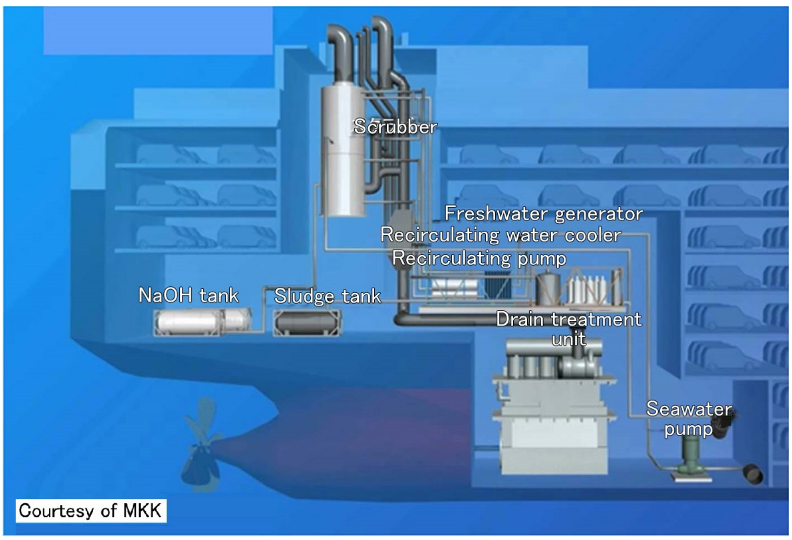

Figure 5 Example of system layout on a ship

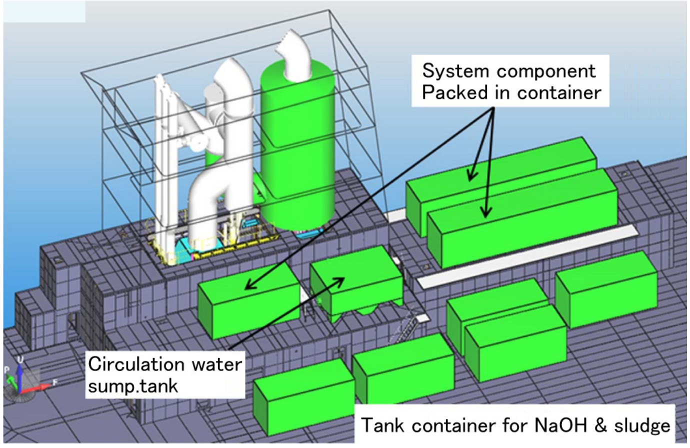

Figure 6 Layout example of container-type module housing this system

5. System installation on a ship

5.1 Installation onto large-scale car carrier

A large-scale car carrier, the M.V. DRIVE GREEN HIGHWAY (**Figure 7**) with a 7,500-vehicle carrying capacity, was built under "K" Line's DRIVE GREEN PROJECT aiming for an environmentally-friendly maritime industry. It is a flagship showcasing next-generation environmental performance. In the Sox scrubber system in the car carrier, the flue gas pipes from the main engine and three power generation units are connected to the scrubber tower in the engine casing, such that this system solely cleans flue gas that is equivalent to 15 MW-class engine emissions in its entirety. A 40-ft container (**Figure 8**) housing the main components such as the heat exchanger and circulation water treatment unit is mounted on the exposed stern garage deck. The NaOH and sludge are separately stored in the heater-equipped stainless ISO tank containers mounted inside the ship.

Figure 7 Large-scale car carrier "M.V. Drive Green Highway"

Figure 8 Packaged module housing main components

5.2 Sea trials

During the sea trials of the car carrier, the FGD performance of this SOx scrubber system was verified under real maritime conditions. **Figure 9** shows the desulfurization rate against the liquid-to-gas ratio (or Liquid/Gas ratio, meaning the volume of the scrubbing water against the volume of flue-gas). This system sufficiently desulfurizes the flue gas in both cleaning modes, meeting the EGCS Guideline requirements by appropriately adjusting the Liquid/gas ratio. This result is mostly consistent with the results of the demonstration plant test, verifying the desulfurization performance expected for this system.

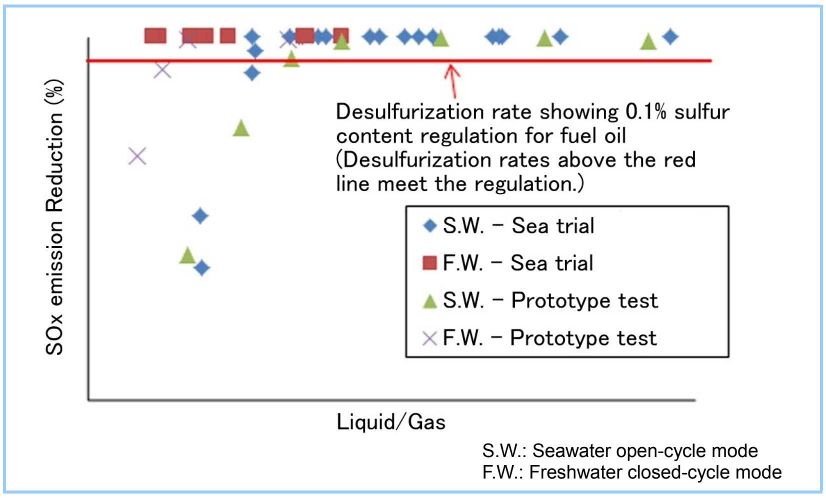

Figure 9 FGD performance of the marine-use SOx scrubber system

6. Conclusions

MHI and MKK jointly developed the marine-use FGD system called the "Hybrid SOx Scrubber System." Thanks to its specifications, the system provides sufficient FGD performance that is applicable in various sailing areas and operates automatically without complicated manual procedures. Packaging the main components in a container makes it possible to use the limited space on a ship more efficiently. During the sea trials of “K” Line’s large-scale car carrier, the M.V. DRIVE GREEN HIGHWAY, this system showed sufficient desulfurization performance under real maritime conditions. The practical use of the system in ECAs is also planned.

The SOx scrubber system was developed and installed in cooperation with Nippon Kaiji Kyokai (also known as ClassNK), "K" Line, Japan Marine United Corporation and MKK, with support from the ClassNK Joint R&D for Industry Program. We would like to express our deep appreciation to ClassNK for various advices and to the other parties for their efforts in the successful completion of this project.