Ecological Ballast Water Treatment System "ECOMARINE UV"

Kenichiro MIYATAKE*, Munetsugu UEYAMA, Shuji HAHAKURA, Hiroki INOUE, Ryusuke NAKAI and Kazuhiro TANIDA

Sumitomo Electric has developed the chemical-free and eco-friendly ballast water treatment system 'ECOMARINE UV' that utilizes filtration and UV disinfection. By using the unique high-efficiency filter unit, the ECOMARINE UV ensures the high organism removal efficiency and the lowest power consumption among UV technology-based systems worldwide. Through the element technology development and the verification tests with prototype system, the ballast water treatment system with treatment capacity of 200 m^3/h was completed and installed on the cruise ship 'ASUKA II' managed by NYK CRUISES CO., LTD. The series of performance tests were successfully finished in January 2014 and the Type Approval was granted by the Japanese government in June 2014. The following is a report of development background, system features and test results of ECOMARINE UV.

Keywords: ballast water, filter, UV and water treatment

1. Introduction

Ships discharge or take up ballast water when loading or unloading to maintain their safety regarding the hull's trim and draught. Ballast water discharged at ports throughout the world is said to amount to five billion tons per year. Since the 1980s, measures have been discussed to counter the impact on the environment of the migration of alien species via ballast water transported by oceangoing ships, especially on the ecological system. Moreover, in 2004, due to the growing global environmental awareness, the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments[(1)] (Management Convention).

The Management Convention requires discharged ballast water to contain an extremely low level of organisms. Currently, when taking up seawater into the ballast tank, 5 to 10 mm strainer mesh sizes are used to prevent the uptake of organisms such as fish and shellfish and foreign matter into the ballast tank. This implies that smaller organisms including planktons and immature organisms as well as bacteria are all taken into the ballast tank and discharged into the bay of the port of call depending on loading conditions. Once the Management Convention takes effect, almost all international ships, including existing ships as well as newly built ships, will be obligated to install a specially designed ballast water treatment system by the renewal and inspection date for the International Oil Pollution Prevention Certificate, the inspection of which is conducted on a ship-by-ship basis.

The Management Convention will enter into force 12 months after the date on which 30 states or more, the combined merchant fleets of which constitute not less than 35% of the gross tonnage of the world's merchant shipping, have ratified the Convention. Thirty-seven states have ratified the Ballast Water Management Convention, as of May 2014. Their combined shipping tonnage has reached 30.25% of the gross tonnage of the world's merchant shipping. States with high shipping tonnage, such as Japan and Singapore, are expected to sign the Management Convention in the near future. The Japanese House of Representatives has passed related domestic laws. Given these factors, it is highly likely that the Management Convention will take effect in 2015.

Against this backdrop, we have worked on the research and development of a ballast water treatment system as part of our recent efforts intended for water treatment technology development. We have analyzed treatment systems as to their advantages and disadvantages, as well as element technologies used to implement individual treatment systems. A filter unit incorporating our proprietary filtration methodology using a nonwoven fabric as a filter medium has been combined with a UV irradiation technology, which uses no chemicals to treat ballast water. The result is the development of ECOMARINE UV. All performance tests were completed in January 2014. The type approval was granted by the Ministry of Land, Infrastructure, Transport and Tourism in June 2014. The present paper reports on the backdrop to the development, the features of the system and various tests conducted for the type approval.

2. Treatment Standards in the Ballast Water Management Convention

The Annex (Regulation D-2[(2)]) to the Management Convention provides standards for the numbers of viable organisms discharged from the ballast tank, as shown in **Table 1**.

Table 1. Ballast water discharge standard

Organism	Discharge standard
Large organism ≧ 50 um	< $10/m^3$
Small organism < 50 um, ≧ 10 um	< 10/mL
Escherichia coli	< 250 cfu/100 mL
Intestinal Enterococci	< 100 cfu/100 mL
Toxicogenic *Vibrio cholerae* (O1 and O139)	< 1cfu/100 mL

cfu : colony forming unit

In seas close to Japan, a few thousands of large organisms (greater than or equal to 50 μm in minimum dimension) per cubic meter exist in low-concentration cases and hundreds of thousands per cubic meter in high-concentration cases. To meet the standard in the table, it is necessary to reduce large organisms to one hundred-thousandth in a reliable manner. Ballast water is taken up very fast, large ships pumping a few thousands of tons per hour. Consequently, ballast water treatment systems are required to exhibit an extremely high organism treatment capacity and a seawater management capacity.

To fulfill these requirements, several ballast water treatment methods have been proposed and system development has been promoted. Representative treatment methods include mechanical removal (filtration), ultraviolet (UV) irradiation, chlorine formation by electrolysis, injection of chemicals, ozone treatment, gas injection, coagulation and separation, and heat treatment. Especially, currently used dominant methods are UV irradiation, electrolysis and injection of chemicals. In addition to these dominant methods, in many cases, filtration and other mechanical removal techniques are incorporated on an as-needed basis to enhance treatment efficiency. Generally, these treatment processes are followed before filling the ballast tank. However, some methods, such as neutralization (detoxication) after the use of a chemical, do require retreatment at the time of discharge.

Ballast water treatment method which can support every situation does not exist at present. Consequently, it is reasonable to select appropriate equipment depending on the features of individual ships and voyage areas.

3. Features of ECOMARINE UV

3-1 Principles and Features

The ballast water treatment system ECOMARINE UV developed by Sumitomo Electric employs a filtration-UV system. This system combines the Company's proprietary high-performance filter and a UV system to successfully achieve high levels of treatment performance and cost-effectiveness.

Figures 1 to 3 show the treatment principles of ECOMARINE UV, an example system configuration and water uptake and discharge flowchart. The system incorporates a filter to separate large organisms and return them to the sea just as they are. The portion of small organisms that have passed through the filter unit and bacteria are disinfected in the UV irradiation section.

The features of ECOMARINE UV are as follows:

(1) High filtration performance and low power consumption by UV unit. This is specifically advantageous to small ships that are subject to limited onboard electricity.

(2) Environmental friendliness. The system uses no chemical substances. It uses a filter unit and UV unit to remove and kill aquatic organisms.

(3) The system uses no chemicals, which realizes operation at low cost. No management or storage of chemicals onboard or procurement of chemicals at ports of call is required.

(4) Unlike electrolysis, the system operates in freshwater areas and is subject to no particular seawater temperature limits.

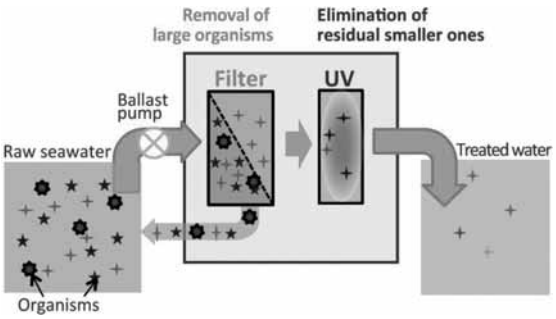

Fig. 1. Treatment principles of ECOMARINE UV

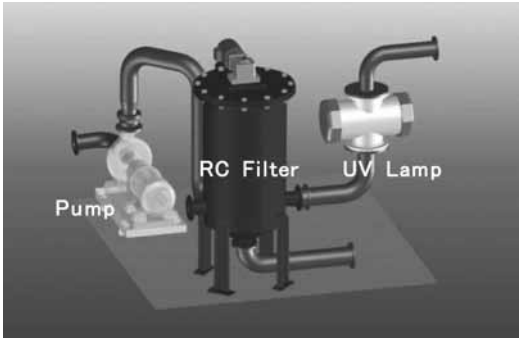

Fig. 2. ECOMARINE UV system configuration

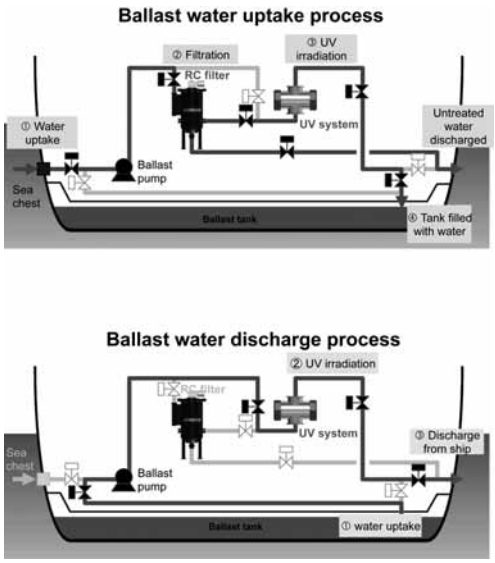

Fig. 3. Water uptake and discharge processes

3-2 Rotational Cleaning (RC) Filter

Meshed metal filters that remove large organisms are used widely in ballast water treatment. However, they are incapable of separating most small organisms (less than 50 µm in minimum dimension and greater than or equal to 10 µm in minimum dimension). Moreover, many organisms have a soft and amorphous structure. Even if the mesh size is not greater than 50 µm, part of large organisms pass through one to several layers of a metal filter. As a solution to this problem, Sumitomo Electric has employed a nonwoven fabric as a filter medium whose fibers are intertwined in a complex manner in the thickness direction, as shown in **Fig. 4**. This filter, in a single filtration process, removes all small organisms greater than or equal to 30 µm, as well as large organisms.

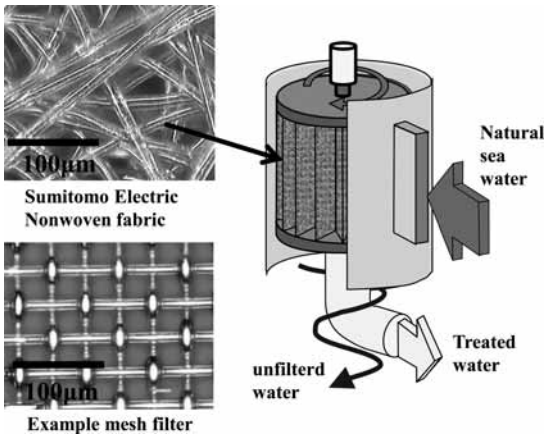

Fig. 4. RC filter principle

Meanwhile, one important point with high-performance filters is to take measures to counter clogging. Usually, the differential filter pressure is monitored to stop filtration and perform backwashing with the filtrate when the differential pressure exceeds a predetermined value.

The RC filter developed by Sumitomo Electric performs filtration and filter cleaning simultaneously, maintaining a constant filtration rate and achieving a high cleaning effect. A filter cartridge consisting of a pleated cylindrical filter medium rotates, introduces raw water (seawater) around the cartridge via an incoming slot, and filters the seawater and cleans the filter medium surfaces simultaneously, as shown in **Fig. 4**. This design makes backwashing unnecessary during operation, and operates continuously without stopping the equipment while the ballast tank is being filled. From around the filter material, filtered-out organisms and particles are discharged as return water to the source sea. Consequently, separated organisms return alive to the original sea.

Figure 5 shows Sumitomo Electric's RC filter and several metal mesh filters (6, 25 and 30 µm mesh size equivalent) and compares their filtration performance. The raw water contains 100,000 organisms per cubic meter. After treatment by the RC filter, the filtrate contains zero large organisms per cubic meter. In contrast, the filtrates of metal mesh filters contain 1,000 or more organisms per cubic meter. Furthermore, the figure shows that the RC filter performs excellently in removing small organisms, separating all organisms greater than or equal to 30 µm and 90% or more of organisms between 10 µm and 30 µm.

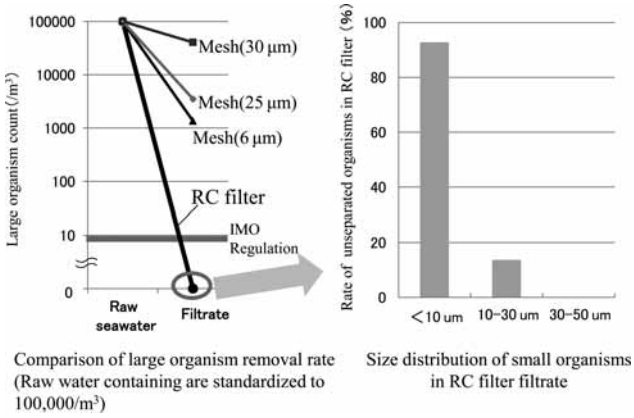

Fig. 5. Comparison of organisms removal performance between Sumitomo Electric's RC filter and mesh filters

3-3 UV Unit

The UV unit incorporates a medium-voltage UV lamp, which is space efficient and delivers a high lighting intensity. As mentioned above, the filtrate that has passed through the RC filter contains no large organisms and only a small fraction of small organisms. Consequently, it is possible to reduce the power consumption of the UV lamp since the amount of irradiation required by the UV unit is such that

is needed to kill the portion of small organisms and bacteria smaller than them.

Almost all animal organisms fall into the category of large organisms. Compared with vegetal organisms, animal organisms are said to be difficult to fully eliminate by ultraviolet rays, survive inside a dark ballast tank, and pose a high risk of propagation, although further studies are required to verify this. With a capability to fully remove large organisms during the water uptake process, ECOMARINE UV radically reduces the probability of organism propagation in the ballast tank.

4. Type Approval

4-1 Type approval process

In each country, ballast water treatment systems are approved by the concerned authorities in accordance with the Guidelines for Approval of Ballast Water Management Systems (G8)[(3)], which is one of the guidelines developed to ensure compliance with the Management Convention. Chemicals- or electrolysis-based systems that possibly have an impact on the environment need to be approved by IMO in accordance with the Procedure for Approval of Ballast Water Management Systems That Make Use of Active Substances (G9)[(4)] prior to G8. Without the need for the use of any active substances, ECOMARINE UV is not required to follow the G9 procedure.

Presently in Japan, the Ministry of Land, Infrastructure, Transport and Tourism has an established process for ballast water management system pre-installation testing, according to which ballast water management systems are required to pass an environmental test, testing of rated performance on land using a tester (land-based test), and an onboard performance and operation verification test (shipboard test).

Sumitomo Electric's ballast water treatment system rated at 200 m^3/h has completed all the tests required for the above-mentioned type approval and has obtained official approval. The following sections explain the details of the land and onboard tests.

4-2 Land-based test

The land-based test uses test water that contains a specified amount of organisms and meets the specified water quality requirements, to test the performance of the system on land that has a higher treatment capacity than the rating noted on the application for type approval.

One test cycle comprises the following:

(1) Preparation of raw water (water for treatment and water for control test)
(2) Uptake operation (water for treatment and water for control test), plus water quality and biological analyses
(3) Storage for five days (voyage simulation)
(4) Discharge operation (water for treatment and water for control test), plus water quality and biological analyses

This test cycle must be successfully completed five times each with two levels of salt concentration selected from seawater, brackish water and fresh water, totaling 10 consecutive test cycles.

The 200 m^3/h rating test conducted for the present report selected seawater and brackish water and prepared test water by adding necessary turbidity and organisms to raw seawater. Approx. 300 m^3 of test water for treatment and also approx. 300 m^3 of water for control test were provided. The water for control test, which was taken up and discharged bypassing the treatment system, was intended to confirm that biological treatment was achieved by ECOMARINE UV. The test was conducted at Marine Technology Institute (Imari, Saga Prefecture). A barge tank was provided to simulate a ballast tank. Test water was prepared and used for uptake and discharge operations.

Table 2 shows performance test results treating large and small organisms. The average count of large organisms contained in the treated and discharged water was 0.8 / m^3. The count of small organisms in each sample was 0 / mL. The treatment system fulfilled the specified requirements with an adequate margin in an operating environment simulating shipboard test installation. Meeting all requirements concerning assessment items such as bacteria and water quality, ECOMARINE UV was verified to deliver sufficient performance as a ballast water treatment system.

Table 2. Land-based test results

Test	Organism size	0 days (before treatment)		5 days (after treatment)	
		Test result	Standard	Test result	Standard
Seawater (average of 5 cycles)	≧ 50 μm	333,967	> 100,000 (/m^3)	0.7	< 10 (/m^3)
	< 50 μm ≧ 10 μm	2,165	> 1,000 (/ml)	0	< 10 (/ml)
Brackish water (average of 5 cycles)	≧ 50 μm	291,850	> 100,000 (/m3)	0.9	< 10 (/m^3)
	< 50 μm ≧ 10 μm	1,946	> 1,000 (/ml)	0	< 10 (/ml)

4-3 Shipboard test

Shipboard test requires the ballast water treatment system to be installed on a ship, operates for at least six months, and successfully undergoes three consecutive cycles of performance testing during that period.

The shipboard test was conducted in collaboration with NYK Cruises Co., Ltd. A system rated at 200 m^3/h was installed on the luxury cruise ship Asuka II (**Photo 1**).

Photo 1. Onboard test ship Asuka II

Table 3 shows performance test results treating large and small organisms. The treatment system met all requirements concerning assessment items such as bacteria and water quality. Fulfilling the standards, as in the land-based test, ECOMARINE UV has been proven to deliver sufficient performance onboard.

Table 3. Shipboard test results

Test cycle	Organism size	Uptake (control)		Discharge (treated)		Discharge (control)	
		Test result	Standard	Test result	Standard	Test result	Standard
No.1	≧50 um	293,337	≧100 (/m³)	0.2	< 10 (/m³)	140,688	≧10 (/m³)
	< 50 um ≧ 10 um	142	≧100 (/ml)	0	< 10 (/ml)	103	≧10 (/ml)
No.2	≧50 um	580,629	≧100 (/m³)	0	< 10 (/m³)	189,446	≧10 (/m³)
	< 50 um ≧ 10 um	287	≧100 (/ml)	0	< 10 (/ml)	95	≧10 (/ml)
No.3	≧50 um	33,703	≧100 (/m³)	0	< 10 (/m³)	2,582	≧10 (/m³)
	< 50 um ≧ 10 um	763	≧100 (/ml)	0	< 10 (/ml)	485	≧10 (/ml)

5. Conclusion

Sumitomo Electric developed the ballast water treatment system ECOMARINE UV incorporating filtration and UV methods. Using the Company's proprietary high-efficiency filter unit, ECOMARINE UV ensures high organism removal efficiency and the lowest power consumption among UV technology-based systems worldwide. This system is friendly to the environment since it uses no chemicals during ballast water treatment, kills a minimum amount of organisms and ensures a low level of energy consumption. Successfully completing all the performance tests required for type approval, ECOMARINE UV has been proven to deliver sufficient performance.

In concluding this report, we would like to express our sincere gratitude to all the individuals concerned at the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of the Environment for guidance concerning various type approval procedures, NYK Cruises Co., Ltd. for their cooperation in the onboard installation and testing of the system, and the testing laboratories for their performance of various tests.

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Contributors (The lead author is indicated by an asterisk (*).)

K. MIYATAKE*
• Manager, New Business Frontier R&D Laboratories

M. UEYAMA
• Manager, New Business Frontier R&D Laboratories

S. HAHAKURA
• Assistant General Manager, New Business Frontier R&D Laboratories

H. INOUE
• New Business Frontier R&D Laboratories

R. NAKAI
• Senior Assistant General Manager, New Business Frontier R&D Laboratories

K. TANIDA
• General Manager, New Business Frontier R&D Laboratories