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**GUIDE TO DIAGNOSING CONTAMINANTS IN OILY BILGE WATER
TO MAINTAIN, OPERATE AND TROUBLESHOOT
BILGE WATER TREATMENT SYSTEMS**

1 The Marine Environment Protection Committee, at its fifty-ninth session (13 to 17 July 2009), noted the outcome of the discussion, during the fifty-second session of the Sub-Committee on Ship Design and Equipment, on the proposed Guide to diagnosing contaminants in oily bilge water to maintain, operate and troubleshoot bilge water treatment systems developed by the Institute of Marine Engineering, Science and Technology (IMarEST), and in particular, noted the Sub-Committee's view that the Guide could be an excellent tool to help engine-room crews to comply with MARPOL requirements.

2 The Committee noted also that, in order to refine the current text, further consideration would be beneficial and should be pursued through the DE Sub-Committee. However, recognizing the usefulness of the information contained in the Guide as a means to address the most common system maintenance and operations problems leading to equipment failure, the Committee agreed to disseminate the Guide (MEPC 59/24, paragraphs 10.28 and 10.29), attached at annex, as an MEPC circular for the benefit of all those dealing with operations and maintenance of oily bilge water treatment systems in port or on board ships.

3 Member Governments are invited to bring this circular to the attention of all interested parties, especially shipboard personnel sailing in ships flying their flags.

ANNEX

**A GUIDE TO DIAGNOSING CONTAMINANTS IN OILY BILGE WATER
TO MAINTAIN, OPERATE AND TROUBLESHOOT
BILGE WATER TREATMENT SYSTEMS****Purpose**

A properly functioning Oily Water Separator (OWS) is needed to ensure compliance with MARPOL. The OWS controls operational discharges overboard of waste water that accumulates in machinery spaces. An understanding of both the oil-water separating equipment and shipboard wastes that enter the bilge is necessary to properly manage onboard bilge water and oily waste. This Guide describes a six-point process to diagnose contaminants in bilge water. It recommends approaches to prevent contaminants from entering bilge water and to remove contaminants that hinder the operation of an OWS.

Organization of the Guide

The Guide provides a basic understanding of what contaminants can enter the bilge and from what source. A simple chart is presented to diagram sources of contaminants. It describes how to diagnose the presence of contaminants using a troubleshooting decision tree and a six-point diagnostic process found in six annexes. It also describes chemical and physical analytical techniques used in the diagnostic processes. Last, the Guide describes and provides recommended preventive and remedial or corrective measures. For ease of use of this Guide, basic theory is included in three Appendices.

Appendix I: Theory of Operation of Oil Content Meters

Appendix II: Diagnostic Techniques

Appendix III: Recommended Major Preventive, Remedial and Corrective Actions

Specific applications of the diagnostic techniques are detailed in six annexes linked to the decision tree. These six annexes comprise the six-point process to diagnose contaminants in bilge water. The annexes also link to the Appendices to provide amplifying information and recommendations on recommended remedial and/or preventive actions.

Annex 1: Troubleshooting Contaminant Related Oil Content Meter Malfunctions (light scattering/turbidity OCMs)

Annex 2 Detection of Detergents and Solvents

Annex 3: Detection of Emulsions

Annex 4 Detecting Particulates: Biological, Soot and Rouge (Iron Oxide Compounds)

Annex 5 Post-treatment (OWS) Oil Sheen

Annex 6: Detecting Both Oil and Oil Emulsion: Multiple Contaminants and/or Mechanical Failure

Use of this Guide can only be successful with crew and shoreside personnel awareness; adequate funding for maintenance, training, retrofitting and upgrades; attention to manufacturer's maintenance and operating procedures and details; and careful monitoring, communication and oversight.

Background

There are a number of bilge water treatment technologies and products commercially available for use on board ships to remove oily waste from bilge water. A typical bilge water treatment system may be composed of the following components: a holding tank(s); a pre-treatment settling tank; an OWS; post-OWS secondary treatment and/or polishing units; and an oil content meter (OCM). Unfortunately, many of these basic bilge water treatment systems are unable to handle the mixture of contaminants presently found on board ships. Newer and more advanced systems are theoretically capable of handling most of these contaminants but there are still presently issues with the processing of bilge water.

The OCM is critical to the proper functioning of a bilge water treatment system. It controls the discharge of processed bilge water from the OWS, ensuring that the discharge does not exceed 15 parts per million of oil. Oil content meters are designed to detect oil particles in bilge water. They may also detect particles other than oil. Newer oil content meters are built to International Maritime Organization (IMO) standard resolution MEPC.107(49). They are specifically designed to detect oil emulsions particles and prevent their discharge. A design limitation in most oil content meters is that they are limited in their capability to discriminate between oil and some non-oil particles. Older resolution MEPC.60(33) oil content meters are poor at detecting oil emulsions. Newer resolution MEPC.107(49) meters are more finely tuned to detect emulsions and iron oxide particles; however, there are still limitations in their ability to detect some particles and non-oily emulsions. (See Appendix I for a discussion on the theory of OCM operation.) When there is a heavy particulate load in the processed bilge water, oil content meters can often prevent the discharge of processed bilge water. To this end, determining what contaminants, particulates, and particulate and emulsion forming chemicals are present in the bilge is essential.

A lack of understanding of present-day contaminants remains an obstacle in the efficient operation and troubleshooting of bilge water treatment systems. Furthermore, many equipment manufacturer's maintenance, operating, and troubleshooting manuals do not adequately address the larger problem of contaminants, and the need for proper shipboard oily waste water and bilge water management. Improper bilge water management practices are a major factor in problems which can lead to equipment failure. This Guide provides the foundation for the development of bilge water contaminant identification skills, along with diagnostic and bilge water treatment system troubleshooting techniques. Sources of bilge water contamination and techniques to identify the potential contaminants are presented for the marine engineer to assist in both preventing and diagnosing system failures. A diagnostic decision tree for bilge water treatment systems operating in the full range of shipboard environments is provided for use in troubleshooting common system problems. The decision tree is annotated and includes detailed diagnostic techniques and recommended remedial or corrective measures for both acute and chronic conditions. The decision tree is designed to be used by shipboard engineers (from the "4th engineer" to the Chief Engineer) and shoreside technical support. Interviews with ship operators, marine engineers and others indicate the need for more information to make environmentally sound and cost (e.g., life-cycle costs) effective decisions to design, procure,

operate and maintain adequate OWS and supporting components (i.e. the bilge water treatment system). The diagnostic and troubleshooting decision tree will also facilitate informed decisions by marine engineers and shoreside management on bilge water treatment options. These options include retrofitting or upgrading equipment or employing other oily waste water and bilge water management practices, including contaminant minimization. Contaminant minimization is directly associated with practices related to maintenance, cleaning and operation of all equipment, and systems within a machinery space.

Both the volume of waste oil to be separated and the volume of water entering the bilge are a major concern for the proper management of onboard bilge water. A ship operator's inattention to excessive oily waste generation directly associated with the maintenance, cleaning and operation of equipment, and systems within a machinery space can increase the "wear and tear" on bilge treatment systems and the likelihood of system failure. Excessive introduction of clean water into the bilge also increases the likelihood of failure. A more detailed analysis and discussion of these issues are beyond the scope of this Guide.

Diagnosing Contaminants in Oily Bilge Water

Figure 1 is provided for illustrative purposes. It is an example of a flow diagram of several (of many potential) sources of bilge water treatment system failures due to contamination. Contaminants include but are not limited to: waste oils, solvents, detergents, iron oxide particles (rust or "rouge"), engine-room soot, and "biological" contaminants. Biological contaminants are products of bacterial and microbial decomposition such as sewage and growth of life forms in the bilge and piping. In a typical vessel, the main sources of contamination in bilge water and bilge holding tanks include:

- .1 Diesel engine aftercoolers (clean water);
- .2 Sludge from decanting/bottom draining storage and sludge tanks. Lube oil and fuel oil purification (oily water);
- .3 Fuel oil storage and settling tanks (oily water);
- .4 Lube oil and fuel oil filtration (oil);
- .5 Machinery leakages;
- .6 Condensate from air compressors and compressed air systems;
- .7 Diesel engine piston stuffing box leakages and piston underside blow-down (slow-speed diesels only);
- .8 Boiler water/condensate drains (different than piston cooling water because these include other types of chemicals (e.g., solvents), causing different concerns);
- .9 Equipment and engine-room washing;
- .10 Economizer water washing;

- .11 Seawater/freshwater cooling (a potential source of biological contaminants);
- .12 Fire-fighting foam;
- .13 Water treatment chemicals;
- .14 Engine coolant;
- .15 Grey water drains;
- .16 Sanitary system leaks and overflows; and
- .17 Air conditioning and refrigeration condensate.

Some or all of these contaminants can be present in the bilge at any time. Solvents, detergents, and soot are often found after equipment cleaning in machinery spaces. Iron oxide particles and biologicals are common in older ships (leaking pipes, rusting equipment and hull) or when bilge treatment systems have not been operated regularly.

To prevent problems with the operation of bilge water treatment systems or when problems arise, it is important to establish the source of a potential or actual system failure. It is highly recommended that shipowners, port engineers/company superintendents, and chief engineers develop a similar flow diagram for the source(s) of bilge water contaminants for each ship in the company fleet. Simple diagnostic techniques are provided for these purposes in Appendix II.

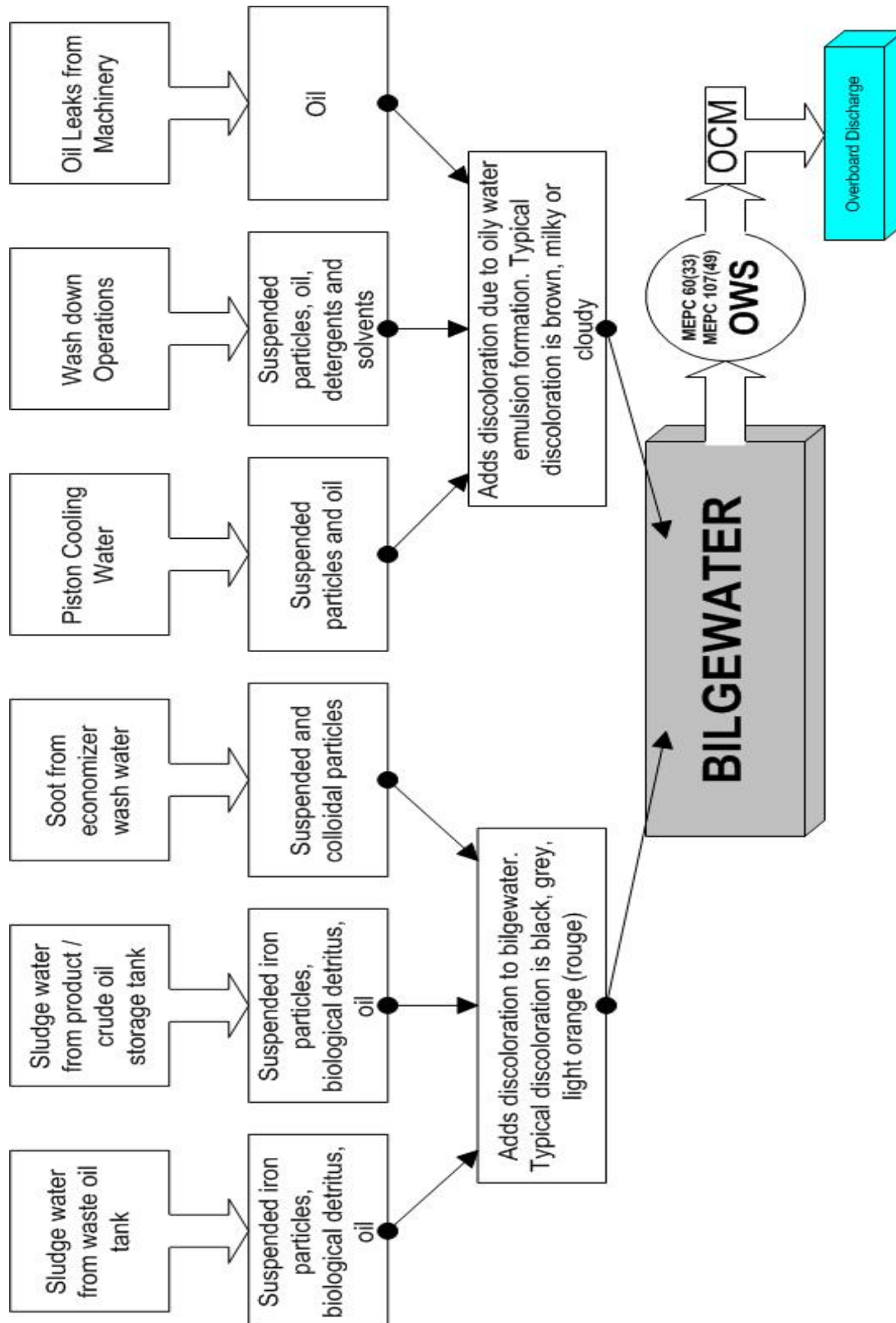


Figure 1 – Example of a Shipboard Flow Diagram: Sources of Contamination Characteristics in Bilge water

Using the Diagnostic/Troubleshooting Decision Tree

The Diagnostic/Decision Tree, Figure 2, is formatted as a flow chart and reads from top to bottom. It may be used to address both acute and chronic problems. Each branch of the tree is formed on the basis of an opening line of inquiry or “opening argument” based on the symptoms of system failure. Following the argument is a series of prescribed tests to determine the possible source(s) of the problem(s), and recommended remedial or corrective action(s). These tests can be performed by ships’ crew, diagnostician or troubleshooter. Personnel are referred to detailed instructions in the annexes keyed to one or more branches of the decision tree.

The first question assumes the OWS is in recirculation mode preventing the discharge of processed water overboard. It also assumes that personnel have performed the basic troubleshooting prescribed by the manufacturers’ and/or shipping company’s bilge water treatment system maintenance and operating (M&O) procedures. The first question directs the troubleshooter to flush the OCM with clean water per the manufacturer’s instructions to ensure that the OCM is working. The troubleshooting process follows through the tree, carrying out various tests based on a series of questions and observations. These lead to the identification of the problem or potential problems and recommended fixes. Many of the remedies or corrective actions can be taken by ships’ crew. This could involve discontinuing or limiting the use of solvents and detergents after flushing the system, and discharging all the wastes ashore. Other problems that cannot be remedied by the ships’ crew may require company action. For example, the system may need a retrofit of the basic OWS system (60(33) or 107(49)) with post-treatment filters and/or polishers. (Note that some 107(49) OWS have been found incapable of handling high emulsion and particulate loads.) Or the system may need an upgrade of an older 60(33) OWS with a replacement 107(49) OWS that could better separate free oil or remove emulsions and particles.

- Diagnosing and troubleshooting the acute condition: This troubleshooting process is designed to help the marine engineer in resolving operating problems which may arise. These are conditions where retrofitting or upgrading the OWS is not necessarily an option. The engineer must be able to determine the cause of a problem and be provided immediate and practical remedial options. Examples could include: cleaning the OWS with hot water, installing polishing filters on an *ad hoc* basis, identifying and addressing OCM errors. Unfortunately there have been many instances where acute and often chronic problems plague a ship’s bilge treatment system, even with a 107(49) OWS system. Retrofitting may be the more cost effective solution in either the near or long term. However, upgrading to a better quality 107(49) OWS or more appropriate unit (depending on the nature of the problem) should also be considered. These practical guidelines and recommendations are the primary focus of this aspect of this Guide.
- Diagnosing and troubleshooting chronic conditions in bilge treatment system: This Guide provides tools to identify both the acute and chronic conditions that should be addressed, both on the ship design and operation levels to retrofit or upgrade a failed bilge treatment system, and also for improving existing equipment performance. Unfortunately for some ships, problems are not acute and are not easily remedied without significant costs or a radical change in shipboard practices. It is sometimes impossible to void chronic conditions, particularly on older ships. This can be due, all or in part, to shortcomings in

understanding the nature of bilge water. These can range from poor bilge water management practices to equipment operation and maintenance. In some cases, problems may be caused by OWS design shortcomings. In such circumstances, the consideration of replacement or improvement of existing bilge water management equipment is appropriate.

- Diagnosing chronic conditions in bilge water management: Figure 1 identifies many sources of bilge water contamination. Controlling these contaminants *at the source* should be one of the primary corrective actions. It should also be a consideration in bilge water management. Often, however, this requires radical changes in shipboard practices. Contaminant minimization is directly associated with practices related to maintenance, cleaning and operation of all equipment and systems within a machinery space. Two other issues that can also impact the effective operation of an OWS are the volume of waste oil to be separated and the volume of water that enters the bilge. Ship operators' inattention to excessive oily waste generation directly associated with machinery maintenance and operation and the excessive introduction of clean water into the bilge from a variety of sources can increase "wear and tear" on bilge treatment systems and the likelihood of system failure. A list of several successful recommended remedial and corrective actions is provided in Appendix III.

It is important to note that all OWS operations including diagnostics should be logged in the Oil Record Book (ORB). It may also be helpful to maintain a separate but related log of diagnostics conducted and findings, including but not limited to: diagnostic test(s) performed, date, time, results/findings, remedial or corrective actions. It is also recommended that the International Safety Management (ISM) system be used for dealing with persistent bilge water contamination and OWS problems. Proper use of the ISM system will greatly aid all parties in recording, communicating, verifying and remedying bilge water treatment problems.

Appendix I

OIL CONTENT METERS (OCM)

This Appendix provides the basic theory of a light-scattering OCM to assist the troubleshooter in diagnosing problems with an OCM.

There are three types of (OCM). The older 60(33) OCM and most of the newer 107(49) OCM are based on light scattering. They are essentially turbidity meters. These meters measure the cloudiness of the water. The newer 107(49) light scattering meters are better calibrated to detect oily emulsions than the older 60(33) meters. This increased sensitivity of the 107(49) light-scattering OCM to oily emulsions does sometimes lead to situations where other light-scattering particles will be detected. These meters are, however, designed to discriminate between oil and oily emulsion, and iron oxide particles. The third type of OCM uses a different type of detection technology, fluorescence detection technology. These OCM also meet the 107(49) standard. Fluorescence occurs when a molecule absorbs light energy of one specific wavelength and emits light energy of a longer wavelength. Fluorescent compounds (such as oil) each have a unique wavelength signature. These compounds can be detected and correlated to the concentration of oil in water. Silt/algae/iron oxide and other particles do not fluoresce at oil's wavelength. This allows an OCM based on fluorescence technology better to discriminate oil and oil emulsions from other contaminants. Until recently, this technology was limited to use in the offshore oil industry. There are now models for shipboard use. However, this promising technology has a limited track record at this writing.

The following discussion focuses on light-scattering OCM models (from <http://oilinwater.org/theory.html>). All light scattering OCMs use similar components but may be arranged differently. There is insufficient experience available to discuss fluorescence detection OCM technology in shipboard use in this Guide. A cross-section of the probe body of a light-scattering OCM is depicted in Figure 3.

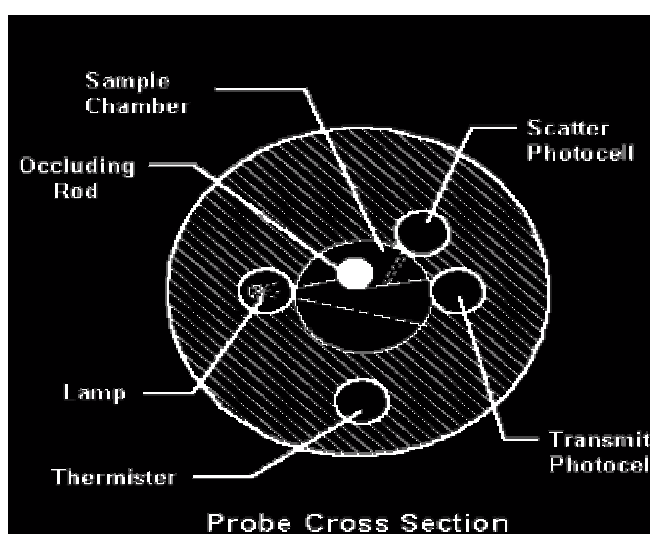


Figure 3 – Cross-section of a Light-scattering Oil Content Meter

In a light-scattering OCM, a light shines from the Lamp (light source) to the other side of the chamber. The light is detected at a Transmit Photocell and a Scatter Photocell. When clean water is introduced, the light received at the Transmit Photocell will be of the same quality as that which left the light source. Water is a good transmitter of light so it does not attenuate the light.

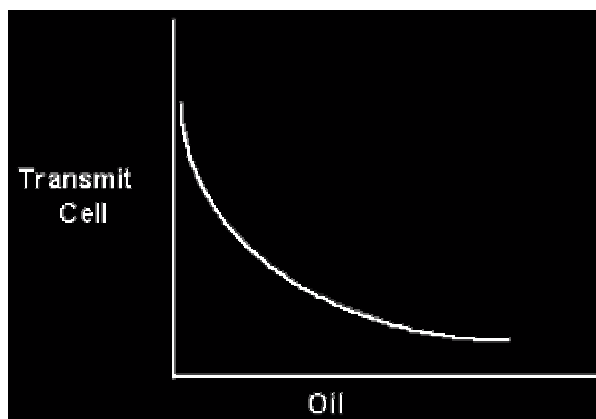


Figure 4 – Relationship of Oil Concentration and Light Transmission

As the amount of oil in the effluent is increased, the light received at the transmit photocell will be reduced due to the oil's opacity. The curve in Figure 4 shows this decrease in light transmission. This curve can also be distorted by the presence of solids and emulsions as well as ageing of the light source(s).

Also in the detection chamber is a rod which blocks or "occludes" the light to the Scatter Photocell. The light from the light source cannot reach this Scatter Cell directly. Oil droplets act as prisms, refracting or scattering the light around the occluding rod so light will be picked up at the Scatter Cell, and less light will be received at the Transmit Photocell. This physical phenomenon is used to measure the oil content. The Scatter Photocell light curve as a function of oil concentration is depicted in Figure 5. The amount of light received at the Scatter Photocell is zero with no oil present [due to the occluding rod] and increases with effluent oil content.

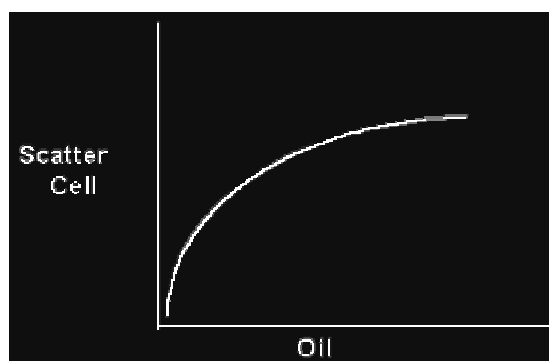


Figure 5 – Scatter Photocell Light Curve

In summary, a light-scattering OCM is essentially a meter that detects cloudiness or turbidity in bilge water. The newer 107(49) OCM use a variety of light wavelengths from several light sources, including near infra-red and white light, and usually have multiple diodes to detect both direct and scattered light. In this way, the newer OCM are tuned to detect oily emulsions and

reject, *within limits and type*, most but not all solid particulates. Due to the construction of the meters, some non-oily emulsions and soot can also be detected as oil.

Detection of non-oily substances: Although it is not supposed to occur, materials which are not oil are sometimes detected by the OCM. The most common are:

- *Fine particulate matter* – Soot as a result of contamination from cleaning operations; iron and iron compounds as a result of biological contamination; and biological detritus or particles (usually accompanied by a foul odour in the bilge).
- *Non-oil organic compound* – Soaps and solvents together or alone will form droplets in water (i.e. emulsified droplets approximately 0.1-1.0 millimetre in diameter). These droplets will scatter light just as emulsified oils do and will be detected by the OCM.

Detection of non-oily substances can result in occasional false positives (high readings) or an inability to get reproducible readings. This is not to say that the 60(33) or 107(49) meters are somehow defective. A 60(33) is unable to detect clear emulsions of any type and therefore may yield false negatives (low readings). In that sense, a 60(33) is imperfect by design in that clear emulsified oily wastes pass through the OCM undetected. All instruments are able to detect certain materials and are unable to detect and/or will falsely detect others. Technology commonly used in shipboard oil content meters is the best current solution when one takes into account cost and potential problems with other detection instruments. The 107(49) light-scattering OCM is more sensitive by design than the older 60(33) units. It detects both turbid and clear oily emulsions while the 60(33) units do not detect clear emulsions, allowing these emulsions to pass. Newer 107(49) light-scattering unit OCM also distinguish some types of particulates (e.g., iron oxide compounds). If one understands how the OCM operates and performs regular maintenance and calibration, it can be a reliable instrument. The instrument alone cannot diagnose all the additions to the bilge which may have occurred on a ship. It is important for proper OCM operation to prevent exposure of the OCM to these confounding factors. Refer to annexes 3 to 6 to diagnose and troubleshoot these problems.

Understanding the theory of operation of an instrument allows one to be aware of potential factors which may interfere with the OCM's accurate functioning. All analytical instruments have Achilles heels and the new 107(49) OCM is no exception. Understanding these susceptibilities will allow the marine engineer properly to operate the instrument and interpret data. The only sure-fire way to accurately and reproducibly detect organic oils in aqueous solutions is through voltometry using a method called cyclic voltometric stripping (CVS). These instruments cost approximately US\$100K and are not able to operate continuously in line under shipboard conditions. Short of this, any instrument which detects the presence of oil through indirect means will experience similar pros and cons just as the current generation of the newer 107(49) light-scattering OCM units.

Appendix II

DIAGNOSTIC TECHNIQUES

This Appendix provides the basic theory of and describes the physical and chemical analytical techniques used to diagnose the presence of contaminants in the annexes.

A. Visual inspection – *Detection of non-emulsified oil*

➤ Visual inspection can be very informative and is one of the best ways to evaluate the presence of oil (when there is reason to believe that there is a problem with the OCM). Unlike most of the other constituents of bilge water, there are no easy, cut-and-dry chemical or direct instrumental methods for this purpose. Oil residues are very characteristic and will leave a film on glass surfaces. Inspection of a sample often times is adequate to determine the presence of oil, as it will generally be floating on the water and will leave an oily residue which can be detected by rubbing a finger against the glass. This method is very dependable for the detection of non-emulsified oil.

➤ The standard chemical analysis for the presence of oil and grease is United States Environmental Protection Agency PA method 1664, hexane-extraction. This is a very dependable method but would be difficult and possibly dangerous to do on board ship. Samples can be taken and analysed at a shoreside facility using this method for purposes of confirming OCM readings. This is a useful test when there is reason to believe that there is a problem with the OCM. (The United States Coast Guard uses gas chromatography.)

B. Acid split test – *Detection of emulsified oil*

If there is no visible layer of oil on top of the sample and the sample is turbid (cloudy), it is possible that the turbidity is caused by emulsified oil. The addition of three drops of concentrated sulphuric acid to a 50 ml bilge water sample in a tall glass container will cause any emulsified oil to break out of emulsion and form a clearly visible layer of oil on top of the sample after approximately 15 minutes.

C. Evaporative residue pH test (ERT pH test) (also known as non-volatile residue (NVR) test) – *Detection of detergents and non-volatile (i.e. high-boiling temperature) alkaline solvents*

If the acid split fails to clear the turbidity, the presence of detergents and/or some solvents and/or oils may be the cause of the turbidity or cloudiness. Note that most detergents and solvents used in the engine-room are alkaline solvents. (Some acidic solvents are used in electronics and metal cleaning.) Detergents and some solvents are alkaline and non-volatile. To determine the presence of detergents, take a 50 ml bilge water sample in a beaker or evaporating dish and evaporate until all the water is gone. If the water is not clean, a non-volatile residue will remain. Moisten a piece of pH paper with water and swipe the residue. If the pH paper turns blue, indicating alkalinity, then this residue is most likely detergent or other non-volatile alkaline materials such as caustics. Note that the presence of some solvents and detergents in the absence of oil, alone and together, form micro- and mini- emulsions in water. These contaminants, alone or together, may or may not cause turbidity, depending on the exact composition and temperature

of the processed bilge water. These non-oil emulsions can be detected by the OCM even when no visible turbidity exists. (Visible to the naked eye; visible is a relative term when instrumentation is involved.) There are limitations of the ERT pH test in detecting volatile solvents and solvent/detergent mixtures. *Detection of volatile and non-alkaline solvents is perhaps the most difficult to address with quick and easy analysis.* Volatile solvents will NOT be detected by the evaporative residue test. The most reliable method is the process of elimination and a basic understanding of why the solvents are so hard to detect. These solvents are either soluble (e.g., alcohol used for cleaning) or insoluble (e.g., diesel oil used for cleaning) in water. In the absence of oil, water-soluble solvents will not cause turbidity in water and will not be detected by typical oil content meters. (Ultraviolet (UV) and infra-red (IR) type oil content meters will detect the presence of solvents.) Water insoluble solvents can sometimes cause turbidity, especially in the presence of detergents. These can be detected by oil content meters and read as oil. When mixed with oil both soluble and insoluble solvents will cause oils to emulsify, causing turbidity and an indication of oil at the oil content meter. Additionally, other contaminants and physical processes can also cause emulsions and turbidity. Consulting with the crew to determine if the bilge system is contaminated with alkaline solvents is the best next step if solvent contamination is suspected. If solvent contamination is highly suspected, samples should be taken and sent for laboratory analysis. (Note that sometimes a coffee filter can be used to detect soot, but the soot particles are often so small that they tend to clog these filters.)

D. Combined evaporative residue test (ERT) and particle filtration – *Detection of soot*

In general, if soot is present in the bilge, its presence and cause are usually known by the crew. Soot presence is usually the result of machinery space equipment cleaning. In order to physically identify the presence of soot, one can inspect the residue from an ERT. Soot residues are very characteristic and are easy to detect and recognize. When dry-soot residues can be detected by visual inspection and physical examination; soot residue is black. It is also possible to filter a sample using 5-micron filter paper and inspect the residue on the paper. Again, soot is very characteristic; black residue on the filter paper, which has been confirmed not to be iron oxide per a citric acid test, can safely be assumed to be soot. Because of the difficulty in passing bilge water through a 5-micron filter under shipboard conditions, this should be done in a shoreside laboratory.

E. Citric acid test – *Detection of turbidity-causing iron compounds (rouge or rust) particles*

Add a pinch of citric acid (approximately 0.2 to 0.5 grams) to a 50 ml bilge water sample. If the discolouration or turbidity-causing agent is reddish there will be an outgassing (effervescence) and a reduction or elimination of the colour within 5 minutes. Outgassing and colour elimination are a positive indication of iron oxide compounds. High-iron oxide compound concentrations are usually indicative of unusual discharges to or in the bilge from cleaning operations or from intermittent operation of the OWS. These iron-oxide compounds are from inorganic sources and are often found in older and/or poorly maintained machinery spaces. These particles can be detected by an oil content meter and read as oil.

F. Citric acid test – *detection of products of bacterial and microbial decomposition (from sewage and growth of life forms in the bilge and piping)*

Addition of citric acid to a sample will result in turbidity-causing microbial products of bacterial and microbial decomposition to precipitate (come out of solution and sink to the bottom) without outgassing and an improvement in clarity of the sample. Addition of citric acid in rouge samples will result in no visible precipitation and only outgassing. Cases of high rouge loading are usually indicative of biological contamination, unusual discharges to or in the bilge from cleaning operations or from intermittent operation of an OWS. (Life forms can grow in piping and tanks that are not operated regularly.) These particles can be detected by an oil content meter and read as oil.

G. Colour

Colour is usually due to one of the above factors. If colour remains after citric acid and acid split analyses, then the cause of the colour is most likely a dissolved compound as opposed to a suspended material. Colour, in and of itself, resulting from a dissolved compound, should not be detected by light-scattering/turbidity-type oil content meters. The identity of the compound is usually most easily determined by backtracking, but may require laboratory analysis.

Appendix III

RECOMMENDED MAJOR PREVENTIVE, REMEDIAL AND CORRECTIVE ACTIONS

This Appendix describes and provides many of the techniques and equipment employed to retrofit or upgrade an OWS. It also describes techniques and equipment to minimize the volume of contaminants entering the bilge. When retrofitting or upgrading, company personnel should consult with marine engineers, equipment manufacturers and other professionals. Specific recommended actions are included in the annexes.

Retrofitting bilge water treatment systems

- Pre-Treatment
 - Improved holding tanks
 1. Higher aspect (height to width ratio) holding tanks
 2. Proper tank sizing
 3. Heating of bilge water
 4. Large particulate screens and filters (in tank weirs, skimming, solids removal)
 - Point source reduction – portable or semi-fixed filters for treatment of highly polluted sources before entry into the bilge; e.g., particulate filters for soot wash down operations. Note: This does not have to be perfect. 90% efficiency is a lot better than nothing.
 - Use of low shear diaphragm pumps or progressive cavity pumps when possible
- Treatment
 - OWS system – periodic hot water flush
 - Periodic diagnostic on OWS effluent
 - Pressures and flows – changes could indicate sludge build-up
- Post-Treatment Polishing: small particulate filters and emulsion polishers (confirm that the operating pressures of post-treatment units will be compatible with the OWS). These include polishing/filtration technologies listed below. Some of the polishing systems may not be available as stand-alone units for retrofitting, may not be compatible with all existing OWS, or may not be suitable for high-volume bilge water treatment. There are several variables that can impact the effectiveness of some of these polishers, such as fouling in the presence of too much oil, desorption (release of previously absorbed oil under certain conditions), bacterial growth on the polishing surface, the presence of other small non-oil droplets, and/or maintenance and operating costs. It is therefore important carefully to evaluate each technology. Before considering a post-treatment polisher/filter, it is also important to evaluate the ship's and company's circumstances.
 - Adsorbers – Adsorbers capture oily emulsions in an extremely thin layer of molecules on the surfaces of the polisher.

- Surface modified oil-affinity filtration is a type of adsorber that uses a molecule imbedded on a filter. The molecule binds together and coagulates hydrocarbons, specifically altering oils and semi-volatile organics into a cohesive viscoelastic mass that repels water. This action allows for extremely efficient capture without developing differential pressure across the filter.
- Flocculation – A chemical immersion process to cluster individual dispersed emulsified droplets together, followed by a process to coagulate the clusters for removal.
- Ultra-filtration membrane – Membrane filtration uses hydrostatic pressure forces the treated bilge water past a semi-permeable membrane that filters small particles including emulsified droplets. The rate of passage depends on the pressure, concentration, and temperature of the emulsion, as well as the permeability of the membrane to each emulsified droplet and other particles.
- Filter coalescers – oil droplets are removed by adhering to the underside of a series of plates in the separator. Upon contact, small oil droplets bind together forming larger droplets, resulting in an increased buoyancy and rise rate to the surface of the unit for removal.
- Change out shearing pumps to low shear pumps (e.g., diaphragm pumps).

Oil Content Meter

- Check calibration and if necessary recalibrate.
- Repair and servicing of unit by manufacturer or by certified technicians.
- Replacement with new 107(49) OCM; check with the OWS manufacturer for compatibility issues (e.g., operating pressure).

Upgrade to new 107(49) OWS system

There are a variety of certified OWS on the market. Before considering an upgrade, it is important to evaluate the ship's and company's circumstances. Excessive oily waste generation, excessive introduction of clean water into the bilge, and contaminants (e.g., solvent and detergents, engine-room soot, and small particulates) introduced into bilge water can contribute to operating problems with any OWS. A new 107(49) OWS should be able to handle the contaminants found and expected to be found in the bilge. As well, a new 107(49) OWS should be able to handle the volume of oil, water and oily emulsions generated by ship operations. Some upgrades may require retrofitting of pumps, holding tanks and extensive piping arrangements. Bilge water treatment systems meeting resolution MEPC.107(49) standard systems are designed using polishing/filtration. Selection of an OWS upgrade by a marine engineer should evaluate which polishing technology is most appropriate for a particular shipboard environment.

Preventive measures: Contaminant minimization

- Control the amount of solvents, detergents and degreasers entering bilge. Additionally, control other engine-room chemicals that will cause problems and promote use of OWS-friendly chemicals.
- Control the amount of soot entering bilge from equipment washing (segregate washwater) and from exhaust leaks.
- Run OWS more frequently to prevent sludge build up in pipes, pumps and holding tanks.
- Control leaks and maintenance discharges of coolants, fuel oil, lubricants, hydraulic fluids and oil sludge into the bilge.
- Control leaks from boiler water and condensate drains, piston cooling water and any other sources of excess water (e.g., air conditioning and refrigeration condensate.) and chemicals. Control the discharge of sewage and food wastes into the bilge.
- Control leakage from sea suction cooling pipes.
- Control the discharge and build-up of rust and other particles in the bilge (e.g., from scraping and maintenance of machinery space equipment).
- Eliminate uncontrolled drain sources into the bilge; e.g., pump or shaft seal leakages. Install new/better seals in order to prevent bilge leakage.
- Point source reduction: redirecting known OWS trouble sources into other storage tanks that will be designated for shoreside disposal.
- Tank coatings and pipe condition play a major role in the operation. Focus on bilge water sources and utilization of composite pipe materials to prevent issues which are caused by corrosion. Tank coatings should also be examined and maintained. This is particularly important in low point collections areas.
- Collect leaking machinery oil in drip trays and dispose directly to sludge tank(s).
- Install skimming arrangements for bilge holding tanks in order to skim oil from the top for discharge into a sludge tank.
- Utilize a vessel's incinerator to burn/evaporate the oil/water mixture.
- Utilize an evaporation tank with steam coils to help boil off water from an oil/water mixture.
- Collect clean water in segregated drains and divert this water from the bilge for disposal/overboard discharge.

ANNEX 1

TROUBLESHOOTING CONTAMINANT RELATED OIL CONTENT METER MALFUNCTIONS

1 Theory (*light scattering/turbidity OCMs only*)

Calibration error – Calibration error in the OCM is one of the most common sources of error. Inability to get a zero reading with clean water renders all subsequent readings suspect especially since this is a single-point calibration. Inability to zero is usually due to rouge or other material (biological film) coating the scatter and transmit sensors and other parts of the internals. A regular inspection, cleaning and maintenance programme of the OCM should be performed according to manufacturer's instructions.

Air bubbles – The presence of air bubbles can cause an OCM to yield non-zero readings when zeroed. Air bubbles interfere with the transmission and detection of the light source(s) and are perceived as turbidity by the OCM. Also, control of the effluent entering temperature is important to the health of the OCM. Too high an inlet temperature can damage the photo cells and render it unable to zero in the presence of fresh water. (Rule of thumb: over heating – too high a sample temperature can damage the photo cells. Temperatures over 60°C at the cells require a sample cooler be installed.)

Detection of non-oily substances – Although it is not supposed to occur, it is well known that materials which are not oil are sometimes detected by the OCM. The most common are:

- Fine particulate matter – Usually soot as a result of contamination from cleaning operations or iron and iron compounds as a result of biological contamination. Biological contamination is usually accompanied by a foul odour of the bilge water. If outgassing occurs after the addition of citric acid to the bilge sample, this is confirmation of the presence of iron. If no outgassing occurs, add two drops of sulphuric acid. If no visible sheen develops and black material is still suspended in the water, this is a confirmation of soot. See Appendix II for test procedures. See annex 4 to test for soot.
- Non-oil organic compound – Soaps and solvents together or alone will form droplets in water (emulsified droplets approximately 0.1-1.0 millimetre in diameter). These droplets will scatter light just as emulsified oils do, and will be detected by the OCM. See Appendix II for test procedures. See annex 2 to test for detergents and solvents; also refer to annex 3, Emulsions.

Detection of non-oily substances can result in occasional false positives (high readings) or an inability to get reproducible readings. This is not to say that the 60(33) or 107(49) meters are somehow defective. A 60(33) is unable to detect clear emulsions of any type and therefore may yield false negatives (low readings). In that sense, a 60(33) is imperfect by design in that clear emulsified oily wastes pass through the OCM undetected. All instruments are able to detect certain materials, and are unable to detect and/or will falsely detect others. Technology commonly used in shipboard oil content meters is the best current solution when one takes into account cost and potential problems with other detection instruments. The 107(49) light-scattering OCM is more sensitive by design than the older 60(33) units. It detects both turbid and clear oily emulsions while the 60(33) units do not detect clear emulsions, allowing these emulsions to pass. Newer 107(49) light-scattering unit OCM also distinguish some types

of particulates (e.g., iron oxide compounds). If one understands how the OCM operates and performs regular maintenance and calibration, it can be a reliable instrument. The instrument alone cannot diagnose all the additions to the bilge which may have occurred on a ship. It is important for proper OCM operation to prevent exposure of the OCM to these confounding factors. Refer to annexes 2 to 6 to diagnose and troubleshoot these problems.

There are many other sources of OCM malfunction or problems that may occur, none of which are related to contaminants or the OCM. These include, but are not limited to, the following items. Annexes 5 and 6 provide troubleshooting guidance for the same. The operator should also refer to the manufacturer's operating and maintenance manual for diagnostic and troubleshooting guidance.

- Oil has unusually high specific gravity and/or viscosity, and/or the purge cycle of OWS is inoperable:
 - Faulty/disabled capacitance probes.
 - Inoperable solenoid valves (purge).
 - Inoperable solenoid valves (pressurize for purge cycle).
 - Leaking isolation valves to allow pressurization.
 - Clogged purge piping – viscous oil.
 - Ineffective heating of upper chamber.
 - Disabled circuitry or probes.
- Too much air in system:
 - Leaking or holed piping on vacuum systems.
 - Inadequate air purging from the system.
 - Inadequate check valves in suction piping.
 - Air may be from the OWS unit itself due to agitation of the effluent in conjunction with a loss of suction (i.e. pressure drop).
- Sludge build-up in OWS:
 - Inadequate maintenance of unit.
 - System overwhelmed with too much bilge water.
 - Too much oil admitted to machine.
 - System operated beyond design capacity.
 - Failure to remove adequately surface oil prior to entering machine.
 - Ingress of high specific gravity oil into the bilge.
 - Excess sludge in bilge holding tanks.
- Corrosion or clogging of separator plates:
 - Too much sludge accumulation (non-buoyant material).
 - Clogged sludge drain valves.
 - Too much solid debris in bilge.
 - Too much solid debris in rose boxes.
 - Internal corrosion of piping.
 - Failed strainers (excessive porosity) in bilge well and inlet piping strainers.

- Bypass of OWS:
 - Internal bypassing of unit.
 - Corroded components.
 - Failed internal gasket(s).
 - Improper reassembly of unit.
 - Short circuiting of fluid flow.

- Flow rate too high:
 - Wrong supply pump configuration.
 - Wrong piping sizes on inlet or outlet.

- Pseudo-stable emulsion formed by shearing of pump and transfer operations. See annex 3:
 - Use of centrifugal pumps on inlet of machine.
 - Low concentrations of soaps and solvents causing pseudo-stable emulsions.

In many cases the causes above may be remedied by better management of the bilge, including removal of foreign material and sludge, and/or repair, reconfiguration and/or replacement of drains, strainers, piping and pumps as indicated. The above may also indicate that either or both the OCM and the OWS require cleaning, inspection and servicing back to manufacturer's specifications. More residence time may be needed or the OWS should possibly be recirculated at a lower flow rate. Refer to annexes 5 and 6 for specifics.

2 Causes of error and recommended remedial and corrective actions

A. The most common causes of OCM malfunction are deposition of rouge or other deposits on cuvet (glass tube) surfaces or detection of non-oily substances as oil. Air bubbles, very small emulsified droplets of soaps and solvents, and particulate matter such as soot and rouge, can cause the instrument to misread if introduced to the sensor chamber. Uncertainty in OCM readings can be caused by materials such as emulsified droplets of soaps or solvents which alter the refractive index of the solution often without causing turbidity or by particulate matter which may cause turbidity.

- Coating of surfaces by rouge (iron oxide compounds). For the purposes of this Guide, rouge is any iron-based compound of small micron size. Although rouge is always present to some extent when water and iron are in contact, certain conditions on a ship, such as biological contamination of the bilge, can greatly increase the amount of rouge that is present. In the initial stages of rouge contamination, a black film, which is easily wiped away, can be seen. As this condition progresses, a reddish deposit, which is resilient and very difficult to remove by mechanical means, will develop on surfaces. In the case of oil content meters, this deposited film reduces the amount of transmitted light to the detector and causes a non-zero reading on the OCM when conditioned with clean water. Most manufacturers have recommended procedures using mild acids to dissolve rouge coatings in their OCMs. Alternatively, a vinegar or 10% citric acid solution is particularly effective for this purpose.

- Presence of air or other gaseous bubbles (e.g., water vapour). The presence of air and other bubbles can cause OCMs to give non-zero readings when zeroed. Bubbles interfere with the transmission and detection of the light source and are perceived as turbidity by the OCM. Readings are usually erratic when air bubbles are present causing the

OCM display to change rapidly from low to high ppm. The presence of bubbles has several causes. The most common is cavitation, caused by obstruction in the sampling tube, a leak on the suction side of the separator, or pressure drop across a valve, any of which can result in the formation of bubbles. This can be corrected by inspecting and plunging out the obstruction in the sampling tube and/or by flushing the valve and reinstalling the sampling tube. Air leaks in the system, which can cause air bubbles bypass through the sample tube (and also result in cavitation near the sampling tube) can be remedied by checking for and repairing leaks. Other causes may exist depending on the unit or physical installation.

- Sample outgassing: A less common cause is outgassing of the effluent due to the presence of biological activity or other physiochemical processes involving *in situ* generation of gas. In this case, it is best to do the zeroing operation with a source of water that is known to be clean.

Related problems include the inability to zero an OCM.

- Attempt to zero the OCM with clean water flushing using water that is known and confirmed to be free of turbidity and air bubbles. If the meter still fails to zero, inspect the sampling port tubes for obstructions. If obstructions are found, clearing of these obstructions will usually correct the problem. Note that most new OCMs have calibration modes that use the clean flushing water piped to the cell.
- If the above measures fail to zero the OCM, one should inspect the glass tube/cuvet surfaces for a black or reddish film (rouge or iron oxide). If this film is present, it is most likely the cause for the meter failing to zero. The OCM should be cleaned per the manufacturer's instructions. If there are no instructions, vinegar or 10% citric acid solution can be used for this purpose. Once this cleaning is done, the system should be thoroughly flushed. Dissolution of iron deposits will result in outgassing and bubble formation.
- If these measures fail, the OCM should be serviced or replaced. The OCM does not need to be replaced if it is determined to be detecting particulates or non-oily emulsions. Refer to annexes 2, 3 and 4 for recommended remedial actions.

3 Preventive Measures

- Regular maintenance, inspection and calibration to assure the above conditions do not exist should be performed. Longer-range preventive actions, such as preventing rouge formation, usually involve conditions upstream of the OCM and are addressed in the relevant sections.
- OCMs should be flushed with clean water after use and their measuring cell cleaned with a bottle brush or where manual/automatic cleaning mechanisms are provided they should be operated prior to shutting down the equipment.

Weekly documented maintenance of OCMs has demonstrated that an OCM can successfully operate for more than 20 years.

ANNEX 2

DETECTION OF DETERGENTS AND SOLVENTS

1 Theory

Detergents and/or some solvents and/or oils may be the cause of turbidity or cloudiness of a bilge sample. Water-soluble solvents and detergents do not emulsify in water by themselves, however, they contribute to the emulsification of oil and insoluble solvents. In many cases, water insoluble solvents act like oils in that often they form droplets (though colourless and transparent) that may be read by both 107(49) and older oil content meters. Most light scattering 107(49) OCM are more sensitive to these type of emulsions. The majority of solvents will not form stable emulsions unless emulsification enhancers are present as is the case with industrial metal cleaners and other types of formulated cleaners. Many shipboard detergents and some solvents used in the engine-room are alkaline and non-volatile and can be easily detected using a simple test described below. The presence of some solvents and detergents in the absence of oil, alone and together, form micro- and mini- emulsions in water. These contaminants, alone or together, may or may not also cause turbidity, depending on the exact composition and temperature of the processed bilge water. This type of non-oil emulsions can be detected by the OCM even when no visible turbidity exists (visible to the naked eye; visible is a relative term when instrumentation is involved).

2 Causes

- Most common – introduction of formulated cleaners (which contain detergents, water-soluble solvents, water-insoluble solvents and surfactants) by machinery cleaning into the bilge.
- Introduction of detergents, which emulsify solvents (e.g., diesel oil and lubricants) already present in the bilge.
- Introduction of stabilized solvent formulations from machinery space cleaning that allow residues to enter the bilge and subsequently become emulsified by certain types of pumps often used on OWS units.

3 Confirmatory Tests

- The best way to detect the presence of solvents (instrumental and chemical analysis not possible on ship) is by smell. Most common solvents possess a characteristic smell that is easy to identify and backtrack to the source.
- The ERT pH paper test is a very dependable indicator of detergent.

Sampling Instructions

- *Take a small container and draw bilge water before OWS. (To diagnose bilge water contamination.)*
- *Take a small container and draw bilge water at OWS outlet. (To diagnose OWS capability to handle contaminated bilge water.)*
- *Take a small container and draw bilge water after post-treatment polishing and particulate filters if installed. (To diagnose post-treatment capability to handle contaminated bilge water.)*

4 Remedial and Corrective Actions

- Heat – this will not remove detergents but might cause evaporation of the solvents (phase inversion) and separation of the solvent component.
- Polishing technology – employ chemically active polishing filters and absorbents. Specific recommendations for a particular post-treatment depend on the ship's circumstances.
- Store – (segregate and then clean the bilge) or pump the detergent/solvent loaded bilge water to a shoreside reception facility.

5 Preventive measures

- Segregate/minimize solvents, cleaners and detergents from bilge.
- Use non-emulsifying cleaners, detergents and solvents.

ANNEX 3

EMULSIONS

1 Theory

Emulsions are the result of the stable dispersion of droplets of one immiscible liquid (not soluble in each other) in another. There are many types and classifications of emulsions. The emulsion of concern for the marine engineer is the oil in water (O/W) emulsion. For the purposes of this Guide, oil will mean any water-insoluble hydrocarbon, (i.e. diesel, benzene, etc.). It takes energy to disperse oil stably in water. This energy can be mechanical (shearing due to pumping, pressure, non-laminar flow in pipes and transfer operations) or chemical (detergents, solvents). Both factors usually contribute to the formation of stable emulsions on ships. Emulsions are problematic because oil droplets of mean particle size of approximately less than (<) 15 microns are neutrally buoyant in water and will not separate under the force of gravity alone, though some small OWS use centrifuges or coalescers. These droplets will be detected by the OCM. In order to destabilize an emulsion, one must cause the neutrally buoyant droplets to coalesce into larger droplets, which will then have positive buoyancy and separate from the effluent (approximately 50-100 microns) and float to the surface. This can be accomplished through the use of heat destabilization, pH adjustment or chemical addition. Polishing technologies utilizing chemical affinity, ultra-filtration or flocculation are also appropriate. The best approach is to minimize factors that will contribute to and enhance emulsion formation. Resolution MEPC.107(49) OWS separators were developed specifically to deal with bilge water in the form of free oil and oily emulsions. Some of the less expensive 107(49) and older 60(33) OWS are not designed to handle any or all of the contaminants, and may require retrofitting with polishing units, and/or particulate filters and/or non-shearing pumps. Poorly operated and maintained 107(49) separators may not perform as expected.

2 Causes

A. Mechanical Action – the shearing action of pumps, non-laminar flow (that can impinge or press together or apart particles under pressure) inherent in transfer operations, and turbulent conditions in general will cause dispersion of oil in water. It is difficult to form stable emulsions with purely mechanical means (these will separate in a tank after some hours); however, such mechanical factors greatly enhance the efficacy of small amounts of other emulsifying agents, which can be present in the bilge. In many cases, the presence of materials such as soot, rouge, soap and diesel (all emulsifying agents) is inevitable and, in small amounts, greatly enhances emulsification when oil is caused to disperse by aggressive mechanical action (high agitation of the bilge water). Certain types of pumps are more prone to disperse oil in water than others. Diaphragm and progressive cavity pumps are the least shearing. Centrifugal pumps are fairly aggressive and can cause shearing and become problematic in cases of cavitation due to insufficient NPSH (net positive suction head).

B. Emulsifying Agents – The following materials all enhance emulsification of oil in water:

➤ Particulate matter:

- Soot – Soot will absorb onto the surface of oily droplets and cause stable emulsions to form. This effect is greatly exaggerated by shearing and non-laminar flow. Note that soot itself can be stably dispersed, pass through primary treatment and be detected by the OCM as oil.

- Rouge – same as soot.
- Chemicals:
 - Soaps and detergents – reduce the surface tension of the oil/ water interface and cause formation of stable droplets.
 - Solvents – diesel, kerosene, and benzene greatly enhance the effectiveness of soaps/detergents and shearing action. They can cause stable emulsions themselves in high quantities (>1% to approximately 5% of the total weight of the bilge water), especially when sheared.
 - Cleaners – Industrial cleaners usually contain detergents and solvents and are formulated to emulsify oil. Introduction of these types of materials into the bilge is the most common cause of o/w emulsion formation.
 - Microbial contamination – It is rare but microbial contamination can cause oil emulsification. More often when microbial contamination is present, rouge produced by microbes is being detected.

3 Confirmatory tests

If the decision tree indicates that there is an emulsion, draw a sample of effluent in a 25 ml graduated cylinder or other tall, narrow and clear cylindrical container, and let the sample set for one hour. After one hour, if there is no visible separation (oil or oil sheen forms at the top of the water column in the cylinder) then the emulsion is stable. It may be necessary to perform the other tests listed in the appendices to identify the cause(s) of the emulsions.

Sampling Instructions

- *Take a small container and draw bilge water before OWS. (To diagnose bilge water contamination.)*
- *Take a small container and draw bilge water at OWS outlet. (To diagnose OWS capability to handle contaminated bilge water.)*
- *Take a small container and draw bilge water after post-treatment polishing and particulate filters if installed. (To diagnose post-treatment capability to handle contaminated bilge water.)*

4 Remedial and Corrective Actions

- Flush OWS with hot water (sometimes this can enhance performance). Pump the washwater into bilge and try circulating again. If this brings the OCM reading down, repeat.
- Heat the bilge water prior to entering the OWS. Heat will cause droplets (emulsion) to coalesce and come out of solution.
- Engage polishing technology.
- For particulates that create emulsions only: employ (by and large for newer ships or major upgrades only) high-aspect ratio (height to width) separation tanks in conjunction with heat and serial decanting. See annex 4 and note below.
- Store (segregate and then clean the bilge) or pump the emulsified bilge water to a shoreside reception facility.

- While recognizing that small solids can create an “emulsion” it may be best to treat the solids removal separately, see annex 4.

Note: These techniques reduce the overall loading seen by the treatment system. Removal of solids that create emulsions using these kinds of methods will reduce the amount of material being sheared in the treatment system. Particulate matter can contribute to emulsification of oils and can present problems on its own. In the broadest sense, this recommendation probably belongs in the particulate filtration area, with reference made to the tendency of some particulate matter to enhance emulsification of oils. Additionally, these emulsions are pseudo-stable and over time some significant portion does tend to coalesce out in tank. This is an important point to consider in regard to future design of ships in order to minimize the burden on the treatment system and to make the whole system more user-friendly and observable.

5 Preventive measures

Depending on the results of other diagnostic tests performed, any or several of the following measures are recommended:

- Prevent cleaners, solvents and detergents from entering bilge.
- Prevent soot from entering bilge (capture cleaning residues) and divert from the bilge. See annex 4.
- Keep rust from ageing machinery and fittings from entering bilge. See annex 4.
- Install pre-treatment particulate strainers and separators (settling tanks).
- Do not discharge biologically active water (sludge water, sanitary water, etc.) into the bilge.
- Employ minimal shearing and turbulent transfer operating.
- Replace pumps with low shear pumps when possible.
- Design the bilge treatment system, including bilge storage tanks to take advantage of available heat in the engine-room. Fit bilge storage tanks with heating coils to assist with separation.
- Design and retrofit system for addition and availability of post-treatment modular polishing and particle filtering technology. If not possible, consider upgrading 60(33) OWS units to 107(49) units. Specific recommendations for a particular post-treatment retrofit or OWS system upgrade depend on the ship’s circumstances.
- For particulates that create emulsions only: employ (by and large for newer ships or major upgrades only) high-aspect ratio (height to width) separation tanks in conjunction with heat and serial decanting. See note above and annex 4.

ANNEX 4

DETECTING PARTICULATES: BIOLOGICAL, SOOT AND ROUGE (IRON OXIDE COMPOUNDS)

1 Theory

The primary particulate contaminants of concern to the marine engineers are biologicals, soot and rouge (iron oxide and related compounds). Often their presence is interrelated as the presence of one can cause or enhance the presence of the other. Examples include:

- A by-product of sulfate-reducing bacteria sometimes found in bilge water is rouge (iron oxide and related compounds). In septic conditions that can occur in tanks rouge can be up to 90% of the weight of the total contamination.
- Soot can promote bacterial growth by providing a surface for bacteria to multiply and can also become a food source. In turn, rouge is often the by-product of bacterial contamination.
- Rust from machinery (iron oxide (rouge)).

2 Cause

- Biologicals (from microbial decomposition). Micro-organisms are usually present in the bilge. Nutritional limiting factors and ecological competition usually prevent problematic septic conditions. Development of problematic biological conditions can usually be traced to one of the following conditions: Introduction of anaerobic bacteria as exists in sewage and sometimes oily sludge/sludge water or an introduction of an excess of nutrients such as soaps and detergents can alter the biological balance leading to a dominance of anaerobic bacteria. This sort of bacteria is often characterized by a filamentous deposition on filters and other surfaces and has a sulphurous or malodorous smell. Filamentous bacteria will preferentially accumulate in the high flow/sheening areas and will cause development of higher pressures or reduction of flow. These particles can be detected by oil content meters.
- Rouge (Iron Oxide Compounds). A major source of rouge is from microbial decomposition; bacteria need iron to grow. If bacteria growth is unchecked, large quantities of iron oxide compounds can be produced. A major source of iron and iron oxide compounds on ship is from ageing machinery, the hull and fittings. These particles can also be detected by older 60(33) oil content meters and, when in large quantities, some newer 107(49) oil content meters.
- Soot. Carbon-based soot particles accumulate in engine-rooms from normal operations. These carbon particles are highly absorbent. Exhaust leaks and cleaning of engine-room machinery are the largest source of soot. Bilge treatment system failure often follows heavy engine-room cleaning when soot particles are allowed to enter the bilge. (Also, see annex 3 – Emulsions.) Soot particles can contribute to the creation of oily emulsions and can be detected by an OCM.

3 Confirmatory tests

- Biological – citric acid test
- Rouge – citric acid test and visual examination of reddish (rouge) particles. High amounts of iron oxide compounds will cause turbidity and lack of transparency of the water sample. The sample will look characteristically rouge or red. Lower concentrations of rouge can cause what appears to be discoloration of the water without apparent turbidity. The sample will look clear, but have reddish or rouge colour. This is simply because the human eye is not sensitive enough to detect the turbidity difference at these low concentrations.
- Soot – citric acid followed by ERT pH test, and visual evaluation of black or brownish particles. High amounts of soot will cause turbidity and lack of transparency of the effluent sample. The sample will look characteristically brown or black. Lower concentrations of soot can cause what appears to be discoloration of the water without apparent turbidity. The sample will look clear, but have a brownish or black colour. This is simply because the human eye is not sensitive enough to detect the turbidity difference at this low concentration. Confirmation may require laboratory analysis.

Sampling Instructions

- *Take a small container and draw bilge water before OWS. (To diagnose bilge water contamination.)*
- *Take a small container and draw bilge water at OWS outlet. (To diagnose OWS capability to handle contaminated bilge water.)*
- *Take a small container and draw bilge water after post-treatment polishing and particulate filters if installed. (To diagnose post-treatment capability to handle contaminated bilge water.)*

4 Remedial and Corrective Actions

- Pre-treatment filtration of solids
- Bilge pre-treatment high-aspect ratio (height to width) settling tank to allow large solids to settle.
- Post-OWS filtration with small particle and polishing filters if soot is persistent.
- Upgrade to a MEPC.107(49) OWS which is more tolerant of some solids.

5 Preventive Measures

- Treatment and discharge of contaminated bilge water to a reception facility.
- For biological contamination, treat bilge tank(s) with a biocide.
- Hot water flush of OWS clean out tanks and piping that have sludge build-up.
- Cleaning of bilge and other affected areas to remove sludge and rust.

- Segregate soot from entering bilge (capture cleaning residues) and divert from the bilge. Repair exhaust leaks.
- Keep rust from ageing machinery and fittings from entering bilge.
- Tank coatings and pipe condition play a major role in the operation. Focus on bilge water sources and utilization of composite pipe materials to prevent issues caused by corrosion. Tank coatings should also be examined and maintained. This is particularly important in low point collections areas.
- Segregation of nutrient and contamination sources: Check for and replace leaky sewage and cooling (sea suction) pipes.
- Retrofit modular post-OWS (before but not in line with (i.e. full flow) the OCM) particle filters.
- Pre-treat soot containing [cleaning] water before entry to bilge or segregate sooty water resulting from machinery cleaning.

ANNEX 5

POST-TREATMENT (OWS) OIL SHEEN

1 Theory

If a layer of oil or sheen is present post-OWS and the oil is not cloudy this indicates that gravity separable oil is bypassing the OWS. (The OCM is in recirculation.)

2 Causes

There is a range of possible causes due to one or more component, maintenance or operational failure(s) that can in turn lead to multiple system failure(s). These possible causes may not apply to all separator designs and review of the manufacturer's manual is recommended.

- Oil has unusually high specific gravity and/or viscosity, and/or the purge cycle of OWS is inoperable:
 - Faulty/disabled capacitance probes.
 - Inoperable solenoid valves (purge).
 - Inoperable solenoid valves (pressurize for purge cycle).
 - Leaking isolation valves to allow pressurization.
 - Clogged purge piping – viscous oil.
 - Ineffective heating of upper chamber.
 - Disabled circuitry or probes.

- Too much air in system.
 - Leaking or holed piping on vacuum systems.
 - Inadequate air purging from the system.
 - Inadequate check valves in suction piping.
 - Air may be from the OWS unit itself due to agitation of the effluent in conjunction with a loss of suction (i.e. pressure drop).

- Sludge build-up in OWS.
 - Inadequate maintenance of unit.
 - System overwhelmed with too much bilge water.
 - Too much oil admitted to machine.
 - System operated beyond design capacity.
 - Failure to remove adequately surface oil prior to entering machine.
 - Ingress of high specific gravity oil into the bilge.
 - Excess sludge in bilge holding tanks.

- Corrosion or clogging of separator plates.
 - Too much sludge accumulation (non-buoyant material).
 - Clogged sludge drain valves.
 - Too much solid debris in bilge.
 - Too much solid debris in rose boxes.
 - Internal corrosion of piping.
 - Failed strainers (excessive porosity) in bilge well and inlet piping strainers.

- Bypass of OWS.
 - Internal bypassing of unit.
 - Corroded components.
 - Failed internal gasket(s).
 - Improper reassembly of unit.
 - Short circuiting of fluid flow.
- Flow rate too high.
 - Wrong supply pump configuration.
 - Wrong piping sizes on inlet or outlet.
- Pseudo-stable emulsion formed by shearing of pump and transfer operations. See annex 3.
 - Use of centrifugal pumps on inlet of machine.
 - Low concentrations of soaps and solvents causing pseudo-stable emulsions.

3 Confirmatory tests

Visual examination should be followed with immersion of the top layer of a sample and testing with an oil-affinity material (e.g., sorbent).

Sampling Instructions

- *Take a small container and draw bilge water at OWS outlet. (To diagnose OWS capability to handle contaminated bilge water.)*

4 Remedial and Corrective Actions

- Recirculate – more residence time may be needed.
- Flush system with hot water, re-engage and recirculate.
- Recirculate at lower flow rate.
- Inspect unit for bypass.
- Open, clean, and inspect system to determine cause of failure. Repair and service OWS. Repair, service or replace OCM Unclog or replace drains and/or piping to manufacturer's and/or to system design standards.
- Retrofit with polishing and particulate filters (for acute conditions).
- Upgrade to a 107(49) unit (after considering the capacity, age, condition and/or quality of the existing OWS).
- Consult manufacturers' manual(s) for filter/coalescer replacement.

Note: Consider designing and retrofitting the system for the addition of post-treatment modular polishing and particle filtering technology. Also, consider upgrading a 60(33) unit to a 107(49) unit. Specific recommendations for a particular post-treatment retrofit or an OWS system upgrade depend on the ship's circumstances.

5 Preventive Measures

- Perform regular maintenance and inspection of all parts of bilge treatment system. As part of regular maintenance periodically flush the system with hot water and clean components.
- Conduct regular performance evaluations with clean water and confirm that no oil is present after the system is cleaned and flushed with clean water.
- Conduct annual manufacturer (or vendor) inspection and certification.

ANNEX 6

DETECTING BOTH OIL AND OIL EMULSION: MULTIPLE CONTAMINANTS AND/OR MECHANICAL

1 Theory

This is a complex problem which can have many causes. Indicative of the problem(s) is the presence of an emulsion in conjunction with the OWS not separating oil effectively. If the water is cloudy, there may also be soot, biological and/or iron oxide particles present. In addition to mechanical failure of the OWS, some possibilities are:

- A pseudo-stable emulsion is able to bypass the OWS but subsequently separates over time under gravity.
- A stable emulsion is formed that the OWS cannot separate and visible oil is bypassing the unit.
- If the water is cloudy, there may also be soot, biological and/or iron oxide particles present.

2 Causes

Possible causes for the above are numerous and can be traced to equipment (pumps, tanks, OWS) contamination and/or multiple factors simultaneously.

3 Confirmatory Tests

Refer to annexes 3, 4 and 5.

4 Remedial and Corrective Measures

- Refer to annexes 3, 4 and 5 to isolate each [potential] problem.
- Engage joint support from all vendors of relevant equipment to determine cause of failure and long-term prevention measures.
- Manage bilge to minimize contaminants.
- If indicated, it may be necessary to change or install additional equipment to handle bilge conditions.

5 Preventive Measures

- Conduct a complete chemical analysis of bilge effluent.
- Conduct regular and complete system inspections and maintenance.
- Refer to annexes 3, 4 and 5 as appropriate.
- Engage joint support from all vendors of relevant equipment to develop long-term prevention measures.

GLOSSARY FOR TROUBLESHOOTING

1. Bilge Water Treatment Unit – For the purposes of this document a bilge water treatment unit is defined as, but not limited to, an oily water separator augmented with filters and a polishing or secondary treatment capability (if fitted) along with a metering device operating in unison to prevent discharge of effluent exceeding 15 ppm of oil. This unit could also use a bio-treatment process.
2. Bilge Water – For the purposes of this document bilge water is taken to be water with a complex cocktail of soluble and insoluble organic and inorganic materials with a primary component being oil or oily hydrocarbons.
3. Biological Contamination – In the case of bilge water the most prevalent biological contamination is sulphate-reducing bacteria. The presence of these bacteria results in high amounts of suspended particulate matter composed primarily of colloidal iron and other iron compounds. Biological contamination is most often caused by exposure of the bilge to material in the sludge tanks. Nutrient rich environments (chronically dirty bilge water) will also enhance the occurrence of biological contamination.
4. Cloudy Water – Water which is not totally transparent to the naked eye due to the presence of suspended materials.
5. Clear Water – Water which is totally transparent upon inspection with naked eye. Note: Water can possess a colour and can still be clear. Clean water is taken to be clear and colourless.
6. Detergent – Any liquid or solid cleaner which when added to water has the ability to emulsify oil.
7. Emulsion – The stable suspension of droplets in one immiscible liquid by another. The formation of emulsions is enhanced by the presence of detergents and solvents, by the presence of finely suspended particulate matter or by mechanical action such as shearing action of pumps. Emulsions are destabilized by heating, acidification or chemical action.
8. OCM – Oil Content Meter. This is a somewhat generic term for a meter capable of detecting the presence of hydrocarbons in water. The most common types are based on light dispersion. Ultra-violet (UV) based fluorescence meters are also able to detect the presence of carbon-hydrogen bonds.
9. OWS – Oily Water Separator. This is also a somewhat generic term for mechanical devices, many of which exploit gravity or density differences between two immiscible liquids in order to achieve separation into two distinct phases. This type of equipments includes centrifuges, parallel and inclined plate separators and a variety of other configurations. The coalescing oily water separator is self-contained in a tank shell and includes an improved oil coalescing medium for separating oil out of wastewater and a series of baffles and weirs to direct flow, skim the separated oil and control the liquid level in the separator. This unit could also use a bio-treatment process.

10. Oil – A liquid that is a water insoluble animal or mineral based hydrocarbon (for the purposes of this document we will consider a material a liquid if it has a freezing point above 32°F).
11. Oily bilge water – Water which may be contaminated by oil. Any liquid entering the bilge system including bilge wells, bilge piping, tank top or bilge holding tanks is considered oily bilge water.
12. Particulate Material – Aerosolized solid matter which when captured with a filter has no less than 50% non-volatile residue.
13. Polishing – Secondary (post-OWS) treatment of bilge water. This category can include flocculation, surface modified filtration, biological digestion, membrane filtration, distillation and other techniques.
14. PPM – one ppm is one ten thousandth of a per cent. One milligram per litre of water is equal to 1 ppm.
15. Soot – Carbon based particulate matter resulting from the incomplete combustion of hydrocarbons.
16. Sheen – Diffraction colours visible to the naked eye when a thin layer of oil is floating on water. Rainbow sheen is the most familiar. A rainbow sheen is produced over one square nautical mile by the addition of 40 gallons of oil.
17. Sulphuric Acid – A highly corrosive mineral acid. H_2SO_4 utilized to lower the pH of a sample. Sulphuric acid is used to split droplets of suspended hydrocarbons from water. Cloudiness resulting from hydrocarbons will be eliminated in the presence of sulphuric acid. This is not the case with other categories of opacity causing agents.
18. Visible Oil – Oil which is clearly visible as sheen or distinct layer floating on the collected sample.
19. Retrofit – the modification of equipment already installed.
20. Upgrade – renewal or replacement of equipment with a newer or more appropriate (e.g., powerful) model.
