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Abstract:

JFE Engineering developed a proprietary ballast water management system (hereinafter abbreviated JFE-BWMS. JFE BallastAce® is a registered trademark for

water treatment system for ships. For practical applica-

object aquatic organisms in studies from basic experiments
formed to the guidelines

established by the Interna-
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discharge standards[5)]
an assessment of the results showed that the system has no adverse impacts on the ship's crew and the shipboard environment or marine environment. These results dem-

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1. Introduction

In recent years, the movement and spread of plankton, bacteria, and other aquatic organisms by ship ballast water has emerged as a global problem with adverse effects on the marine environment, fsheries and other industries, and human health[6)].

In response to this problem, in February 2004, the International Maritime Organization (IMO) adopted the "International Convention for the Control and Management of Ships' Ballast Water and Sediments"[7)] and established the D-2 standard[5)] as a discharge standard for ballast water. Following this, "Guidelines for Approval of Ballast Water Management Systems (G8)"[3)] and "Procedure for Approval of Ballast Water Systems that Make Use of Active Substances (G9)"[4)] were established by the 53rd Session of the Marine Environment Protection Committee (MEPC53) in June 2005.

These guidelines require that ballast water management systems not only satisfy the D-2 standard, but also minimize impacts on the ship's crew and shipboard environment, and on the marine environment when ballast water is discharged. Concretely, for treatment systems using active substances (chemical substances such as chemical agents that may possibly affect the environment), which includes the JFE BallastAce® (registered trademark of JFE Engineering Corp.; hereinafter abbreviated JFE-BWMS), after receiving fnal approval[8–10)] from the IMO in connection with environmental assessments on impacts by conducting land-based tests and onboard tests by the methods specifed in the above-mentioned guidelines, "type approval" must be obtained from respective administration.

JFE-BWMS is a proprietary ballast water management system utilizing flter(s), two chemical agents, and Venturi tubes as a ballast water treatment system for ships developed by JFE Engineering.

This paper describes the results of the study of prac-

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tical application of the JFE-BWMS, focusing on the above-mentioned land-based and onboard tests.

2. Outline of JFE-BWMS

2.1 Principle of JFE-BWMS

The JFE-BWMS uses two chemical agents, a chlo-

2.2.2 Operation of system during ballast water discharge

During ballast water discharge, the JFE-BWMS is switched from the treatment system used in ballast water uptake to the bypass system by operation of a motor driven valve. In the bypass system, first, the TRO concentration of the ballast water is measured, and an inverter-controlled pump injects a sufficient amount of TG Environmentalguard® to completely neutralize the measured TRO concentration. The TG Environmentalguard® injection point is upstream of the ballast pump. The neutralization reaction is accelerated by the stirring effect of a powerful turbulent flow generated by impeller blades of the pump, which rotate at high speed. As a result, TRO is completely eliminated in the piping before the ballast water is discharged from the ship. Downstream from the ballast pump, the ballast water is monitored by a high accuracy TRO meter which enables measurement of the condition of chemical reduction. Sure neutralization of the treated water is confirmed by continuous measurement of the reduction condition of the water. The discharging system is also designed to shut down automatically in the unlikely event that TRO is detected for a certain period of time.

The plankton and bacteria extinction operation during ballast water uptake is called primary treatment, and the above-mentioned neutralization treatment is called secondary treatment. In particular, the properties of the secondary treatment water which is to be discharged from the ship are important in assessing the performance and safety of the treatment system.

2.3 Control of Chemical Injection

2.3.1 Concept of control

The water quality of the seawater in ports and harbors is affected by a variety of factors, including the topography of the surrounding land, the presence or absence of rivers, the flow rate of any rivers, etc., and chlorine consumption differs depending on the sea area. Therefore, control of the injection ratio based on the

a slightly higher value than the target value. However, after several minutes, feedback control began and the TG Ballastcleaner® injection rate decreased. As a result, the concentration of TRO in the treated water was controlled to within the target range within a short time. Thereafter, the trend was stable, with values within the target range.

Figure 6 shows time series data for ballast water discharge operation. Simultaneously with the start of operation, TG Environmentalguard® was injected at a constant rate, and as a result, the TRO concentration of the treated water immediately decreased to 0 mg/*l* or less. After the transition to feedforward control of the TRO concentration, the TRO concentration of the treated water showed a trend of less than 0 mg/*l*. From this, it was judged that the treated water is maintained in a reducing condition by the JFE-BWMS.

3.1.2 Treatment performance

Table 1 shows the quality of the test water used in the land-based test specified by G8[5], together with the threshold values.

It is normally necessary to add artificial substances and plankton in order to satisfy these conditions. Likewise, in this test, suspended solids (SS), particulate organic carbon (POC), and dissolved organic carbon (DOC) were added to the water, in order to satisfy the chemical water quality conditions, and large and small planktons and, when necessary, heterotrophic bacteria, were added to satisfy the biological conditions as shown in Photo 1. As test water salinity conditions, brackish water and seawater were selected.

In all tests, 200 m^3 or more of primary treatment water was prepared and stored in a light-shielded model ballast tank for 5 days, after which neutralization treatment was performed to obtain the secondary treatment water used as the object of the test. Treatment performance was assessed by analyzing the organism content of the water after secondary treatment.

In these land-based tests, the tests were performed for a total of 10 test cycles, comprising 5 cycles each with brackish water and seawater, as required by G8[3]. **Table 2** shows the results of the treatment performance test for plankton. These results confirmed that the plankton content of the secondary treatment water satisfied the D2 standard[5] in all of the test cycles. The results of the analysis of bacteria species also confirmed that the D2 standard[5] was satisfied for all species, *Escherichia coli* (*E. coli*), *Enterococcus*

3.2 Onboard Tests

3.2.1 Method of onboard tests

The onboard tests were performed by providing a bypass line in the ballast water piping on the port side of the SAGA Pioneer, which is a 47 000 DWT Box Shape Bulker owned by SAGA Ship Holdings AS, a member company of the Nippon Yusen Group, when that vessel was newly constructed, and installing a JFE-BWMS with a treatment scale of 1 000 m^3/h aboard the ship. **Photo 2** and **Photo 3** show the SAGA Pioneer and the component equipment installed aboard the ship, respectively. Operation of the system was performed remotely from the BWMS operation panel installed in the ballast control room.

In the onboard test, 3 ballast tanks on the port side were used to hold the treated water, and for comparison purposes, 3 ballast tanks on the starboard side were used with untreated control water. Sampling of the treated water and control water was performed using a sampling pipe with a valve installed in the

3.3 Corrosion Resistance of Equipment Materials and Stability of TG Ballastcleaner® Concentration

3.3.1 Sodium hypochlorite corrosion resistance of materials

Because the main ingredient of TG Ballastcleaner® is sodium hypochlorite, which is a corrosive substance, it is necessary to use component materials with adequate corrosion resistance against sodium hypochlorite in sections from the chemical tank to injectors, which come into contact with the stock solution. Furthermore, the ballast piping and inner surfaces of the ballast tanks are exposed to seawater with a maximum chlorine concentration of 20 mg/*l*. Because no data were available for corrosiveness at this concentration, corrosion tests of the following items were carried out using primary treatment water containing 20 mg/*l* of TG Ballastcleaner®. From the results, it was concluded that there is no observable effect, in comparison with natural seawater, for any of the items except unpainted steel plate.

(1) Corrosion test of tar epoxy-coated, modified epoxy-coated, and Zn-coated steel plates with simulated defects.
(2) Condensation test of the above materials.
(3) Corrosion test and condensation test of unpainted steel plate.
(4) Test to confirm effect on the performance of Zn electrode for sacrificial corrosion protection.
(5) Test to confirm effect on piping packing.
(6) Test to confirm effect on component materials of valves in ballast piping system.

3.3.2 Stability of TG Ballastcleaner® concentration

The available chlorine concentration of sodium hypochlorite, which is the main ingredient of TG Ballastcleaner®, decreases gradually as a result of self-decomposition at high temperatures. Self-decomposition can be suppressed, and a suitable concentration for use can be maintained for an extended period of time, by providing a cooling function for the ship's TG Ballastcleaner® storage tank in order to hold the temperature to no more than 20°C. The effectiveness of this counter-

onboard tests.

References

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