PRESENT SITUATION AND PROBLEMS RELATED TO MARINE OILY-WATER SEPARATING TECHNIQUES

K. Watanabe*, H. Yamanouchi*, Y. Ueta** and O. Nagata*

*Ship Equipment Division, Ship Research Institute, Ministry of Transport, Shinkawa 6-38-1, Mitaka, Tokyo, Japan
**Japanese Association for Preventing Marine Accidents, Yuseigojokai Kotohira Building, Toranomon 1-14-1, Minato-ku, Tokyo, Japan

ABSTRACT

Merchant ships are required to be provided with oily-water separating equipment that meets the requirements of the International Performance Testing Standard A.393 prescribed by the International Maritime Organization (IMO), where the discharged oil contents of the effluent measured at the outlet of the equipment are controlled to 15 ppm or 100 ppm according to the classification of ships by gross tonnage. However, investigations are being undertaken to find international solutions centring on the Marine Environment Protection Committee (MEPC) of IMO to improve the not-necessarily-satisfactory-service-performance of oily-water separating equipment, as is evident in cases reported overseas. In this study, the actual service performance of the existing oily-water separating equipment in Japan was investigated and a study on new oily-water separating techniques was conducted with expertise acquired as outlined below.

1) In view of the fact that the engine room bilge in an actual ship contains suspended solids (SS), detergents and other materials in addition to fuel oil and lubricating oil, it is difficult to clear the discharged oil control requirement of 15 ppm at all times, inasmuch as the existing oily-water separating system relies only on a gravitational separation system comprising multiple parallel plates and a filter-type coalescer.

2) The newly developed oily-water separating mechanism relying on oil flocculation and froth flotation has displayed its usefulness for oily water containing oil particles and suspended solids with a particle size smaller than 10 μm, and thus is promising for application to oily-water separating equipment to be designed for clearing the 15 ppm discharge requirements.

KEYWORDS

Marine pollution; Engine room bilge; Oily-water separation; Suspended solid; Oil coagulant; Froth flotation

INTRODUCTION

The MARPOL 73/78 International Convention for Preventing Marine Pollution from Ships prescribes in its Appendix I that engine room bilge in ships must be led through oily-water separating equipment before the bilge is discharged overboard, so that the discharged oil content can be controlled to the specified level or less. That is, a recommendation on the international performance and test specification for oily-water separating equipment and oil content meters (A.393) was adopted at IMO. Oily-water separating equipment meeting this specification is installed in ships all over the world under the approval of the respective governments. However, there is a growing recognition that even the oily-water separating equipment approved in accordance with such international performance specification does not necessarily achieve the targeted performance in actual service aboard ships. As a result, IMO is conducting questionnaire surveys on a global scale to grasp the present situation surrounding oily-water separating equipment and oil content meters, whereby the respective problem areas are being identified with the necessary countermeasures being promoted. Under the circumstances described above, the results of a study 1) on oily-water separating techniques which have been newly developed by the authors are introduced, and the desirable form of oily-water separating techniques in Japan is discussed in this paper.
OUTLINE OF EXISTING MARINE OILY-WATER SEPARATING TECHNIQUES

Characteristic properties of engine room bilge in actual ships

The processing of bilge containing oily sludges produced by fuel oil and lubricating oil discharged from oil purifiers is the dirtiest and hardest task in the engine room, and it is gaining added severity along with the ever degrading quality of marine fuel oil (higher viscosity and higher specific gravity) that requires still greater care and labour of crew members. What is more, since the residual oils and water of this sort govern the properties and the quantities of the bilge generated directly, it has been pointed out as the major cause of the contamination of engine room bilge that has a serious impact upon the function of oily-water separating equipment in the engine room. In more specific terms, the separating mechanism of the existing oily-water separating equipment employs the principle of gravitational separation by employing an aggregate of multiple plates arranged in parallel, an integration of small-bore tubes or a highly porous filtering material, each acting as a coalescer, to promote gravitational separation by combining oil particles in water. On the other hand, the quantities of suspended solids and surface active agents in sludges discharged from oil purifiers have increased in association with the purification of degraded fuel oil, the purification of the increasingly deteriorating lubricating oil due to severer working pressure and temperature. As a result, the presence of these matters is considered to have had a serious impact upon the degrading of the existing gravitational oily-water separating system.

In this paper, the focus is principally laid on the problem of suspended solids among the items contributing to the deterioration of actual oily-water separating performance, and the discussion centers on oily-water separating performance when dealing with the engine room bilge containing these matters. 

IMO has made its tentative countermeasures public against the analyzed results of an international questionnaire survey conducted by IMO. By noting that, which characterizes the engine room bilge and is inevitably contained in it, the authors conducted an experimental study on the effects of on the gravitational separating system provided with a filter using commercial oily-water separating equipment designed for 15 ppm as a test machine. The chemical composition of SS (contained in the sample sludge taken from the bottom of bilge wells), obtained through the authors' property investigation of engine room bilge in an actual ship, is given in Table 1, where eight elements including silicon, iron, sulphur and phosphorus were detected in the qualitative analysis of elements by fluorescent X-ray spectrometry.

<table>
<thead>
<tr>
<th>Item</th>
<th>%</th>
<th>Item</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Organic component</td>
<td>59.0</td>
<td>SiO₂</td>
<td>5.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fe₂O₃</td>
<td>9.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MgO</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CaO</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C'</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Na₂O</td>
<td>0.51</td>
</tr>
</tbody>
</table>

The results of the quantitative analysis show that the organic compounds share approximately 60%, and the remaining inorganic compounds are broken down to approximately 10% for Fe₂O₃, and a little less than 6% each for SiO₂ and PO. From the above, it may be seen that the chemical composition of the sample SS from the ship is characterized by a large amount of ferrous and sand components, and the similar results have been reported in other studies.

Note: Since the organic component in Table 1 was determined by the ignition loss method, the unburnt carbon contained in the bilge, if any, is included in the organic component.

TEST OILY-WATER SEPARATING EQUIPMENT

The test oily-water separating equipment of the latest model was chosen from among those designed and manufactured to the requirements of the International Performance Test Standard (A.393) of IMO for the 15 ppm criterion and then type-approved by the government of Japan. The main body of the test oily-water separating equipment has a single cylinder construction and internally comprises (1) a gravitational separation chamber, (2) wire-mesh coalescer, and (3) oily-water separating membrane cartridge. The membrane is a coarse grain membrane made of unwoven polyester cloth. The fine oil particles which were not successfully captured by the gravitational separating chamber (1) and wiremesh coalescer (2) are formed into lumps of oil particles by the pleat-shaped separating membrane for subsequent gravitational separation. The samples for oil content, concentration of SS, and particle size distribution measurements were taken from the inlet of the separating equipment, intermediate position of the separating equipment (downstream side of (2)) and the outlet of the equipment (downstream of the oily-water separating membrane).
TEST RIG AND TEST METHOD

The test rig is shown in Fig. 1. Taking into account the characteristic properties of engine room bilge, the test rig is provided with an oily-water stirring device and another device to feed matters other than oils into the sample bilge. In more specific terms, two homogenizing mixers (8,000 rpm) arranged in series on the line and one small regenerative pump were provided to ensure that the peak of particle size distribution at the inlet of the oily-water separating equipment is in the vicinity of 10 μm, which is close to the processing limit of the gravitational separation mechanism, and SS or detergents were fed into the sample oily-water mixture with a chemica-feeder. (In this paper, descriptions on detergents are omitted.)

![Diagram of test rig]

Gas oil (specific gravity 0.836/15°C, kinematic viscosity 3 cSt/37.8°C) and tap water at room temperature were used in the test. Among the test dust specified in JIS Z 8901, Classes 8 and 11 loamy soil powder of Kanto and Class 12 carbon black were selected as SS.

<table>
<thead>
<tr>
<th>Table 2 Testing dust</th>
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<tbody>
<tr>
<td>Item</td>
</tr>
<tr>
<td>JIS Class 8</td>
</tr>
<tr>
<td>JIS Class 11</td>
</tr>
<tr>
<td>JIS Class 12</td>
</tr>
</tbody>
</table>

Table 2 shows the properties of these materials. The patterns for a series of performance tests are shown in Fig. 2. A test normally terminates after 2 hours, but it was extended to a total period of 4 hours or more to check the filtration resistance of the oily-water separating element under the same inlet.
conditions. For the oil content measurements, the oil content was extracted by carbon tetrachloride and the absorption spectra in the proximity of a wavelength 3.4 μm were measured with a spectrophotometer. The particle size distribution in the sample oily-water mixture was measured with a Coulter counter (Model TA-II), and the concentration of SS was determined by weighing the SS recovered using a glass fibre filter sheet. The oily-water separation membrane cartridge was renewed each time the SS was changed, and the interior of the body of the separating equipment was cleaned each time so that the previous test had no effect on the next test.

TEST RESULTS AND DISCUSSION

The changes in the oil content at the outlet of the oily-water separating equipment when the type of SS was changed with the above inlet conditions and water temperature at 20 to 26°C and pH 7.0 kept unchanged, and the time-series changes of filtration resistance at the fine oily-water separating element are described below. (White dots and broken lines show the results of a blank test, while black dots and full lines show a test with dust added.)

Fig. 3 shows the case when JIS Class 8 test dust was mixed in the sample. As can be clearly seen from the figure, in the case of a simple mixture of tap water and gas oil, the measured oil content at the outlet of the equipment is lower than 10 ppm against an oil content of 2,300 ppm on average at the inlet. When SS is mixed to approximately 60 ppm, the oil content at the outlet of the equipment increases to 14 ppm on average against an oil content of 3,000 ppm on average at the inlet, where the filtering resistance of the oily-water separating membrane was doubled in 2 hours against the value measured before SS was added. The time-series resistance increased to reach near 0.05 MPa in 5 hours. In view of the fact that the nominal pore size of the membrane of the oily-water separating equipment is said to be 4 μm, and the cumulative residue % of Class 8 dust with a particle size larger than 6 μm is 65% according to the particle size distribution of the test dust, a considerable part of the dust added is thought to be unable to pass through the membrane, and thus dust particles are trapped in the membrane as time passes with the narrowing passage area and increasing filtration resistance (pressure loss). As the reasons for the temporal decrease in the oil content at the outlet in the period from 2 hours and thereafter, it may be pointed out that the processing rate was lower than the rated value of 150 l/hr with the reduced membrane passing speed (by approximately 20%), and the apparent pore diameter of the membrane became smaller because of the accumulation of dust particles.

Fig. 4 shows the oily-water separating performance when JIS Class 11 test dust of JIS is added to the sample oily-water mixture, where a significant difference from the result shown in Fig. 3 is created. Namely, when no dust is added, the oil content at the outlet is 20 ppm on average against an oil content of approximately 2,100 ppm on average at the inlet, but when 200 ppm or less of dust is added, the oil content
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at the outlet rises to approximately 250 ppm within 2 hours and thereafter against an oil content of approximately 2,700 ppm at the inlet, thus it reached 10 times or more of the level recorded before dust was added. According to literature 4), the particle size distribution of JIS Class 11 test dust is such that the cumulative undersize of % smaller than 4 \( \mu m \) reaches as much as 80%. When simplified merely in terms of particle size, such a high oil content value at the outlet is considered to have been caused by the fact that nearly 80 percent of SS has permeated through the membrane oily-water separating element, and that the lump-forming action of the oil, which is attached to the surface of the dust and is then carried away, suffers from interference 5). As can be seen clearly from the figure, no appreciable difference has been created in the filtration resistance regardless whether SS is added or not.

Fig. 5 shows the results of the test using JIS Class 12 test dust, where no difference of any significance was created in the oil content at the outlet of the oily-water separating equipment throughout the 4-hour test. The amount of test dust added at the inlet of the equipment was less than 200 ppm on average, but the average content measured at the outlet of the equipment was approximately 3 ppm, thus it is shown that almost all of the carbon black added was accumulated in the oily-water separating equipment. This is considered to be ascribable to the strong adsorbing power of the carbon black. The carbon black which had adsorbed the oil content attaches to the wire mesh coalescer and coarse particle membrane fabrics and subsequently settled. The filtration resistance of the membrane showed a tendency toward a slight increase from one hour after starting the test, and for this reason the standard water discharging pressure of 0.07 MPa could not be maintained. The water discharging pressure dropped to a level lower than 0.04 MPa in 4 hours, and the processing rate of the oily-water mixture at this stage was reduced by approximately 20% of the rated value. In an actual ship, there is a possibility that a large amount of washings containing the unburnt carbon produced by the cleaning of an exhaust gas economizer etc. will fall onto the bilge wells in the engine room. In such a case, the separating function of the precision separating filter of the oily-water separating equipment deteriorates to a large extent. Hence, it is necessary to study the work procedure and proper control and management of washings of this sort.

Through the above study and tests, the authors have acquired expertise on the effects of the particle size of dust itself and three types of particles having different physical properties on the actual service performance of the existing oily-water separating equipment. However, the contents presented in this paper represent only the results obtained under limited inlet condition and a specific model of oily-water separating equipment, and hence the actual service performance differs from unit to unit depending on the maintenance of the separating element and would not be compatible even if the equipment is the same model. The actual service performance can of course differ according to differences in structure and operational requirements, and also to the difference in design concerning the target oil particle size. As mentioned earlier, the tests in this study were carried out under such stringent mixing conditions as a peak of particle size distribution at the inlet of the oily-water separating equipment set at 8 to 10 \( \mu m \).
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gives a particle size condition even stricter than that prescribed in the Test Standard A.393 of IMO 6), and thus is believed to provide basic data for the breakthrough to identify the cause of difficulties for the existing marine oily-water separating equipment to clear the oily-water separating performance requirements.

According to the measured results of the concentration of SS in the actual ship test of the oily-water separating equipment carried out by the authors, it was shown several times, that sample oily-water mixture with the concentration of SS in the range from 100 to 200 ppm at the inlet of the oily-water separating equipment remained at almost the same values at the outlet of the equipment. Thus, the inclusion of parameters such as detergents and SS in the contents of the Performance Test Standards A.393 now under assessment at IMO is an important item on the agenda in relation to the actual service performance of oily-water separating equipment.

OUTLINE OF OILY-WATER SEPARATING TECHNIQUE USING THE OIL FLOCCULATION METHOD

An attempt has been made to develop a new, compact marine oily-water separating system of extremely high performance using chemicals for oil flocculation and froth flotation (hereafter called the "oil flocculation method") in the post-separating process as an integral part of the new oily-water separating loop where the existing equipment is supposed to be used in combination. In chemical processing seen in large land water treatment plants, the separation progresses under atmospheric pressure (the tank where oil flocculation and froth flotation are performed is open to atmosphere), but if this technique is to be effective in marine applications, the tank for oil flocculation and froth flotation, which is a nucleus of this system, is essentially required to be of the closed structure. As far as we know, there is no such marine oily-water separating equipment actually operated under the operating principle as above, and thus there are many unsolved technical problems.

On the basis of the results of basic studies on the oil flocculation method as applied to oily-water separation, a full-scale model of oily-water separating equipment (rated processing rate of 500 l/hr) comprising the existing gravitational oily-water separating mechanism (combination of multiple plates arranged in parallel and a filter) and the component using the oil flocculation method, was fabricated experimentally, whereby a general test was carried out using the sample oily-water mixture of gas oil and tap water, and another sample mixture of blended oil including the elements of actual engine room residual oils and tap water, and the oily-water separating effects of the model were evaluated.

OILY-WATER SEPARATING EQUIPMENT RELYING ON THE OIL FLOCCULATION METHOD

Sample oil coagulant: This single liquid oil coagulant comprising a derivative of amino acid developed by company A in Japan, and in the test 2% water solution of this oil coagulant was used. The oily-water separating process using this oil coagulant is considered to be as shown in Fig. 6, and an oily-water separation test can be carried out by adding the specified oil coagulant to the engine room bilge containing sea water and by mixing them. From the viewpoint of the importance of simplicity in operating marine equipment, the fact that this coagulant is a single liquid oil coagulant is noteworthy.

![Fig. 6 Oil-water separating process by oil flocculation method](https://iwaponline.com/wst/article-pdf/23/1-3/319/112497/319.pdf)

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Experimental equipment to study an integrated system relying on the oil flocculation method: As shown in Fig. 7, the basic system of this experimental equipment comprises an oil coagulant line and a pressure...
water line (air is dissolved in water under high pressure, and after passing a nozzle air bubbles are generated at reduced pressure), and by causing these to become confluent at the mixing chamber where oil particles are subjected to froth flotation with the aid of fine air bubbles in their lifting motion to collect the separated oil particles in the closed stationary chamber. The automatic operating function and the automatic discharge procedure of floc in this experimental system have been established and the effectiveness of this equipment for oily water containing a non-ionic surface active agent and SS has been verified. To be more specific, as a result of a 6-hour continuous running with the oily-water mixture in which particles (oil and SS) of a size smaller than 5 μm share approximately 90% of the total quantity, a stable oil content of 30 ppm (the internal pressure of the stationary tank at approximately 0.05MPa) at the outlet has been achieved against an inlet oil content of 350 ppm. Furthermore, it has been verified that SS of approximately 170 mg/l at the inlet, measured at the same time as above, showed 60 to 55 mg/l of residual weight in the effluent, thus demonstrating that approximately 70% was captured by floc.

**TEST WITH THE EXPERIMENTAL EQUIPMENT OF FULL-SCALE MODEL RELYING ON THE OIL FLOCCULATION METHOD**

Experimentally fabricated full-scale model: Fig. 8 is the flow diagram of the full-scale model of the experimentally fabricated oily-water separating equipment relying on the oil flocculation method. As can be seen from this figure, this model represents an additional separating mechanism with the oil flocculation method placed downstream of the existing oily-water separating equipment.

The basic operation of this system is as follows. The oily water containing fine oil particles fed into the No. 1 cylinder by the bilge pump is subjected to a growth in oil particle size when it passes through the concentrically arranged multiple plates. It then floats and separates from the water due to the difference in density. The oil particles which failed to separate from the water are subsequently subjected to a growth in oil particle size by the filter placed in the 1st stage filter holder, and then separate from the water due to the difference in density in the No. 2 cylinder. For those fine oil particles which could not be separated successfully through these two stages of the existing gravitational separation process, primary mixing (hydrodynamic mixing) of oil particles with the oil coagulant supplied by a chemica-feeder is carried out at the 1st stage static mixer. Subsequently, the oily water containing this coagulant and pressurized water become confluent, and then the secondary mixing is carried out at the 2nd stage static mixer. At this time, bivalent ions (Mg²⁺ etc.), which are necessary for the oil coagulant in the oily-water line to form floc are added to the pressurized water (in an actual ship, sea water may be used as the pressurized water). The oil coagulant combines with air bubbles, forms floc, and most of it floats and separates in the No. 3 cylinder. In order for the particle size of the floc that failed to separate and overflows from the No. 3 cylinder to grow, the 2nd stage filter holder and the No. 4 cylinder are provided.
Sample oily water: For oily-water separating tests, two types of gas oil and blended oil (base material: residual oil in the engine room) were used. Table 3 shows the properties of the sample oil. Since the residual oils of engine room obtained from actual ships have extremely high specific gravity and viscosity and contain large quantities of SS, assuming that such oils mix with the engine room bilge, the blended oil was prepared by adding gas oil and surface active agent to them. The test was carried out by pulverizing the oil content in the oily water comprising the aforementioned sample oil and tap water with the line-assembled homo-mixer rotating at a speed near 8,000 rpm (mechanical mixing by turbine blades), and then supplied to the experimental full-scale model via the bilge pump. The oil content at the inlet at this moment was targeted at 5,000 ppm. Of those general tests implemented, the results of two or three tests are described below.

### Table 3 Properties of testing oils

<table>
<thead>
<tr>
<th>Type of oil</th>
<th>Specific gravity (15/4°C)</th>
<th>Kinematic viscosity (cSt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas oil</td>
<td>0.836</td>
<td>4.73/37.8°C</td>
</tr>
<tr>
<td>Composite residual oil in engine room of an actual ship</td>
<td>Approx. 1.16/70°C</td>
<td>20,000 or more/60°C</td>
</tr>
</tbody>
</table>

Oily-water separating characteristics when the discharge pressure is changed

This test has a direct effect on the generation of air bubbles within the closed stationary chamber and the test results have relevance to one of the important performance characteristics for marine applications of the equipment.

The 1st stage filter holder was filled with 23 sheets of 200 mm dia. polypropylene filter coalescer (free thickness: 5 mm/sheet) and the 2nd stage filter holder, approximately 1 kg of stainless steel chip coalescer. The 1st stage filters had a laminar structure, but they were charged in a slightly compressed state.

The sample oily water was prepared with gas oil and tap water. The processing rate of oily water during the test was set at 500 l/hr, pressure water, 200 l/hr, oil coagulant, approximately 1 l/hr, the discharge water pressure was raised to approximately 0.06MPa, and after carrying out an 8-hour continuous run, a 2-hour test was carried out by lowering the discharge water pressure to approximately 0.06MPa. Fig. 9 shows the results of the above tests. Until the 8th hour under a high discharge water pressure, the oil content of approximately 6,000 ppm at the inlet of the equipment was reduced to slightly more than 300 ppm at the outlet of the No. 2 cylinder, approximately 60 ppm at the outlet of the No. 3 cylinder (the outlet of the stationary flotation tank relying on the oil flocculation method), and approximately 15 to 24 ppm at the outlet of the No. 4 cylinder (the outlet of the 2nd stage filter holder). The measured results of the inlet oil particle size distribution using the Coulter counter show that the peak assumed between 10 and 13 µm, and those oil particles with a particle size below 10 µm shared approximately 50 vol. % of the total, and the particle size distribution of oil particles had a peak between 2 and 3 µm at the outlet of the equipment.

At the 10th hour when the discharge water pressure was lowered, the oil content in the oily water under processing apparently dropped to less than 10 ppm. It is assumed that the inner pressure of the No. 3 cylinder came down as a result of the drop of the discharge water pressure with the increased generation of air and the improved effect of the flotation of floc.

### OILY-WATER SEPARATING PERFORMANCE WITH QUASI-BILGE WATER

When the 1st stage filter holder is filled with unwoven polypropylene filters, an increase of the inner pressure due to the loading of the filters was observed under the influence of the SS content in the engine room's residual oil used as the base material for the blended oil as the test time elapsed. When the pressure loss due to loading of the filter increases, it naturally caused a rise in the pressure at the inlet side of the oily-water separating equipment, i.e. the discharge pressure of the bilge pump, and when the rise exceeds a certain value, operation becomes no longer possible. For this reason, the 1st stage filter holder was filled with a stainless steel coalescer which seldom causes loading, and the results are shown in Fig. 11 to investigate the effects, the particle size distribution at the test, in Fig. 12, and the concentration of SS, in Fig. 13. Against an oil content of 370 to 1,080 ppm at the inlet, the oil content at the outlet of the No. 3 cylinder and at the effluent discharge outlet were 45 to 59 ppm and 29 to 35 ppm respectively, proving to be a failure in complying with the present international requirement of 15 ppm.

As shown in Fig. 12, the oily water in the No. 3 cylinder and No. 4 cylinder contains a relatively large volume of extremely fine oil particles with a particle size smaller than 2 µm, and this suggests that the successful realization of techniques to achieve the effective processing of oil particles of a few µm in size in emulsified oily water will be of vital importance to clear the 15 ppm discharge criterion at all times.
PROPOSED COUNTERMEASURES FOR PROCESSING ENGINE ROOM BILGE

It is the real intent that every type-approved marine oily-water separating equipment can successfully process engine room bilge of any properties. In reality, however, the available performance of marine oily-water separating equipment does not necessarily exert its essential performance for many reasons such as the ever degrading quality of marine fuel oil. Accordingly, the following measures must be established to clear the prescribed 15 ppm (100 ppm) effluent discharge content criteria under any service conditions.

i) Precautions in handling engine room residual oils and detergents:
In an engine room where diesel engines are running, oils spilled from the engines, various types of residual oil, tank drains, detergents etc. tend to collect in the bilge wells. In particular, the residuals of lubricating oil and detergent contain a variety of surface active agents, thus giving serious adverse effects on oily-water separation. It is therefore very important to provide means to prevent mixing of engine room bilge with these matters.

ii) Employment of the bilge preprocessing system:
It is necessary to improve the system provided to remove part of the oils, S5, detergents etc. in a passage between the bilge wells and the oily-water separating equipment to reduce the load imposed on the existing oily-water separating equipment. Although such a system is currently available, it must be urged to develop an effective preprocessing system with emphasis laid on removing S5. Along with this direction, the system relying on the oil flocculation method, as introduced in this paper, must be developed for the positive utilization of such a system as an integral part of the preferred bilge processing system.

CONCLUDING REMARKS

In the absence of any effective means and ways to counter the ever degrading engine room bilge itself, efforts have been made to comply with the present technical requirements. This is more or less an issue that is common to all merchant ships of the world. It is therefore necessary to assess not only the unitary aspect of oily-water separating equipment but also the system features of such installations including the operational aspects as well towards realizing better compliance with the requirements for preventing marine pollution from ships.
Fig. 11 Separating performance of quasi-bilge with base materials of residual oils of an actual ship

Fig. 12 Particle size distribution in testing quasi-bilge

Fig. 13 Concentration of SS when quasi-bilge was tested

REFERENCES


