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Ballast Water Management Systems; Oversight of Shipboard Testing

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Ballast Water Management Systems; Oversight of Shipboard Testing

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16. Abstract (MAXIMUM 200 WORDS) Ballast water management systems (BWMS) going through the United States Coast Guard's (USCG) type approval (TA) process must complete biological efficacy evaluations in both land-based and shipboard testing. Shipboard testing verifies the BWMS is operating as intended and meets the discharge standard. This report details shipboard testing requirements such as vessel selection, necessary sampling equipment, and test execution; and the challenges that the crew and testing personnel may face while underway. Operating with an active ship can lead to a myriad of issues such as scheduling, fitting testing in between operations, handling, storage of materials, and most of all, trying to conduct scientific work in a non-laboratory environment. The purpose of this report is to offer suggestions to those who may design or perform an audit of the independent laboratories (ILs) or sub-laboratories (SLs) as part of the USCG's oversight authority of BWMS testing. This report includes suggested preparations and considerations for each facet of ship selection, sampling, analysis, and documentation paired with a set of example questions that an auditor may ask to ensure ILs or their SLs are conducting a proper examination. Additionally, the report addresses the challenges a tester might face and provides potential alternative solutions that an auditor can implement to ensure the completion and ease of examinations.					
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EXECUTIVE SUMMARY

This report provides basic guidance and recommendations to new and experienced United States Coast Guard (USCG) type-approval (TA) auditors to consider while performing their audit oversight of the Ballast Water Management System (BWMS) TA process by independent laboratories (ILs) and sub-laboratories (SLs). The BWMS TA process requires shipboard testing that should represent “real world” conditions of use. The TA process is designed to evaluate a BWMS while installed on a ship, operated by the ship’s crew and generally in use as intended by the BWMS manufacturer. The verification that a BWMS operates as intended and meets the discharge standard in five consecutive test cycles is a final and critical check before TA. Consequently, the USCG’s oversight of shipboard testing is important to assure a BWMS meets statutory test requirements.

The sections in this report: (a) review the regulatory requirements of shipboard biological efficacy (BE) testing, (b) describe some of the unique challenges of conducting testing (and test oversight) on active ships, (c) consider the BWMS manufacturer’s planning and preparatory work, especially the ship selection process, and (d) propose some potential oversight approaches, given these requirements and challenges.

USCG auditors may verify many regulatory requirements simply through review of the various processes: vessel selection, communications and information exchanged between the crew and the test team, sampling infrastructure, and prior contingency planning to assure test cycles represent various source water characteristics. This verification can occur through discussions with test personnel and by reviewing procedures, test reports and other documents. However, shipboard testing comes with many logistical challenges. Probably the greatest challenge is that testing source-water must have an organism concentration greater than ten-times the allowable discharge standard. This requires careful selection of uptake location during vessel voyage(s). Additionally, in-person audits of technical systems must consider the variations in ships schedules and should focus on the testing organization’s procedures related to assuring variability among valid test cycles.

Despite the challenges, shipboard testing is a vital step in BWMS type approval and requires thorough oversight of processes and personnel involved. Auditors may augment their oversight abilities by relying on photo or video documentation of the testing process to verify that processes are conducted as intended and as required by statute. This can be done in real-time or archival, but each method comes with their own set of obstacles. USCG auditors might also rely on local commands such as sector or district staff to augment their workforce and allow for greater visibility during remote auditing.



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TABLE OF CONTENTS

EXECUTIVE SUMMARY v

LIST OF FIGURES viii

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS..... ix

1 INTRODUCTION..... 1

2 SHIPBOARD BIOLOGICAL EFFICACY TESTING REQUIREMENTS 2

 2.1 Vessel Selection 2

 2.2 Sampling Equipment 2

 2.3 Test Execution..... 2

3 CHALLENGES OF SHIPBOARD TESTING..... 3

 3.1 Ship Operations 3

 3.2 Scheduling..... 3

 3.3 Scientific Work in a Shipboard Environment 3

4 TEST PREPARATIONS AND CONSIDERATIONS..... 4

 4.1 General 4

 4.2 Ship Selection..... 5

 4.3 Shipboard Sampling and Analysis 5

 4.4 Documentation 7

5 OVERSIGHT CONSIDERATIONS..... 7

 5.1 Challenges of an In-person Audit..... 7

 5.2 Requests for Alternative Methods..... 8

 5.3 Demonstration of Preparation and Planning 9

6 CONCLUSIONS 10

7 REFERENCES..... 11

APPENDIX A. PREPARATION FOR SHIPBOARD TESTING A-1



LIST OF FIGURES

Figure 1. Summary of requirements for ship selection (46 CFR 162.060-28). 9



LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

BE	Biological Efficacy
BW	Ballast Water
BWDS	Ballast Water Discharge Standard
BWMS	Ballast Water Management System
°C	Celsius (degree)
CFR	Code of Federal Regulations
COC	Chain of Custody (Appendix A)
EPA	Environmental Protection Agency
h	Hour
IL	Independent Laboratory
ISO	International Organization for Standardization
m ³	Cubic meter
O&M	Operational & Maintenance
POC	Point-of-Contact
PPE	Personal Protective Equipment
SL	Sub-laboratory
TA	Type Approval
TRC	Treatment Rated Capacity
U.S.	United States
USCG	United States Coast Guard



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1 INTRODUCTION

On ships, Ballast Water Management Systems (BWMSs) are designed to treat ballast water (BW) so the discharged water meets the requirements published by the United States Coast Guard (USCG) as specified in 33 CFR §151.2030(a):

Vessels employing a Coast Guard-approved ballast water management system (BWMS) must meet the following BWDS [Ballast Water Discharge Standard] by the date listed in §151.2035(b) of this subpart:

- (1) For organisms greater than or equal to 50 micrometers in minimum dimension: Discharge must include fewer than 10 organisms per cubic meter of ballast water.*
- (2) For organisms less than 50 micrometers and greater than or equal to 10 micrometers: Discharge must include fewer than 10 organisms per milliliter (mL) of ballast water.*
- (3) Indicator microorganisms must not exceed:*
 - i. For toxicogenic *Vibrio cholerae* (serotypes O1 and O139): A concentration of less than 1 colony forming unit (cfu) per 100 mL.*
 - ii. For *Escherichia coli*: a concentration of fewer than 250 cfu per 100 mL.*
 - iii. For intestinal enterococci: A concentration of fewer than 100 cfu per 100 mL.*

46 CFR §162.060 describes the type approval (TA) process for BWMSs. The TA process includes Biological Efficacy (BE) testing in both land-based and shipboard environments. Test requirements also include environmental testing, where components of the BWMS are subject to varying shipboard conditions such as temperature variations, changes in pitch and roll, vibrations, and voltage fluctuations. Independent laboratories (ILs) oversee the TA testing, usually performed by one or more sub-laboratories (SLs) with the equipment, personnel, and expertise needed to perform such specialized testing. The USCG, which issues TA certifications, has the responsibility to maintain oversight of ILs.

This report is one in a series focused on the USCG's oversight of the TA process and the operations of accepted ILs and SLs. Other documents in the same series focus on auditing SLs that perform land based, BE tests (First, et al. 2020) and general oversight of ILs and SLs (First, et al. 2023)

This report addresses the requirements of shipboard BE testing and oversight of the SLs performing this work as defined in 46 CFR §162.060-28. SLs may specialize in shipboard testing, or they may be part of an organization that performs other work for the IL, such as land-based BE testing. Many of the audit criteria overlap with land-based BE tests (First et al. 2020), however, there are unique criteria that are fundamental to shipboard tests. The following sections in this report: (a) review the statutory requirements of shipboard BE testing, (b) describe some of the unique challenges of conducting testing (and test oversight) on active ships, (c) consider the BWMS manufacturer's planning and preparatory work, especially the ship selection process, and (d) propose some potential oversight approaches, given these requirements and challenges.

The report also includes an appendix that addresses preparation for shipboard testing, including health and safety considerations for those performing or auditing shipboard testing (Appendix A).



2 SHIPBOARD BIOLOGICAL EFFICACY TESTING REQUIREMENTS

2.1 Vessel Selection

Shipboard testing is intended to occur on in-service, commercial vessels.¹ Therefore, testing must consider the ships' routes and cargo operations. The BWMS manufacturer is required to make the arrangements to assure the ship has a functioning BWMS installed. A vessel selected for testing must (1) have tank volumes and flow rates equal to those used in land-based testing, (2) operate at the upper end of the treatment rated capacity (TRC) (e.g., >80% of the TRC, although the threshold for *the upper end* is not clearly defined), and (3) uptake ballast water representative of harbor or coastal waters, where ambient organisms are >10x the concentration of the discharge standard (e.g., >100 per m³ for organisms $\geq 50 \mu\text{m}$). The vessel also must visit ports that allow access for scientific and analytical personnel.

2.2 Sampling Equipment

A vessel selected for testing must have sample ports installed that meet the requirements defined in the United States (U.S.) test protocol for land-based testing (EPA, 2010). The protocol requires that the port is designed with consideration of the (1) diameter of the main pipe, (2) expected flow rate through the main pipe, and (3) desired flow rate through the sample port. The characteristics and operation of the sample port are also described in international standards (ISO, 2019; ISO, 2022). The positioning of the sample port is also specified by 46 CFR 162.060, where an uptake sample is collected upstream, but as close as practicable, to the BWMS. The discharge port is installed as close as practicable to the overboard outlet (46 CFR 162.060-28(f)).

2.3 Test Execution

A shipboard BE test consists of at least five consecutive, **valid test cycles**. The bold terms have specific meanings as follows:

- A **test cycle** includes uptake, storage, treatment, and discharge of ballast water. The treatment process is performed by the ship's crew and without changes in the treatment protocol. For example, crew must not manipulate or adjust the parameters (increase power, dose rate, or slow water flow) beyond typical ranges or operating parameters.
- A **valid test cycle** builds upon a **test cycle** and requires full characterization of the source water on uptake (with source water exceeding the threshold organism concentration), completion of the treatment (without error or failure), the required sample analysis (including whole effluent toxicity), and neutralization of active substances.

The required sample collection upon uptake must characterize the biological community and assure that concentrations of organisms test source water are $\geq 10x$ the discharge standard. The source water must also be characterized by basic water quality parameters, such as salinity, and concentrations of dissolved and particulate matter. To complete a **valid test cycle**, testing must occur over *at least* six months.

¹ A unique case is the Training Ship *Golden Bear* which hosts the "Golden Bear Research Center" and serves as a recognized test facility (<https://www.csum.edu/gbrc/index.html>).



3 CHALLENGES OF SHIPBOARD TESTING

3.1 Ship Operations

A successful test will require the IL/SL test team to collect and analyze samples of source water upon uptake. Uptake operations may occur while: (1) unloading cargo at port, (2) offshore during a ballast water exchange (performed, e.g., to manage sediment loads in ballast tanks), or (3) underway to control list, trim, and draft during navigation. Potentially, a ship may perform an uptake operation to facilitate testing as this may be considered “consistent with its final intended use on operating vessels (46 CFR 162.060-28(d)). In this instance, such a test cycle could be acceptable if other requirements are met. Regardless of the occasion for ballasting, flow rates and tank volumes must equal or exceed those in land-based tests.

The ship must also provide an *acceptable* range of variability in geographic or seasonal conditions. The acceptable range is not clearly defined, and it is likely that if all five test cycles ballasted water from the same location (and in an environment where seasonal changes are minor), this *would not* be considered an acceptable range of variability. In many sub-tropical and temperate waters, testing must occur over *at least* six months where there may be sufficient variability across seasons.

To facilitate testing, uptake samples may be collected, preserved, shipped, then analyzed on shore (46 CFR 162.060-28(g)(4)(ii)) by trained microscopists. Since uptake samples may be taken off the ship, it may be possible that a test cycle is completed prior to verification that organism concentrations were sufficient. As a result, test cycles could be completed, but it could later become evident that uptake waters did not provide sufficient variability. These challenges may result in numerous invalid test cycles, such that the overall cost and effort of testing are difficult to estimate.

3.2 Scheduling

The challenge for shipboard testing is that a ship’s schedule must coincide with the schedule of the test team. As a valid test cycle includes sampling and analysis of source water, the IL/SL test team may need to be present at two locations and times (e.g., to collect at both the uptake port and the discharge port, several days apart), over five test events in a *more-than* six-month period. In some instances, this may require personnel accommodations aboard the ship during transits.

Commercial ships that have dynamic schedules may not be able to predict their destinations well in advance of arrival. For IL/SL test teams and USCG auditors, the lead-time required to travel, especially to international locations, may preclude the shipboard work. Scheduling challenges could also reduce the frequency of successful test cycles, as the alignment of ship, crew, and test team availabilities may be uncommon.

3.3 Scientific Work in a Shipboard Environment

An auditor must have familiarity with the TA testing quality assurance project plan (QAPP). As the shipboard environment is likely far different than an established shore-based lab, “routine” shipboard circumstances could add complexities to sampling and test procedures that challenge the QAPP.

Once aboard the ship, the test team must work together with the ship’s crew to collect samples. The crew may be needed to prepare sample ports and probes, start and monitor de-ballasting, maintain records of



Ballast Water Management Systems; Oversight of Shipboard Testing

ballast flow rates and volume (as well as the source location, hold time, etc.), and operate the BWMS. The crew may also assist in managing excess sample water, preparing a workspace for shipboard analysis, and transporting test materials around the ship. Simultaneously, the test team must collect samples, record relevant data, and prepare samples for transport off ship.² Both the crew and the IL/SL test team need to coordinate and communicate, often across noisy engine rooms, between stations on multiple decks, or from control rooms to the point of sampling. Language differences between the crew and the test team may also complicate communication.

For samples intended to be analyzed aboard the ship, the test team must assure that the sample is handled appropriately and analyzed as quickly as practicable. Samples with living organisms should be held in an insulated container such that the ambient heat of the ship does not drive the sample temperature higher than the ballast water temperature at the time of sampling. For extended holding time (e.g., more than 1 hour, but dependent on the water temperature), the sample should be aerated to prevent the death of aerobic organisms as oxygen is depleted. Both the crew and the test team may be handling samples from a BWMS that treats water with an active substance (e.g., chlorine, ozone).

For vessels with active-substance-based BWMS, sampling should occur after neutralization. However, personnel may be exposed to the active substances in low concentrations or residual amounts. The exposure could occur through contact with water, aerosols, or gases released as the water is exposed to the atmosphere. In the event of incomplete neutralization or a failure of the neutralization process, concentrations of active substances may be harmful. The test team and the crew must prepare for unexpected conditions that risk exposure and put the health and safety of those working on the ship at risk.³

Appendix A describes some of the health and safety considerations for performing scientific and analytical work aboard ships. Careful planning, training, and procedures may minimize the risk of personnel injury, and also assure data quality and test integrity. Nevertheless, a shipboard environment may represent a challenge, with limited spaces for equipment and personnel, with high noise and heat in some locations, and simultaneous duties taxing the crew.

4 TEST PREPARATIONS AND CONSIDERATIONS

4.1 General

Given the challenges in vessel scheduling, it is unlikely that USCG auditors may attend an actual shipboard test and witness the entire test cycle. Alternatives may include requesting photographic or video documentation during trials. The test documentation should include: (1) rationale for selecting the ship, the BW uptake location, and test parameters (flow rates, test volumes); (2) qualifications and roles of the IL/SL test team and the participating crew; (3) detailed procedures for testing, including sampling, sample handling, and analyses; and (4) documentation of all attempts at performing a valid test cycle (especially failed or invalid tests).

² A well-written test plan will clearly state the functions and responsibilities of the vessel (and crew) as distinguished from the functions and responsibilities of the test team.

³ One case of acute exposure was attributed to a volatile disinfection byproduct, perhaps tribromomethane (Dock et al. 2020).



4.2 Ship Selection

The BWMS manufacturer has the responsibility to select a ship and make all the arrangements to facilitate testing. Prior to accepting the manufacturer's ship selection, the IL should review whether the selection will facilitate shipboard testing. If an SL will be performing the work, representatives from the SL should be aware of these determinations. The SL may be able to accommodate realities of the selected ship, but routes, ports of call, etc. may influence the level of effort estimated to complete the test requirements. As part of its oversight of ILs and SLs, the USCG should consider verifying that the following questions were asked during ship selection:

- Will the ship exceed the tank volumes (200 m³) and flow rates (200 m³ h⁻¹) of land-based tests? Will the ship be operating at flow rates near the upper range of the TRC? (46 CFR 162.060)
- What are the anticipated routes and ports-of-call? Does the ship repeat routes from year-to-year? How soon prior to arrival may the ship change its routes?
- What are the typical ports or locations where ballast water is taken in (or discharged)?

The ship's command and crew must also be able to assist the IL/SL test team. As the crew operates the BWMS during the test, communication between the crew and the test team is essential. The IL and SL must verify that the ship's personnel are willing to participate and assist the team with these aspects of the test:

- Does the ship's command have a full understanding of the testing goals? Are the crew trained and competent in the operation of the BWMS?
- Does the ship have designated personnel to oversee the BW operations and communicate with the test team? What is the method of communication during the testing (verbal, hand-held radio, electronic communication, etc.)?
- What is the working language of the ship? Do the designated personnel speak English?
- Will the ship's command permit the sharing of operational, ballasting, and navigation data with the test team?

After the ship is selected and meets these other criteria, the IL/SL test team and crew must ensure a safe environment to conduct the test. As the IL and SL review the ship selected by the BWMS manufacturer, they must also verify the work can be performed safely.

- If the ship carries hazardous cargo, are there safe locations to collect, process, and analyze samples? Note that the test team may need to operate electronic devices, which may not be rated suitable for some hazardous locations. (46 CFR 162.060)
- Does the BWMS pose any unique risks?
- Where on the ship (and under what conditions) must the test personnel wear work gloves, hearing, and head protection? Are there any specific risks or other Personal Protective Equipment (PPE) needed?

4.3 Shipboard Sampling and Analysis

Shipboard testing requires *most* of the same parameters as land-based testing. A notable difference are the requirements for uptake (source water) samples. Source water samples on a ship only need to be analyzed for organisms $\geq 10 \mu\text{m}$ but $< 50 \mu\text{m}$, and for organisms $\geq 50 \mu\text{m}$; the analyses for indicator microbes are not required for shipboard tests. The samples collected from source waters may be preserved and transported off



Ballast Water Management Systems; Oversight of Shipboard Testing

ship to land-based laboratories. Likewise, discrete samples for water quality analysis (dissolved and particulate organic matter) are typically taken off-ship for analysis (Gollasch and David 2021).

Samples for organisms $\geq 10 \mu\text{m}$ but $< 50 \mu\text{m}$, samples for organisms $\geq 50 \mu\text{m}$, and samples from treated ballast must be analyzed following the requirements of the US TA Test Protocol (EPA 2010). These analyses target living organisms, so samples must be analyzed soon after collection. Therefore, analyses will occur on the ship or at a nearby location or laboratory. The IL and SL must have protocols and contingency plans for analyses which would address the questions below:

- Will the test team analyze samples aboard the ship? If not, what is the process for transporting samples off the ship for land-based analysis? (46 CFR 162.060)
- How will samples of source water be preserved and transported? What is the typical “lowest taxonomic level” identified for organisms $\geq 50 \mu\text{m}$? For organisms ≥ 10 and $< 50 \mu\text{m}$? (46 CFR 162.060)
- Does the test team monitor the sample integrity during transport (e.g., using temperature loggers or accelerometers to detect physical shock)? What are the acceptable ranges for these parameters?

In land-based test facilities, direct counts of living organisms are performed in laboratory environments by manual microscopy. Microscopists scan known volumes of sample and tally living organisms meeting size characteristics. This type of analysis is ideally performed in a laboratory environment, as space, lighting, storage, and equipment are not limited to the confines of a hull. Laboratories can be configured for human interface with the microscope, the related equipment and the sample; components can be arranged to suit the activities and posture of the microscopist to minimize strain. Unlike a vessel, land-based laboratories often have sufficient space to prepare samples, perform manipulations (e.g., adding reagents or incubating samples), store and handle reagents safely, and dispose of waste.

Although shipboard environments are not ideal locations for microscopy, there are some modifications that could help facilitate staging and transport of equipment, and analysis of ballast water. For example, a microscope can be modified by using a self-contained power supply, light source, and motor controls; using a vibration-dampening base or feet; transporting in water-resistant and dust-resistant enclosures with motion locks, padding, or structures to accommodate for acceleration, minor impacts, and rotation; and incorporating bolt holes, eyelets, or other accessories (e.g., suction cups, magnets) on the outer casing to secure the microscope to a horizontal surface aboard the ship.

To facilitate analysis, IL/SL test teams could employ the use of a live video feed from a digital camera on a display (in the event eyepieces are not present), easily accessed controls and interfaces, such as a touch screen with simplified commands, and software to automate routine processes, such as calibration, image-collection, and file-naming and storage. The following items are important for performing analysis on the ship (or in an *ad hoc* laboratory on shore). The ILs and SLs must consider the following:

- Does the selected ship have a suitable location for sample preparation and analysis?
- What equipment is brought aboard the ship for analysis? Is the equipment suitable to perform the analysis and operate in the conditions of a shipboard laboratory?
- Describe the specific training or experience needed by personnel performing analysis aboard ships. What accommodations are needed to safely perform the analyses?



4.4 Documentation

Personnel performing shipboard tests must document conditions on the ship, including descriptions of BW operations, the maintenance and calibration of equipment and sensors, and even the local weather conditions (46 CFR 162.060-28(i)). These conditions are not controlled during the test. For example, the maintenance operations are conducted following preset schedule of the crew, and it is likely that testing will occur at different portions of the maintenance cycle (e.g., soon after maintenance versus immediately prior to planned maintenance).

The locations and volumes of BW uptake and discharges must be reported in detail. For example, test personnel must record start and end times and locations of BW operations. The provenance of all BW sampled during testing should be known at the tank-level, so if a tank contains BW from multiple sources, this information is documented. All this information provides context to the outcomes of the shipboard testing. In the case that a test cycle is invalid, this information may help the test personnel in troubleshooting and preparation for future test cycles. The IL and the SL must work closely with the ship operators and personnel to assure that this information is collected accurately and made available to the testing team.

5 OVERSIGHT CONSIDERATIONS

5.1 Challenges of an In-person Audit

In contrast to land-based BE testing, where test activities are pre-scheduled, shipboard BE testing will be difficult to observe while it occurs. First, the date and location of the ship's arrival may not be known until weeks (or days) prior, and those arrivals may be postponed or rerouted with little notice. Deballasting may occur rapidly (appx. 1 hour) or over the course of several days. The timing of the deballasting—trying to find conditions when organisms are heterogeneously distributed in tanks—may challenge protocols designed to collect representative samples (Gollasch and David 2017). It is due to these challenges that witnessing a shipboard test in process may be impracticable for an USCG auditor or audit team. Taking these challenges into consideration, alternative approaches for auditing may be necessary. Some potential options are described below:

Strategy 1: Real-Time Video Documentation and Communication

Mobile devices capable of video communication may allow an USCG auditor to witness, remotely, shipboard work in process. When in locations with available wireless, satellite, or cellular data networks, these point-to-point video communications are facilitated through commonplace software for hosting multi-party, web-based meetings. For auditing a shipboard test cycle underway, the remotely located USCG auditor would require some notice of the estimated time of activity. They will require a point-of-contact person to communicate and display portions of the analysis. For a small test team, this may not be feasible. One major issue is that the shipboard testing may occur in regions without cellular or wireless coverage. Certain locations on a ship may have too much interference to maintain a signal, or too much noise for verbal communication. In these cases, a remote video audit may be a challenge.

Strategy 2: Archival Photograph and Video Documentation for Later Viewing

To address the absence of cellular or wireless networks, which limits real-time video communication, the important activities occurring during the shipboard tests may be recorded by videos or photographs and reviewed later by an USCG auditor. In this approach, the auditor viewing the processes remotely would



Ballast Water Management Systems; Oversight of Shipboard Testing

likely not be able to interact with someone at the test location. In lieu of sending real-time instructions, the remote USCG auditor would need to deliver clear instructions prior to the test. These instructions should include which processes to document by video and which processes may be captured with single photographs. While photographs are typically captured during testing and included in the test report, video documentation is critical to witness the dynamic processes of sampling and sample analysis.

Strategy 3: Partnering with Local Personnel

The auditor may find a trusted agent at a local Coast Guard command to perform an on-site audit during the actual shipboard sampling. The advantage of partnering with a local person is that the costs and effort associated with getting the Traveling Inspection Staff to the site of the testing are minimized. This is not to infer that a field command should routinely be used in place of the Traveling Staff whose focus specifically includes overseeing 3rd party inspection audits to ensure compliance with applicable laws, regulations, and CG Policy.

These three strategies may be a reasonable substitute for witnessing the testing operation in-person, especially when test schedules are not known weeks in advance. Of these three options, photograph and video documentation (Strategy 2) may likely be the most feasible, especially if the testing team would provide the imagery. 46 CFR 162.060 does *not* require photo and video documentation; however, IL/SL test teams still collect images to describe their work. The USCG auditor may communicate the need for documentation (e.g., number of videos, processes documented, etc.) to the IL and SL early and prior to the test event, so the test teams can be prepared to accommodate the request for photo and video documentation.

5.2 Requests for Alternative Methods

An IL or BWMS manufacturer may request alternative, but equivalent, test methods for procedures considered not practicable (46 CFR 162.060-10(b)1). (These requests for alternative methods are sometimes referred to as “10(b)1” requests). While the ship operators must follow the statutory requirements as closely as possible, there are likely cases that a test requirement cannot be practically met. For example, the position and characteristics of the in-line sampling ports is specified in the U.S. Test Protocol (EPA 2011), but due to the configuration of piping, the ideal sample port location may be inaccessible. Likewise, the volumetric flow of ballast water may not be continuous or even over time. The test team may not have the final flow characteristics until sampling and analysis are complete, and if analysts were aware of operational deviations as they happened, it still may not be possible to complete the test cycle. As a result of these factors, shipboard testing will likely generate requests for alternative methods at higher rates than for other tests required for U.S. TA (e.g., shore-based testing).

Those overseeing the BWMS testing and the TA process must have access to all “10(b)1” requests submitted by the IL, the SL, and the BWMS manufacturer. As the BWMS manufacturer identifies the ship used in testing, initial “10(b)1” requests should be received early, prior to developing a test plan and well before testing. These requests may ask for modifications to the sample port placement requirements, the flow rate, the treatment capacity of the BWMS, or other technical requirements. The USCG Marine Safety Center will notify the requester of any actions on the “10(b)1” requests. All changes must be included in the test plan for shipboard testing. The USCG auditor should check for all approved and disapproved requests for alternative methods.



5.3 Demonstration of Preparation and Planning

The shipboard testing organization, whether the IL or SL, should develop a general test schedule which includes the ports and terminals where the IL/SL test team and auditors may meet the ship. Test personnel should know the ballasting conditions that would likely yield a valid test (e.g., source water represents a variety of challenging conditions from port waters). With this information, the test team can identify transits likely to yield valid test cycles with suitable variation in conditions. Planning should demonstrate foresight in preparing to meet the statutory requirements. Apart from the concentration of organisms in source waters, most of the requirements may be verified during ship selection or known based upon transit characteristics (Figure 1). Minimum concentrations of organisms in source waters, although beyond the control of the BWMS manufacturer, ship, and testing organization, are likely met in many coastal, port, and harbor waters in temperate to tropical climates (Gollasch and David 2021). In Figure 1, requirements are regrouped into three categories: BWMS, Ballast Operations, and Sampling Ports. The asterisk indicates the one requirement mostly beyond the control of the BWMS, the SL, and the IL – the concentrations of organisms in the source water.

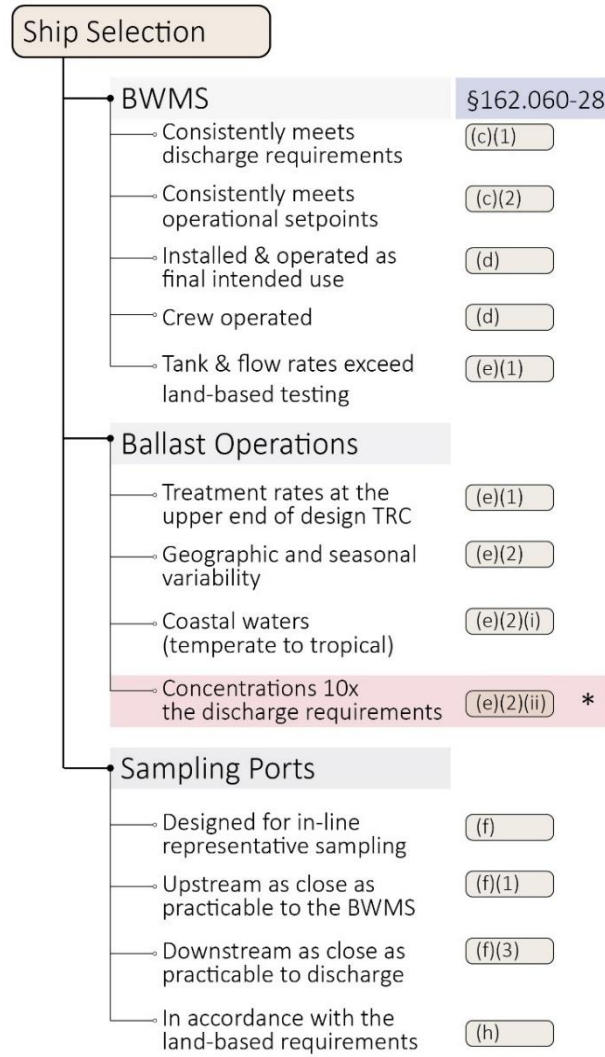


Figure 1. Summary of requirements for ship selection (46 CFR 162.060-28).



Ballast Water Management Systems; Oversight of Shipboard Testing

Given the importance of geographic variability and the importance in obtaining source waters from ports and harbors, the IL and SL must assure that the ship selected by the BWMS manufacturer will meet requirements for at least six months of testing. Polar environments are *not* among acceptable climates. For example, a shift in operational profile from the North and Baltic Seas (temperate waters) to the Barents and Kara Seas (arctic waters) may preclude additional test cycles. Therefore, the BWMS manufacturer should select a ship with an operational profile that is suited for the routes and ports that facilitate testing. When selecting a ship, the BWMS manufacturer must work with the ship operators to install the BWMS, train the crew in its operation, and assure the sampling infrastructure is in place. Shipboard test requirements clearly state that the BWMS must be permanently installed and operated as intended for its final use. This requirement likely excludes using a modular or containerized BWMS installed temporarily on the deck or cargo areas unless that is the manufacturer's intended final use or as applied to an accepted shipboard testing facility (e.g., Golden Bear Research Center).

Completion of test cycles occurs over at least six months, and the interval between test cycles (approximately one month or more) should allow time for all results to be summarized and available to the IL and SL. Following each test cycle, the IL and SL should evaluate:

- Location and timing of ballast uptake (port name, geographic coordinates, seasonality);
- Source water quality (temperature, salinity, dissolved and particulate matter concentrations, etc.);
- Organism concentrations; and
- Deballasting and treatment characteristics.

As part of the 46 CFR 162.060, both valid and invalid test cycles must be reported. Following the completion of a test cycle, the IL and SL should compare the recent test characteristics to the previous test cycles. This comparison may include qualitative characteristics, including descriptions of unforeseen challenges; measurement data that may be compared numerically (e.g., tank hold time, distance between or among uptake locations) and statistical measurements (e.g., the coefficient of variation among dissolved organic carbon measurements). All these comparisons should guide the location and timing of the next test cycle. As test cycles are completed, in the case that source water and other characteristics do *not* show variation, the selection of future test opportunities to add variability becomes more important.

For oversight, personnel reviewing the IL and SL test reports should note whether these analyses occurred between test cycles. USCG auditors may ask personnel involved in shipboard testing whether they have a formal set of criteria to identify and select ship transits to increase variability among test cycles. For example, throughout the six months (or more) of testing, do the IL and SL develop contingency plans so that new test cycles will use source waters from unique ports? As part of its oversight, the USCG may request details of this pre-planning exercise, as it demonstrates the effort in meeting the test requirements.

6 CONCLUSIONS

Shipboard BWMS testing and auditing the type approval process have many challenges. Coordinating schedules between ships and test teams when tests involve multiple locations and times and unpredictable ship schedules, may present logistical challenges for the IL/SL test team and auditors. A significant challenge that BWMS testing faces is conducting ballast uptake where the sample water organism concentrations exceed the discharge standard by at least a power of ten (46 CFR 162.060).



Ballast Water Management Systems; Oversight of Shipboard Testing

Auditors may face many of the same logistical problems concerning scheduling and may need to have a contingency for remote auditing methods like photography and videography. Despite the challenges, shipboard testing is a vital step in type approvals of ballast water management systems and requires thorough oversight of processes and personnel involved. This report provides basic guidance and for USCG auditors to consider while performing their Type Approval audit responsibilities.

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APPENDIX A. PREPARATION FOR SHIPBOARD TESTING

A.1 HEALTH AND SAFETY CONSIDERATIONS

These considerations address personnel performing analytical or scientific work in a shipboard environment. This guidance may be useful to personnel and planners affiliated with independent laboratories (ILs) and sub-laboratories (SLs) performing testing for type approval (TA) of Ballast Water Management Systems (BWMSs). All shipboard work poses some risk to personnel, but sampling and analyzing BW introduces specific risks to the IL/SL test team, technical auditors, and the ship's crew:

- BW may contain toxic chemicals—specifically residual chemicals and disinfection byproducts (DBP) from BWMSs using hypochlorite, ozone, or other oxidants. These compounds may volatilize when BW is depressurized, which will occur during sampling when BW is released from pressurized piping and exposed to the atmospheric pressure. BW originates from surface waters, but containment within a ship's ballast tank could introduce metals and other contaminants, which pose a risk of exposure through contact or inhalation.
- BW may contain harmful organisms, including pathogenic microbes such as toxicogenic *Vibrio cholerae* and exotoxin-producing microalgae.
- At least one BWMS with TA uses heat to treat BW, so sample water may pose a burn risk if the BWMS is malfunctioning. (Treated water should be $<50^{\circ}\text{C}$ at the time of sampling).
- Manual operations, such as connecting tubing and opening/closing valves, introduce risks to nearby personnel. The equipment for shipboard sampling will likely be only used periodically, and the integrity of the materials used for sampling may degrade between uses. A failure in a valve or hose risks physical harm to nearby personnel, but also damage to the ship.

In addition to these specific risks, general health and safety risks also apply, as the shipboard environment will have high-voltage transformers, moving machinery, pressurized fluid lines, and high levels of ambient noise. Many of these risks can be mitigated with use of proper personal protective equipment (PPE), operational protocols to minimize risky activities, and training and oversight for personnel involved in compliance testing.

A.2 WASTE GENERATION

Shipboard testing will generate both fluid and solid wastes. Sampling will likely generate excess ballast water, including water used to purge the probe and sample tubing, rinse water, effluent from filter concentrations, and excess water not consumed in testing. Sample volumes, flow rates, and total sampling time will vary based on the target size class: The $\geq 10\ \mu\text{m}$ and $< 50\ \mu\text{m}$ size class will likely only require sample volumes of liters (less than 100 liters); the $\geq 50\ \mu\text{m}$ size class will require much larger volumes, perhaps up to 1000 liters. The ship's crew must assist the test team in disposing this excess water appropriately, for example, into wastewater tanks or back into the ballast. Solid wastes include laboratory wipes, discarded filters, reagent files, disposable cuvettes, transfer pipettes, pipette tips, and packaging. Solid wastes are best carried out with the test team, when possible.



A.3 CHAIN-OF-CUSTODY (COC)

A chain-of-custody (CoC) is necessary to document the custodian who maintained possession of a sample, how long the sample was held, and at what point the sample was consumed in analysis, discarded, or archived (if appropriate). The CoC provides assurance the sample was handled appropriately under the authority of the custodian. This is important especially for samples collected during uptake operations, as they may be transported off-ship for analysis.

